Swansea University
Prifysgol Abertawe
School of Management
Yr Ysgol Reolaeth

IoT adoption in SME manufacturers in Thailand

Yose Wungcharoen

Submitted to Swansea University in fulfilment of the requirement for the Doctor of Philosophy

Swansea University

2022

Abstract

The Internet of Things (IoT) is one of the most recent information communication technology (ICT) phenomena to have had a global impact upon wireless telecommunications. Due to the benefits of the IoT in terms of developing communication and connectivity between devices, businesses are thus able to enhance profitability, reduce operational costs, become customer-centric and eventually gain sustainable competitive advantage. Identifying and understanding the factors that affect the IoT adoption is critical in order that either the success or failure of an organisation can be determined. The existing literature, however, does point to a knowledge gap regarding IoT adoption in the manufacturing SME sector, in particular within developing countries. This study examines factors that affect IoT adoption within manufacturing SMEs in Thailand and provides further insights into those factors and their interaction.

The theories of technology adoption, such as diffusion of innovation and technology organisation environmental framework, form the theoretical underpinnings of this thesis. Drivers and barriers, or factors, which promote or hinder IoT adoption respectively are of particular relevance. The research adopts a qualitative approach by conducting multiple case studies within 10 manufacturing SMEs in Thailand. Both within-case and cross-case analysis are used to conduct these case studies and this leads to the identification of common themes and categories impacting IoT adoption. The study finds that relative advantage, compatibility, business partner influence, trialability, top management support, organisational structure, technology support from vendors, observability, cost, and security and privacy are perceived to influence the decision of whether adoption of the IoT by Thai manufacturing SMEs is undertaken. Within these 10 factors, relative advantage and business partner influence are found to be the most significant drivers, whereas compatibility is found to be the most significant barrier. This study makes both practical and theoretical contributions to the growing body of knowledge regarding IoT adoption.

The major theoretical contribution of this thesis is that it provides increased insight into the usage, applications and factors that affect the decision to adopt the IoT within the context of manufacturing SMEs in Thailand. The study presents a conceptual framework that highlights the factors affecting adoption of the IoT in manufacturing SMEs. The major practical contribution of this study is the information provided for policymakers, managers in organisations, technology consultants, and vendors in order that they may effectively implement and accelerate IoT development and utilisation among Thai manufacturing SMEs. Managers of SMEs could use this study as a reference upon which to base effective decision-making with regard to whether to adopt the IoT or not, and also for developing policies that could guide further adoption. Furthermore, IT vendors/consultants could use this study to gain productive insight into the specific problems and requirements faced by manufacturing SMEs when they are thinking about adopting IoT systems, thus enabling IT consultants to design suitable strategies for the widespread adoption of the IoT. This study is the first to examine IoT adoption in the context of manufacturing SMEs in Thailand and its findings will be relevant in other, similar developing world economies.

Declaration and Statements

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed ....[redacted]

Date ....11/1/2022..

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed ....[redacted]

Date ....11/1/2022...

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organisations.

Signed ....[redacted]

Date ....11/1/2022...

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loans after expiry of a bar on access approved by the Swansea University.

Signed ....[redacted]

Date ....11/1/2022..

Acknowledgements

This thesis had been a long journey during which I have been supported and accompanied by many people. I would like to express my sincere gratitude to them for their existence through this long and difficult journey. My sincere gratitude goes out to my supervisors, Professor Paul Jones & Professor Gareth Davies, who have supported me throughout my PhD journey with their patience, clear guidance and immense knowledge. Their constructive criticism has helped me to think analytically and brought out the better in me. I really appreciate their time and expertise toward this study. I feel that I have been privileged to have had the best team of supervisors who never failed to demonstrate enthusiasm for the progression of this research.This said,, I would like to apologise for disappointing them, especially at the beginning of the study. Additionally, a debt of gratitude is owed to the top management of various firms who participated in this study. Without the kind assistance of these managers, this research would not have been possible. To my friends,especially Dean, thank you for listening to me when I felt less motivated, and for giving me calming advice. Lastly, and most importantly, I must thank my parents for their support and unconditional love. I dedicate this work to my parents, who always wanted me to study to the highest academic level. I am forever indebted to them for their encouragement and support throughout my entire life and wish them a life filled with health and happiness.

Yose Wungcharoen

Swansea

2022

Table of Content

Abstract 1
Declaration and Statements 2
STATEMENT 1 2
STATEMENT 2 2
Acknowledgements 3
Table of Content 4
List of Figures 11
List of Tables 12
List of Appendices 15
Chapter 1: Introduction 16
1.0 Introduction Chapter 17
1.1 Research Background 17
1.2 Research Aims and Objectives 20
1.3 Proposed Research Design 20
1.4 Envisaged Research Contributions 21
1.5 Organisation of the Thesis 21
1.6 Summary 23
Chapter 2: Background and Context 24
2.0 Background and Context 25
2.1 Global Economy 25
2.1.1 Global Manufacturing Sector 28
2.2 Thai Economy 29
2.2.1 Overview of the Thai Economy 29
2.2.2 Overview of Main Sectors and Industries in Thailand 32
2.2.3 Thai Manufacturing Industries 32
Automotive 33
Electronics and Electrical Appliance 33
Food Processing 34
Summary 35
2.3 The SME Sector 36
2.3.1 Overview of SME Sector 36

2.3.2 SME Definition 36
2.4 Summary 38
Chapter 3: ICT and IoT Literature Review 40
3.0 Literature Chapter 41
3.1 IT and ICT 41
3.1.1 Definition and Current Situation of IT and ICT 41
3.1.2 IT and ICT Introduction and Evolution 43
3.1.3 Impact of ICT on Businesses 46
3.1.4 ICT in Manufacturing 48
3.1.5 ICT in SMEs 49
3.1.6 Emerging ICTs 50
3.2 Internet 51
3.2.1 Definition and Current Situation of the Internet 51
3.2.2 The Evolution of the Internet 52
3.2.3 The Impact of the Internet on Industries and Businesses 53
3.3 IoT 54
3.3.1 IoT Evolution and Definition 54
3.3.2 IoT Architecture and Enabling Technologies 60
1) Perception Layer With the Sensors, Actuators and Wireless Sensor Networks (WSN) as Key Technologies 61
2) Gateway and Network Layers With Gateways and Wired or Wireless as Key Technologies 61
3) Cloud Layer with Cloud Computing Technologies 61
4) Management Service Layer with Data Analytics and Management Tools as a Key Technology 62
5) Application Layer with the IoT Application Software as a Key Technology 62
3.3.3 The IoT: Its Usage and Purposes 63
3.4 IoT in Manufacturing 63
3.4.1 Evolution and Introduction of IoT in Manufacturing 63
3.4.2 Concept, Key Technologies, and Architecture of IoT in Manufacturing 65
3.4.3 Applications and Challenges of IoT in Manufacturing 69
3.4.4 IoT Usage in Manufacturing Industries 71
3.5 IoT in Manufacturing SME 72
3.5.1 IT, ICT and IoT in SME 72
3.5.2. IoT Implementation in Manufacturing SMEs 73

3.5.3 The Use and Challenge of IoT in Manufacturing SME 76
3.6 Summary 78
Chapter 4: Theoretical Framework 79
4.0 Theoretical Framework Chapter 80
4.1 Theory Models and Relevant Factors 80
4.1.1 Evolution and Concept of DoI, TAM and UTAUT 81
Diffusion of Innovation Theory 81
Theory of Reasoned Action 84
Technology Acceptance Model 84
Unified Theory of Acceptance and Use of Technology 87
4.1.2 Evolution and Concept of TOE 89
4.1.3 Evolution of DoI in Relevant Context 90
Diffusion of Innovation in Developed and Developing Countries 92
The Use of Diffusion of Innovation Theory within SMEs 93
The Use of Diffusion of Innovation theory in Manufacturing Industries 94
The Use of Diffusion of Innovation Theory With Different Models 95
The Use of Diffusion of Innovation Theory in Most Recent Technologies 95
4.1.4 The Determinants from DoI Theory in Relevant Context 95
Relative Advantage 96
Compatibility 97
Complexity 98
Trialability 99
Observability 100
Cost 100
Security and Privacy Risk 101
Image 102
4.1.5 The Determinants from TOE Theory in Relevant Context 102
Top Management Support 103
Organisation Readiness 104
Organisational Structure 105
Organisational Size 105
Competitive Pressure 106
Technology Support from Vendors 106

Business Partners Influence 106
4.1.6 The Determinants from Related Theories and Relevant Literature 107
Perceived Usefulness 107
Perceived Ease of Use 108
Experience 108
Social Influence 108
Performance Expectancy 109
Facilitating Condition 110
Perceived Behavioural Control (PBC) 110
Perceived Intelligence 111
Perceived Convenience 111
Perceived Connectivity 112
4.2 Summary of Theoretical Framework 113
4.3 Research Questions 118
Chapter 5: Research Methodology 119
5.0 Research Methodology Chapter 120
5.1 Research Philosophy 120
5.1.1 Ontological Position 121
5.1.2 Epistemological Position 122
5.2 Research Method 122
5.3 Research Strategy 123
5.4 Research Design 124
5.4.1 Rationale for Using Case Study Strategy 124
5.4.2 Unit of Analysis and Unit of Observation 125
5.4.3 Single Case Study Vs Multiple-Case Studies 127
5.4.4 Sampling Strategy 128
5.5 Data Collection 129
5.5.1 Pilot Study 129
5.5.2 The Process of Identifying and Contacting Firms 130
5.5.3 Interview Method 130
5.5.4 Telephone Interviews 132
5.5.5 Interview Process 132
5.5.6 Design of the Case Study Research Instrument 133

5.5.7 Amendments to Research Instruments ... 136
5.5.8 Alternative Data Sources ... 137
5.5.9 Case Study Report ... 138
5.6 Data Analysis Techniques ... 138
5.6.1 Qualitative Computer Software Programs for Data Analysis ... 140
5.7 Validation and Reliability of the Case Study Research ... 141
5.8 Confidentiality and Ethics ... 142
Chapter 6: Findings ... 144
6.0 Findings ... 145
6.1 Overview of Case Studies ... 145
6.1.1 Case study A ... 147
6.1.2 Case Study B ... 148
6.1.3 Case Study C ... 149
6.1.4 Case Study D ... 150
6.1.5 Case Study E ... 151
6.1.6 Case Study F ... 152
6.1.7 Case Study G ... 152
6.1.8 Case Study H ... 153
6.1.9 Case Study I ... 155
6.1.10 Case Study J ... 156
6.2 Thematic Analysis ... 157
6.2.1 Relative Advantage ... 160
6.2.2 Compatibility ... 164
6.2.3 Complexity ... 167
6.2.4 Observability ... 169
6.2.5 Cost ... 171
6.2.6 Security and Privacy ... 173
6.2.7 Trialability ... 175
6.2.8 Organisational Structure ... 177
6.2.9 Top Management Support ... 179
6.2.10 Organisational Size ... 182
6.2.11 Technology Support from Vendor ... 184
6.2.12 Business Partner Influence ... 187

6.2.13 Competitive Pressure 189
6.3 Summary 190
Chapter 7: Discussion 193
7.0 Discussion Chapter 194
7.1 Research Question One: What are the Factors Affecting Adoption Intention of IoT in Manufacturing SMEs in Thailand? 195
7.1.1 Technological Factors 196
7.1.2 Organisational Factors 199
7.1.3 Environmental Factors 200
7.2 Research Question Two: How Do Those Factors Affect the Adoption Intention of IoT in Manufacturing SMEs in Thailand? 201
7.2.1 Relative Advantage 201
7.2.2 Compatibility 203
7.2.3 Complexity 204
7.2.4 Observability 205
7.2.5 Cost 207
7.2.6 Security and Privacy 208
7.2.7 Trialability 209
7.2.8 Organisational Structure 210
7.2.9 Top Management Support 211
7.2.10 Organisational Size 212
7.2.11 Business Partner Influence 213
7.2.12 Technology Support from Vendor 214
7.2.13 Competitive Pressure 215
7.3 Research Question Three: What Guidelines Can be Developed to Guide Practitioners in Assessing the Suitability of Manufacturing SMEs in Adopting IoT Technologies? 216
7.4 Summary 218
Chapter 8: Conclusions 221
8.0 Conclusions Chapter 222
8.1 Contribution to Theory 222
8.2 Contribution to Policy 225
8.3 Contribution to Business Practice 226
8.4 Study Limitations 227
8.5 Future Research Opportunities 228

8.6 Reflection 229
Appendices 231
Appendix 1: Cover Letter 232
Appendix 2: Participant Information Sheet 234
Appendix 3: Consent Form 237
Appendix 4: Statement of Research Ethics Approval 238
Appendix 5: Case Study Research Instrument 243
Appendix 6: Transcription of the Interview with a Water Technology Firm 246
Appendix 7: Transcription of the Interview with an Industrial Gas ManufacturingProducer 254
Appendix 8: The UK Economy and Its Main Sectors. 265
Appendix 9: Applications and Challenges of IoT in Manufacturing. 272
Appendix 10: IoT Usage in Manufacturing Industries 278
References 294

List of Figures

Figure 1: Global Economy through Gross Domestic Product (GDP) 25
Figure 2: Geography of Thailand 30
Figure 3: Digital S-Curve 42
Figure 4: The S-Curve of Digital Technologies in Four Different Stages: Emerging, Improving, Mature and Ageing 44
Figure 5: Cost of Computers 46
Figure 6: IoT Architecture with Key Technologies 60
Figure 7: IoT in Manufacturing Architecture with Key Technologies 68
Figure 8: Benefits and Applications of IoT in Manufacturing 70
Figure 9: Evolution of Theories About Technology Acceptation 81
Figure 10: Theory of Reasoned Action 84
Figure 11: Technology Acceptance Model 85
Figure 12: Technology Acceptance Model 1 85
Figure 13: Technology Acceptance Model 2 86
Figure 14: Technology Acceptance Model 3 87
Figure 15: Unified Theory of Acceptance and Use of Technology 88
Figure 16: Unified Theory of Acceptance and Use of Technology 2 89
Figure 17: Technology, Organisation, and Environment Framework 90
Figure 18: Conceptual Framework Presenting the Factors Affecting Adoption of IoT in Manufacturing SMEs 117
Figure 19: Flowchart for Case Study Questions 135
Figure 20: Revised Conceptual Framework Presenting the Factors Affecting Adoption of IoT 223
Figure 21: Workflow of Information Management System for Precast Concrete 287
Figure 22: Flow Chart for Textile Manufacturing Processes 291

List of Tables

Table 1: International Definition of SMEs 37
Table 2: European Union Definition 38
Table 3: IoT Definitions & Comparison........ 57
Table 4: The Key Aspects of Business Model Change Caused by IoT........ 74
Table 5: The Final 14 Innovation Attributes 82
Table 6: 26 Relevant Factors and Their Literature References 113
Table 7: The Selected Factors and Their Supported Factors........ 115
Table 8: Case Study Protocol 126
Table 9: Role of Key Stakeholders and their Description 126
Table 10: Summary of Expected Value of Data Collected from Key Stakeholders 131
Table 11: Alternative Data Sources........ 137
Table 12: Summary of case-study firms........ 146
Table 13: Summary of Result of the Finding as Evident within the Case Studies........ 159
Table 14: Summary of Factors as Evident within the Case Studies........ 195

List of Acronyms

3PL	third party logistic
5G	5th Generation
AC	Alternating-current
AGVs	Automated Guided Vehicles
AI	Artificial Intelligence
APEC	Asia-Pacific Economic Cooperation
ARPANET	Advanced Research Projects Agency Network
AWU	Annual Work Units
B2B	Business to Business
BI	Behavioral Intention
BIM	Building Information Modelling
BOI	Board of Investment
CAD	Computer Aided Design
CAQDAS	Computer-Assisted Qualitative Data Analysis Software
CIP	Cleaning In Place
CKD	Complete Knock-Down

CO2	Carbon dioxide
CPF	Charoen Pokphand Foods Public Company Limited
CPSs	Cyber-Physical Systems
CPU	Central Processing Unit
CNC	Computer Numerical Control
CRM	Customer Relationship Management
Darpa	Defence Advanced Research Projects Agency
DCS	Distributed Control System
DIP	Department of Industrial Promotion
DoI	Diffusion of Innovation Theory
DOS	Disk Operating System
DWA	Distributed Work Arrangements
EB	Exabyte
EDI	Electronic Data Interchange
EC	European Commission
EEC	Eastern Economic Corridor
ERP	Enterprise Resource Planning
EU	European Union
FEFO	First Expire First Out
GDP	Gross Domestic Product
GIS	Geographic Information System
GPRS	General Packet Radio Service
GPT	General Purpose Technology
GSM	Global System for Mobile communications
GVP	Gross Value Added
HDDs	Hard Disk Drives
HIV	human Immunodeficiency Virus
HMI	Human-Machine Interface
ICT	Information and Communication Technologies
ICs	Integrated Circuits
ID	Identification
IaaS	Infrastructure as a Service
IIoT	Industrial Internet of Things
IM	Industrial Merchandises
IMF	International Monetary Fund
IoT	Internet of Things
IP	Internet protocol
IPL	International Poverty Line
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6

IT	Information Technology
JITIR	Just-In-Time Information Retrieval
KPIs	Key Performance Indicators
KWhr	Kilowatt hour
LAN	local Area Network
LTE	Long-Term Evolution
M2M	Machine to Machine
MES	Manufacturing Execution Systems
Mobile UI	Mobile User Interface
MIS	Management Information Systems
MIT	Massachusetts Institute of Technology
MMI	Man Machine Interface
MRP	Manufacturing Resource Planning
NESDB	Thailand's National Economic and Social Development Board
NSPs	Network Service Providers
OAL	Olympus Automation
OECD	Economic Co-operation and Development
OEM	Original Equipment Manufacturers
O&M	Operation & Maintenance
OP	Operational Technology
OPC	Open Platform Communications
OT	Operation Technologies
PaaS	Platform as a Service
PAN	Personal Area Network
PBC	Perceived Behavioural Control
PC	Personal Computer
PEOU	Perceived Ease of Use
PLC	Professional Learning Community
PLM	Product Life-cycle Management
PU	Perceived Usefulness
QR	Quick Response
REM	Real Estate Manufacturing
R&D	Research and Development
RFID	Radio-Frequency Identification
SaaS	Software as a Service
SCADA	Supervisory Control and Data Acquisition
SME	Small and Medium Sized Enterprises
SMOs	Smart Manufacturing Objects
SN	Subjective Norms
SOC	System on a Chip

SQL	Structured Query Language
SSDs	Solid State Drives
TAM	Technology Acceptance Model
TCP	Transmission Control Protocol
TOE	Technology Organization Environmental
TPB	Theory of Planned Behaviour
TPC	Technology to Performance Chain
TRA	Theory of Reasoned Action
TTF	Task Technology Fit
UPS	United Parcel Service, Inc.
US	United States
UTAUT	Unified Theory of Acceptance and Use of Technology
VAT	Value Added Tax
WAN	Wide Area Networks
Web UI	Web User Interface
WD	Western Digital
WSN	Wireless Sensor Networks

List of Appendices

Appendix 1: Cover Letter 232
Appendix 2: Participant Information Sheet 234
Appendix 3: Consent Form 237
Appendix 4: Statement of Research Ethics Approval 238
Appendix 5: Case Study Research Instrument 243
Appendix 6: Transcription of the Interview with a Water Technology Firm 246
Appendix 7: Transcription of the Interview with an Industrial Gas ManufacturingProducer 254
Appendix 8: The UK Economy and Its Main Sectors. 265
Appendix 9: Applications and Challenges of IoT in Manufacturing. 272
Appendix 10: IoT Usage in Manufacturing Industries 278

Chapter 1: Introduction

1.0 Introduction Chapter

This chapter provides an overview of the research thesis and a generalised introduction to the subject of IoT usage in the context of manufacturing small and medium-sized enterprises (SMEs) in Thailand. The overview of the research methodology and contributions are discussed. In addition, the aims and objectives of this research and the structure of the thesis are presented in this chapter. It should be noted that this thesis has been developed during the Covid-19 pandemic, ergo the research methodology was impacted by the restrictions in place at that time. Therefore, conducting face-to-face interviews, which would have been preferable, was not permissible. For the same reason, the response of the businesses used for the research was limited because they were dealing with the pandemic situation.

1.1 Research Background

The growth of the internet has significantly impacted business performance and the way it operates (Porter, 2001; Liang, You, & Liu, 2010). Kumar and Udhas (2011) state that both the internet technology advancement and the more competitive business environments requires that firms be more innovative with regard to minimising cost, while at the same time providing value so as they may remain in business. This demand has led to information and communication technology (ICT) being viewed as key to building a successful business.
ICT is defined as the enabling of business processes electronically, focusing on sending and receiving technologies for message data transmission (Yang, 2018). ICT allows firms to become more innovative, enhance profitability, reduce operational costs, become customer-centric and eventually gain sustainable competitive advantage (Aragón-Sánchez & Sánchez-Martin, 2005; Simmons, Armstrong, & Durkin, 2011; Ward & Peppard, 2002). ICT adoption provides an enabling mechanism by not only improving the efficiency and effectiveness of business processes but also transforming existing business models (Chong, 2004).

One of the most recent ICTs in the area of modern wireless telecommunications is the Internet of Things (IoT) (Asghar, Negi, & Mohammadzadeh, 2015), which is the topic of this study. The definition of the IoT utilised for this thesis is as follows; a worldwide network of communication and cooperation between human to human, human to machine/things and machine/things to machine/things through the internet and unique identification of each entity by leveraging the set of supporting technologies, thus creating new applications or services that make human lives easier and more productive (Atzori, Lera, & Morabito, 2010; Patel, & Patel, 2016). The IoTs is at the peak of inflated expectations in Gartner's hype cycle (Gartner, 2017). Cisco predict that IoT will add up to 2.4 trillion of US dollars to the world economy by 2025 (Attaran, 2021; Manyika et al., 2015; Markman, 2015). The IoT is experiencing a high rate of technology change, which is affecting the entire world (Afifi, Ghazal, & Kalra, 2021; Dutton, Law, Groselj, Hangler, & Vidan, 2014). The IoTs will be the latest and most advanced ICT to create new growth within the economy as the previous IT innovation becomes obsolete (Magazzino, Porrini, Fusco, & Schneider, 2021; Porter & Heppelmann, 2015). The McKinsey Global Institute announced that by 2025, the internet end-point will be present everywhere; on furniture, cars, personal devices to name just a few items (Manyika et al., 2015). From the perspective of a business level, many industry leaders expect the IoTs to have a significant impact on the growth and productivity of businesses (Gilchrist, 2016), achieved by creating new lines of business, increasing value or aiding the collaboration between partners from different industries (Mourtzis, Vlachou, & Milas, 2016; Turber, Brocke, Gassmann, & Flesich, 2014). The benefit of using the IoTs is that it enables the development of improved communication and connectivity between devices, such as factory automation andlogistics, business management and smart transportation of assets and goods (Alam, 2021; Jeschke, Brecher,Meisen, Özdemir, & Eschert, 2017).

Geographically, it is evident from the literature that the level of adoption of innovation in developing countries is lesser when compared with developed countries. The technology adoption found in developing countries is limited by less communication and cooperation between private and public sectors (Zanello, Fu, Mohnen, & Ventresca, 2016). The governments have a significant role to play in the delivery of sustainable growth for industries, especially in the less developed economy (Jones, Wynn, Hillier, & Comfort, 2017). The efficiency and quality of communication that depends upon the development of infrastructure can also hamper innovation in developing countries (Zanello et al., 2016) but, in contrast, developed countries have efficient transport systems that can better facilitate goods and knowledge (Zanello et al., 2016). Furthermore, internal factors of the businesses, such as limited financial resources alongside a lack of advanced, specific skills have a stronger impact on developing countries, where both the knowledge and financial gap are greater (Persaud, 2001). In addition, the characteristic of innovation adopters and innovation adoption in developing countries is influenced by the knowledge and skills of business owners, and this can be seen less than in developed countries (Khurana, Haleem, Luthra, & Mannan; 2021; Zanello et al., 2016). Thus, most businesses within developing countries are struggling to survive in a global competitive environment and they recognise that increasing their innovation advancement is necessary. However, the majority of existing studies are focused on technology adoption within only the developed countries (Khurana et al., 2021; Niebel, 2018; Parteka & Wolszczak-Derlacz, 2015; Stevens & Johnson, 2016). This shows that there is a need for a study of the adoption of emerging ICT, such as IoT, in developing countries. Thailand, as a developing country, will be a context of focus in this study as the researcher has origins in Thailand and is familiar with the established traditions and legislations found within its borders.

Regarding the Thai economy, manufacturing is the largest sector, and it contributes almost 50 per cent of the gross domestic product (GDP). Therefore, the manufacturing industry will be focused upon in this study. With the globalisation of the world's economy, manufacturing businesses have to cope with increasing competition from their worldwide counterparts, in terms of a volatile market, product price, feature, quality, cost and higher manufacturing standards (Wright, 2014). Consumers demand more diversified and customised products, thus leading to more product and process complexity (Bauer & Horváth, 2014). These challenges pressurise the manufacturing enterprises to be more flexible, efficient and adaptable in production and logistics systems (Bauer & Horváth, 2014) by embracing new technologies in order to both maintain competitiveness and meet client demands. The weakness of Thai manufacturers lies within their high labour costs compared to competitors (OBG, 2017) and this means that the producers are often calling back their products from suppliers (Business Sweden, 2015). The government is trying to solve this issue by developing a policy, called Thailand 4.0, through various government support programmes designed to build the automation ecosystem for manufacturing industries (BOI, 2018). However, the Thai manufacturing industry is facing some obstacles regarding the adoption of automation; currently, the level of automation is growing, but from a low base (Business Sweden, 2015). The automation and robotic systems could not be utilized effectively due to the issue with interconnectivity in the factory.

This emphasises the importance of establishing the IoT within the manufacturing industry in Thailand. In general, IoT technology within manufacturing currently embraces advances in sensor technologies, connectivity, analytics and cloud computing, all of which could help a manufacturer utilise data for their performance management. The IoT's based manufacturing enterprises allow improved agility and adjustability that can shift the manufacturing sector from product-oriented to customer-focused (Tomic, 2017), and the adoption of the IoTs within manufacturing leads to increased resource and operation efficiency, less defects and shorter time to market (De Giovanni & Cariola, 2021; Jeschke et al., 2017). The interconnectivity and digitalisation between all parties - customers, machines, products and workers - will create a more competitive environment, increased sustainable operations and eventually improve the profits of the industry (De Giovanni & Cariola, 2021; Tomic, 2017). This study will focus on the IoT in manufacturing in Thailand, where there is no current literature on this subject.

The context of large companies usually dominates recent discussions regarding the IoT. However, this study will focus on the SME sector, which is recognised as being important for economic development in Thailand. It was found that SMEs account for 98 per cent of all businesses operating in Thailand, businesses which contribute to 37 per cent of GDP and 25 per cent of export (Jones & Pimdee, 2017). SMEs play an essential role in the market's value creation (Hansen & Bøgh, 2021). However, Guelich (2018) states that SMEs in Thailand are struggling due to several constraining factors, such as government policies, financial support, and capacity for entrepreneurship. Currently, supporting SMEs is a top priority for governments (Tortermvasana, 2016); the government is pushing for digital communities, start-up networks, and digital parks to provide this support (Koanantakool, 2016).

Guelich (2018) states that SMEs in Thailand should focus more on ICT investment as a critical success. Pavic, Koh, Simpson, and Padmore (2007) argue that ICT use among SMEs has many favorable consequences: it increases customer responsiveness, improves efficiency, and helps achieve a competitive advantage that develops from new advances. 90 per cent of the experts agree that IoT is a key technology for the betterment of the SMEs' industrial performance (Moeuf, Lamouri, Pellerin, Eburdy, & Tamayo, 2017). Chiang and Lee (2017) argue that the IoT is an opportunity for SMEs to seek new collaborations; nevertheless, Onu and Mbohwa (2021), Warrian and Southin (2017) and Nylander, Wallberg, and Hansson (2017) presented studies relating to the challenges faced by SMEs engaging in IoT solutions. The main results of their studies have highlighted that the most important challenges for the SME is the implementation and integration of new IoT based systems and solutions influenced by the resource scarcity, unstructured processes,competencies of the employees working with IoT, need for partnership, and the need for support related to the government funding, business and innovation systems. The IoT presents several challenges for SMEs; in summary, it is apparent that there is a need for further research to explore the usage of the IoTs in Thailand based on the gaps in the existing literature and the importance of this topic with regard to the SME community. The next section considers the research aims and objectives

1.2 Research Aims and Objectives

This section outlines the research aim and objectives. There is a need for IoT adoption studies in Thailand, particularly within the manufacturing SME sector. However, there exists only limited literature examining IoT in the manufacturing sector within developing countries. The majority of studies undertaken have been related to the IoT adoption in large manufacturing organisations. Furthermore, there is a lack of study that covers all the relevant factors that affect IoT adoption, e.g., technological, organisational and environmental factors. Therefore, the aim of this study is to examine the factors affecting the IoT adoption in the manufacturing industry in Thailand. The individual objectives to achieve the aim are as follows:

1. Identify factors relating to the adoption intention of the IoT in the manufacturing sector.

This objective identifies the factors that will potentially impact the adoption intention of theIoT, allowing further exploration in the context of the thesis. For example, potential factors such as relative advantage and compatibility.

2. Identify the factors relating to IoT adoption intention within SMEs in Thailand.

This objective focuses upon identified factors which will potentially impact on the adoption intention of the IoT within the geographic and firm sized context of the thesis. For example, potential factors such as competitive pressure and organisational structure.

3. To explore the identified factors and the interrelationships relating to the adoption intention of the IoT in manufacturing SMEs in Thailand.

Building upon the insight achieved through realising objectives 1 and 2, this objective will explore how the identified factors may interrelate to affect the adoption intention of the IoT in manufacturing SMEs in Thailand, for example, potential relationships between competitive pressure and relative advantage.

1.3 Proposed Research Design

Having identified the thesis objectives, this section considers how the research will be carried out. The multiple-case study will be adopted as it will enable the development of theory by way of identifying the factors that affect IoT adoption within manufacturing SMEs. The relevance of exiting technology adoption frameworks, such as diffusion of innovation theory (DoI) and technology organisation environmental framework (TOE) will be considered. Drivers, or factors that promote IoT adoption, and barriers, or factors that hinder the IoT, will be of particular interest. The evidence required to fulfill the research aim will be drawn from primary and secondary sources. To find reliable and legitimate answers to the research questions, a combination of interview and document sources of data will be utilised. Thereafter, within-case and cross-case analysis will be analysed. This will lead to the identification of common themes and categories, thus having the potential to create the conceptual framework of factors that affect the adoption of IoT within manufacturing SMEs.

1.4 Envisaged Research Contributions

This section considers the overview of the research contributions. This study makes both practical and theoretical contributions to the growing body of knowledge on IoT adoption. The major theoretical contribution is to provide an insight into the usage and applications of factors that may affect the decision to adopt the IoT in the context of manufacturing SME in Thailand. This includes the perception of whether the factors are drivers or barriers and the explanation of the significance and influences of each factor of the adoption. As a result, the study presents a conceptual framework that highlights the factors affecting adoption of IoT in manufacturing SMEs. Moreover, this study fulfills the gap in the literature as this research is the first that examines IoT adoption among manufacturing SMEs in Thailand.

The major practical contribution of this study is that it provides useful information for policymakers, managers of organisations, technology consultants and vendors that will aid them in the implementation and acceleration of IoT development and utilisation among Thai manufacturing SMEs. Within Thailand, the manufacturing SME industry is struggling due to the competitive pressure from neighboring countries; this is because the neighbouring countries have lower labour costs. For the managers of businesses, this study can be utilised as a foundation to consider whether to adopt IoT into their organisations. The study will help SMEs' managers more effectively understand adoption strategies and increase their knowledge about IoT technologies regarding its benefits and drawbacks. This can help determine whether there is a requirement for IoT within their organisations. Furthermore, the managers within the SMEs' could apply the conceptual framework as a reference for developing policies that could guide IoT adoption within their firms. Finally, IT vendors/consultants could use the conceptual framework developed throughout this study to better understand the specific problems faced by manufacturing SMEs. Knowledge and understanding of the factors affecting whether these small organisations will adopt IoT systems will then enable IT consultants to design suitable strategies for the widespread adoption of cloud technologies and sell them to their customers.

The next section considers the organisation of the thesis.

1.5 Organisation of the Thesis

This section considers an overview of the chapters in this thesis to provide the reader with a guide to its structure. A brief explanation of what constitutes each chapter is provided below:

Chapter 1provides the introduction to the research in terms of the research background, importance, rationale, and scope. The overview of the research methodology and contributions are discussed. In addition, the aims and objectives of this research and the structureof the thesis are presented within this chapter.

Chapter 2 provides a background to Thai and UK economy and their main industries. Manufacturing as an industry of focus in this study is discussed here. Thereafter, the definition and contribution to the economies, and the characteristics of SMEs, are explained.

Chapter 3 provides a working definition, overview and evolution of the key concepts under investigation within this thesis, namely, IT, Internet, ICT, and IoT. A critical review of the literature on IoT adoption focusing upon the manufacturing SME sector is provided. The architecture, usage, application and challenge of IoT in manufacturing SMEs are then discussed.

Chapter 4 explains the theoretical framework used in this study. Initially, existing technology adoption theories are identified and evaluated according to their exploratory and explanatory capabilities. The factors from each theory and relevant previous studies are selected and combined before, a conceptual framework is developed to support a common explanation and understanding of IoT adoption within manufacturing SMEs. This allows us to analyse and understand the scope of factors influencing the adoption of IoT by manufacturing SMEs. The key research questions are developed in this chapter in order to fill the gap in the literature.

Chapter 5 provides a detailed explanation of the research methodology adopted in this research. The research paradigm, which takes into consideration the research question and the complex and subjective nature of the research, leads to an interpretivist stance in this study. The interpretivist position influences the selection of a qualitative research method. The choice of a case study strategy will then be discussed and key aspects of the research design - such as unit analysis and observation, and sampling strategy - are established. Thereafter, the data collection process, including interview process, alternative data collection, pilot study, research instrument amendment will be discussed, followed by an explanation of the different types of approaches to analysing qualitative data and the criteria for choosing the data analysis approach in this study. Finally, the chosen data analysis procedure and evaluation criteria are discussed alongwith the credibility and ethical issues.

Chapter 6 can be divided into two parts. The first part of this chapter provides an overview of case studies. In-depth profiles of participants and a review of usage and impact of IoT will be presented in preparation for analysis of data collection results. The background information was obtained from both primary and secondary sources and the second part of this chapter will provide the research findings and analysis. It will present the various perceived technological, organisational and environmental contexts that influence the adoption of IoT within manufacturing SMEs in Thailand.

Chapter 7 discusses and summarises the key findings regarding the drivers and barriers influencing the adoption of IoT within Thai SMEs manufacturing industry. The findings that are presented in Chapter 6 will be analysed, compared, and contrasted against the extant literature discussed within Chapters 2 and 3, and with theories and models reviewed in chapter 4. The discussion of the research questions is presented.

Chapter 8 provides the conclusion of this thesis. This chapter starts with the research contribution to knowledge and the implications for managers, IT providers, government and policymakers. The revised conceptual framework as a result of the research finding is presented in this chapter. Thereafter, the chapter identifies the research limitations and, based on this, several suggestions and recommendations for future research are proposed. In addition, general critique and reflection on the part of the researcher are provided. Beyond this chapter, the appendices contain further research material, such as interview transcriptions and research instruments.

Finally, the references to citations used in this research are provided in the reference section.

1.6 Summary

This chapter has introduced the focus of this study, namely an investigation into the usage of the IoT within manufacturing SMEs in Thailand. The chapter provides the background to this study and introduces the aim and objectives. Following this, the structure of this thesis is outlined on a chapter by chapter basis. The following chapter will present the key literature considered within this thesis.

Chapter 2: Background and Context

2.0 Background and Context

This chapter provides an overview of the key literature that is to be considered within this thesis. The key variables of investigation are defined as namely manufacturing industries and SMEs and the geographical context of this study.

2.1 Global Economy

This section considers the overview of the global economy in order to provide a contemporary understanding of current global issues that are impacting upon the business world. There has been some economic growth in the wake of the Coronavirus pandemic (Fagerberg & Srholec, 2017; Jackson, 2021), especially among the East and South Asia market (United Nations, 2019). **Figure 1** (below) provides the trend of the global economy through Gross Domestic Product (GDP) shown in Trillions of US dollars. The outlook for the global economy is on the downside (World Bank, 2019a) and developed and emerging countries alike are concerned with regards to the long-term economy, as the current growth appears to be cyclical due to the unusual events, even with the fiscal stimulation and expansionary monetary policy such as low- interest rates, rather than fundamental expansion (Ferreiro & Serrano, 2021; Schwab, 2017; Summers, 2017). The strong per capita income growth is driven by only core industrial and urban areas (United Nations, 2019).

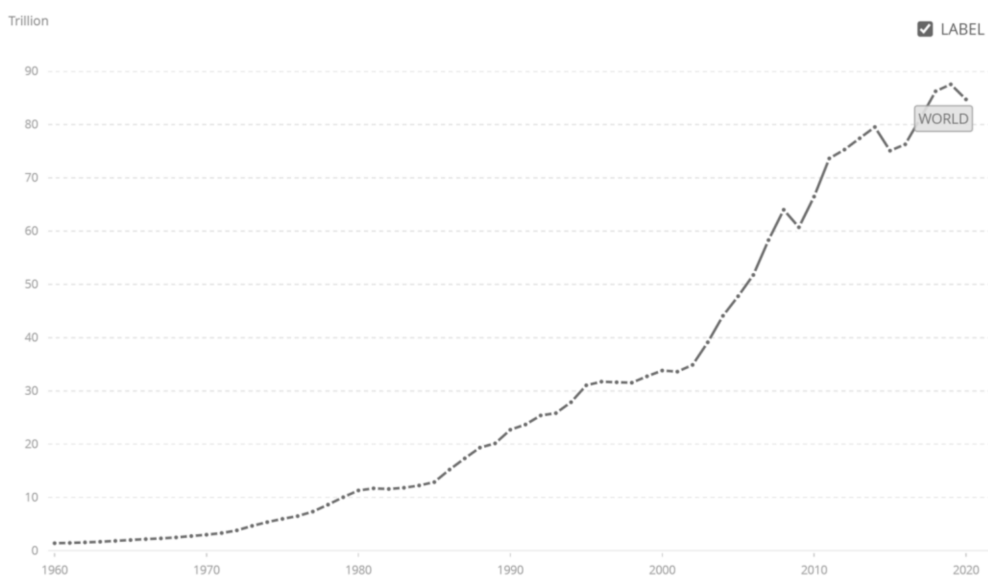

Figure 1: Global Economy through Gross Domestic Product (GDP)

Sourced from Gross Domestic Product (GDP) (current US$), In *World Bank*, n.d., Retrieved March 24, 2022, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD. Copyright 2021 by The World Bank Group. Reprinted with permission.

Global financing conditions have been tightened, production has weakened, private debt is increasing (this may limit the investment growth in innovation and technology adoption (DESA, 2019), investment activities are low (Schwab, 2017) and trade tensions are high (World Bank, 2019a). To overcome the current difficulties, all countries need to soften the financial market stress in the first instance; the policymakers have to strengthen the financial sector to prevent recessions and sustain innovation (Schwab, 2017). Thereafter, they can increase economic growth by increasing human capital, reducing the effect of the barrier upon investments and encouraging trade integration globally (United Nations, 2019; World Bank, 2019a). Productivity is the most critical factor leading to long-term economic growth and income (Schwab, 2019). However, global productivity has been declining due to several reasons: firstly, recent technology does not have the same potential as in the past with regard to productivity-improvement (IMF, 2017). Secondly, it could take more time to realise the benefits (McAfee & Brynjolfsson, 2017) and third, productivity has been affected by the long-term effects of workforce de-skilling. Fourth, lack of continuous technology investment due to high debt and low-interest rate (create a misallocation of capital) (IMF, 2017; Marshak, Wickson, Herrero, & Wynberg, 2021) and finally, most countries rely heavily on monetary policy rather than encouraging productivity-improving reforms. The decline of global productivity could also be explained by the shifting of resources toward less-productive sectors (Alcorta, Foster-McGregor, Szirmai, & Verspagen, 2021; Schwab, 2017).

Domestic demands are the key growth drivers for most nations (Schwab, 2019). Investment activities have been healthy in many developed and developing countries alike, whereas global inflation is moderate but upward (Schwab, 2019). In addition to private consumption, trade and investment flow are significant drivers of growth. However, technology advancement such as 3D printing may decrease the trade in the future by moving the production closer to the customers (Weller, Kleer, & Piller, 2015). Furthermore, all economies have to establish competitiveness in order to sustain growth and income (DESA, 2019). The most competitive nations, in terms of the economy, are the United States (US), followed by Singapore and Germany (DESA, 2019). In addition to the advanced market that, in the past, has been the main driver for economic growth, the emerging markets have been recovering since the last global economic crisis, especially China (Schwab, 2017). They have improved their efficiency and effectiveness at innovation but they need to broaden the benefit (not focus on only some industries or some areas) (Schwab, 2017). High growth emerging countries, particularly China, India and Indonesia, are able to innovate and become centres for innovation (Patra & Krishna, 2015; Schwab, 2017). Emerging countries have produced many patents recently, paying particular attention to the field of digital communications (World Bank, 2019a). Furthermore, China, India and Israel are shifting their focus from imitating development to development, based on technology (Nowak, 2018). The activities undertaken in emerging markets are mainly either complementary or substitute activities within developed countries (Bhattarai, Mallick, & Yang, 2021; Cano-Kollmann, Hannigan, & Mudambi, 2018). For example, the automation of factories within developed countries is a substitute for offshoring low skilled jobs to emerging countries (Cano-Kollmann et al., 2018).

Increased emphasis on knowledge-intensive intangibles is another significant global trend. It can be divided into two categories: upstream research and development (R&D), - knowledge (patents, R&D, software, training and unique organisational forms), - and downstream marketing knowledge (brands, customer service and trademarks) (Cano-Kollmann et al., 2018). This trend generates a large amount of information, ideas and knowledge globally (Cassiman & Valentini, 2016; Cano-Kollmann et al., 2018). With the advancement of connectivity technology, the global integration of the value chain is rising (Cano-Kollmann et al., 2018). This decreases the movement of both goods and people, thus lessening transportation and transaction costs. The integration of the global chain creates benefit for both developed and emerging countries; firms in developed countries can maximize their intangible assets to create value (focusing on core activities) while managing lower value activities through international (Stevens & Johnson, 2016). By contrast, businesses from emerging countries can learn and upgrade to higher value-added activities and finally become recognised globally. However, this trend creates several drawbacks: unskilled jobs in developed countries may disappear as the jobs are either offshored or they become superfluous (Parteka & Wolszczak-Derlacz, 2015). In addition, the businesses in emerging markets that cannot catch up or integrate into the global economy may decline and cease to exist. Furthermore, global integration may cause uncontrollable migrations, as well as creating significant competition on a global scale (Cano-Kollmann et al., 2018; Majidi, Kasavan, & Harindranath, 2021; Nowak, 2018).

To emphasise the technological advancement in both developed and emerging economies, the fourth industrial revolution, which is made up of digital, physical and biological technologies, is potentially a critical source of economic growth (Schwab, 2017) – the factors that will grow significantly alongside the fourth industrial revolution are human capital, innovation, resilience and agility (Schwab, 2019). However, advanced technology evolution makes the political and economic environment uncertain (McAfee & Brynjolfsson, 2017); the economic impact of current innovation remains challenging to measure, and the expected improvement in competitiveness and productivity has not yet appeared (Kotarba, 2017; Schwab, 2017). An explicit requirement for innovation adoption is the country's readiness, which can be measured by the availability of the latest technology, firm-level technology absorption, foreign direct investment (FDI) and technology transfer, internet broadband, international internet bandwidth and mobile broadband subscriptions (Schwab, 2017). Even though technology readiness is on an upward trend globally, some large emerging markets still need to upskill their workforce; China, India and Indonesia's technology readiness is low (Schwab, 2017) and this means that the benefit of the innovations is not distributed evenly (Schwab, 2017). To further underline the issue of skill, the current trend of economic and social outcome is shown by the decline in productivity, even though the output is rising but the employment number is declining significantly, especially in most advanced economies (Cano-Kollmann et al., 2018).

The fourth industrial revolution's main concerns are labour market elasticity and the protection of workers, with a need for all nations to be competitive and share the benefits equally (Schwab, 2017). Innovation becomes a key reason for labour market separation, with the decrease in numbers of middle-skilled jobs, and growth in both low and high-skilled jobs (Darvas & Wolff, 2016). Global inequality has been reducing over recent decades, as the economic growth rate of the weak economies is higher than that of advanced economies (Schwab, 2017), although the inequality has been increasing within each country on average (Lakner & Milanovic, 2016), especially for the emerging economies. In addition, the falling unemployment found in developed countries is nearly offset by the increase in unemployment in some large upper-middle-income nations such as Argentina, Brazil and South Africa (Dasgupta, Dierckxsens, & Verick, 2021; DESA, 2019). To summarise, the global situation: dynamic market structure, different market conditions and the existence of innovate competitors make competition more intense (Chen, Wang, Nevo, Benitez-Amado, & Kou, 2015; Dereli, 2015). In order to be competitive within the global market, businesses need to determine the right strategies and create different values (Dereli, 2015; Noe, Hollenbeck, Gerhart, & Wright, 2017). The essential objectives for organisations are increasing profitability and productivity, the gaining of new markets and the increase in existing market shares, which can be reached by innovation enhancement (Dereli, 2015). They need to generate new ideas, new products and innovative strategies, in addition to managing them appropriately (Dereli, 2015). The largest international firms will be the first to benefit from the technology, as they have excess resources to match, clean up and transform information within different platforms (Nowak, 2018). After all, innovation becomes essential, for both the competitiveness of the businesses and the countries thereafter (Dereli, 2015). This may lead to the question of how may smaller firms benefit from the technological adoption.

2.1.1 Global Manufacturing Sector

This section considers the global manufacturing sector. Globally, the current manufacturing sector, especially within advanced economies, is focusing more on innovation, productivity and trade than growth and employment, as has happened previously (Manyika, 2012). Manufacturing begins to consume and rely on service more than before (Böhm, Eggert, & Thiesbrummel, 2017) and the manufacturing and service sectors are no longer entirely separate. The service inputs, such as logistics and marketing, increase manufacturing activity (Miroudot & Cadestin, 2017). More than half of the employees in some manufacturing industries work in a service role, such as R&D and office support employees, to give example. (Manyika, 2012). Furthermore, there has been a shift of global manufacturing from west to east, as the east is more labour cost intensive. The manufacturing sector in emerging markets, such as China and India, are growing rapidly; in most advanced economies they are shrinking but becoming more productive (Thornton. 2010). There is a trend of ‘moving up’ the value chain to place more focus on technically advanced products or industries, such as aerospace and pharmaceuticals, as they may generate more return (Li, 2018; Thornton. 2010).

Chinese manufacturers are trying to put pressure on western manufacturing firms (Thornton. 2010). Globally, manufacturing accounts for about 16 per cent of the global GDP and is continuing to grow (Manyika, 2012). The largest manufacturing sector by production output is innovative and R&D intensive industries, autos, chemical and pharmaceuticals (Manyika, 2012), and the second largest manufacturing sector is regional processing: printing, and food and beverage. By contrast, the smallest manufacturing sectors are the labour-intensive industries, including apparel, furniture, jewellery, toys and textiles (Manyika, 2012). The leading low technology and high labour-intensive manufacturing country is China, and the leading high technology manufacturing country is the US (Hanson, 2021; Thornton. 2010).

The most significant trend in the manufacturing sector at present is digital transformation, which will not only change the way that manufacturers operate, but will also change the industry and business model (KPMG, 2018) by way of making it more competitive, especially for the businesses that have complex manufacturing and operational processes (KPMG, 2018). It will disrupt every part of the manufacturing value chain (Hartmann, King, & Narayanan, 2015) from R&D, supply chain, factory, marketing, sales and service (Hartmann et al., 2015).

The interconnectivity and being able to access data will be crucial in order that manufacturers will gain more proactive and predictive insight of company's product, operations and customers (KPMG, 2018) (the manufacturing sector generates more data than any other (Hartmann et al., 2015)). This will help businesses to meet new demand, as customers tend to ask for greater variation and a more honed after-sale service (Manyika, 2012). IoT and augmented reality are the most significant technologies that enable digitalisation (KPMG, 2018). Major manufacturing countries already have a strategic plan for digitalisation, such as the Industrial Internet Consortium which is found in the US, Germany has Industry 4.0 and China has a plan called Made in China 2025 (Hartmann et al., 2015). Yet, most of the businesses are not able to utilise digitalisation effectively (Hartmann et al., 2015). This section offers insight into how large organisations within developed economies embrace technology, leaving the question as to how smaller organisations that are from developing economies may approach this challenge; this is the focus of this thesis (see **section 1.1**). The next section will consider the Thai economy, which will be the country of focus in this research.

2.2 Thai Economy

The purpose of this section is to profile the economy of Thailand. The following section provides the overview of the Thai economy, main sectors and industries in Thailand, and the Thai manufacturing industries.

2.2.1 Overview of the Thai Economy

Thailand is located in Southeast Asia. It is surrounded by the Andaman Sea, the Gulf of Thailand, the Indian Ocean and the countries of Burma (Myanmar), Cambodia, Laos and Malaysia. **Figure 2** provides the geography of Thailand.

Figure 2: Geography of Thailand

Sourced from *Map of Thailand*, by AsianInfo, 2010. Retrieved September 5, 2019, from http://www.asianinfo.org/asianinfo/thailand/pro-geography.html. Copyright 2010 by AsianInfo.org. Reprinted with permission.

Thailand is an export-driven economy, and its industrial and service sectors are the most significant contributors to its economy (OBG, 2017; Worldatlas, 2017). Thailand has the 20th largest export in the world (Pines, 2016; Worldatlas, 2017), with the main products exported being automobiles, computers, fishery products, footwear, garments and textiles, integrated circuits, rice, refined petroleum, and rubber (Pines, 2016; ITA, 2018; Worldatlas, 2017). The largest receiving countries of Thai exports are China, Japan and the US (ITA, 2018; Workman, 2019a; Worldatlas, 2017). Furthermore, Thailand's main imports are crude and refined petroleum, capital and intermediate goods, consumer goods, integrated circuits and gold, with its major importers being China, Japan and US (Workman, 2019a; Worldatlas, 2017). In addition to strong export, Thailand's economy is strongly driven by domestic consumption, which comprises 50.8 per cent share of Thailand's GDP (Garcia, 2019). Thailand is ranked 27 out of 190 economies, and is the second largest economy within the ASEAN countries, after Malaysia (ITA, 2018; World Bank Group, 2019). Thailand is considered to be an upper-middle-income country with the lowest levels of extreme poverty gauged by using the international poverty line threshold (IPL) (Garcia, 2019; ITA, 2018). In addition, the current GDP value is at 404 billion dollars, and the GDP growth is at 3.3 per cent according to Thailand's national economic and social development board (NESDB) (Garcia, 2019). The strongest growth is from tourism and exports of manufacturing goods (IMF, 2018a) and the inflation rate is constantly at 1.5 per cent (Garcia, 2019). Tan (2016) states that a 20 per cent investment in ICT adds 1 per cent to GDP, a 2.1 per cent increase in competitiveness, a 2.2 per cent rise in innovation, and a 2.3 per cent increase in productivity. The effective use of ICT can improve quality of life, decrease educational gaps, increase production efficiency and increase government service providing (Jones & Pimdee, 2017). In particular, Guelich (2018) notes that SMEs in Thailand need to shift their focus to ICT investment as a critical success. They should utilise Thailand 4.0 policy by becoming technology driven organisations, rather than industry driven and this switch could be achieved by creating innovations instead of producing commodities. However, Guelich (2018) states that the constraining factors for SMEs in Thailand are government policies, financial support and capacity for entrepreneurship, respectively. Currently, SMEs are the top priority for governments (Tortermvasana, 2016); the governments are creating digital communities, start-up networks and digital parks for SMEs (Koanantakool, 2016). This is because SMEs account for a significant proportion of all businesses operating within the country (Jones & Pimdee, 2017). SMEs in Thailand are accountable for importing more than exporting (Worldatlas, 2018). Nevertheless, income disproportion and corruption are the major issues that can drive down the economy in Thailand (Worldatlas, 2017).

Even though poverty levels have been decreasing significantly over the years, the north, northeast and the deep south rural areas are still weak (Worldatlas, 2017). Furthermore, political instability and the military government has reduced investor confidence and hindered economic policies (Kopper, 2021; McCargo, 2017). There are some more concerns about the current state of the Thai economy; first, the high household debt due to past incentive credit growth (IMF, 2018a), this hinders the household spending. Secondly, although there has been some movement in the private sector over the past five years, the movement has been sluggish (IMF, 2018a). However, the government stimulates the economy by scaling up the infrastructure to bring in more private investors and to increase long-running economic growth (IMF, 2018a). Finally, because of the lack of labour force due to an ageing population (IMF, 2018a), the government has introduced a childrens' service supporting policy in order that more women can be employed within the workforce (IMF, 2018a). The government has also increased labour productivity by increasing the pensionable age and providing adequate coverage, which can help to increase the overall labour force in the country (IMF, 2018a).

Thailand has various incentive policies in place that serve to encourage foreign investors to participate in targeted industries based on the Thailand 4.0 scheme (Garcia, 2019); Thailand's Foreign Business Act allows 49 per cent of foreign shareholdings (Garcia, 2019). The Thai government endeavours to attract skilled foreigners through the four-year smart visa program, which is applicable to expatriates who work or invest in technology-based production activities and service (Garcia, 2019). Another significant factor affecting the Thai economy is the eastern economic corridor (EEC), an exclusive economic zone that aims to create technological manufacturing and service centres in Chonburi, Rayong, and Chachoengsao provinces in order to increase private investment (Royal Thai Government, 2016). Furthermore, Thailand 4.0, the master plan to transform the economic model, has an objective to make Thailand a high-income nation by placing a focus on sustainable growth and development (Garcia, 2019). The previous initiatives move from Thailand 1.0 (agriculture) to Thailand 2.0 (light industry, such as textiles, and food processing), to Thailand 3.0 (advanced/heavy industry and energy) which account for 70 per cent of Thai GDP, and to Thailand 4.0 which will be driven by high-tech industries and innovation (Jones & Pimdee, 2017). It is focused on turning the labour force into knowledge workers (Royal Thai Government, 2016). Thailand 4.0 places particular focus upon ten industries (Jones & Pimdee, 2017), six of which are existing industries: Automotive, Affluent, Agricultural and Biotechnology, food innovation, Medical and Wellness Tourism, and Smart Electronics; the other five industries are classified as new industries (New S-curve): Aviation & Logistics, Biofuels & Biochemicals, Digital, Medical Hu, and robotics (for automotive, plastic, medical & electronic industries) (Jones & Pimdee, 2017). After all, Thailand remains an attractive country for foreign businesses; it has low taxes and a business-friendly environment (Aseanup, 2018; Benyaapikul, 2021). The following section considers the main sectors within the Thai economy.

2.2.2 Overview of Main Sectors and Industries in Thailand

This section considers the overview of main sectors and industries in Thailand. The main sector in Thailand are industrial (majority is managed by the SMEs) (Worldatlas, 2018). Within the industrial sector, manufacturing is the largest industry, contributing almost 50 per cent of the GDP. The two major industries are automotive, e.g., Toyota, Honda and electronics, e.g., Seagate Technology (Worldatlas, 2018); the significant foreign investment from Japanese companies makes Thailand a regional hub for the automotive industry (Aseanup, 2018). There is a sector relating to large electric and electronic appliances and components, for example, Canon, Nikon, that are exported around the world (Aseanup, 2018). Another significant sector is the services sector; the manufacturing sector in Thailand needs the following services to survive, or grow: distribution, retail, customer support (Worldatlas, 2017). Within the service sector, financial and tourism sectors are the primary industries (Worldatlas, 2018); the tourist industry is a critical factor regarding economical growth and also of the large current account surplus, which accounts for 10.6 per cent of Thailand GDP in 2017 (IMF, 2018a). The main tourist area is found within the capital city, Bangkok. Furthermore, Thailand is a leader for tourism in Southeast Asia, in terms of numbers of foreign tourists arrivals (Aseanup, 2018). The next section will consider the Thai manufacturing industries, which will be the industry focused upon within this research.

2.2.3 Thai Manufacturing Industries

This section considers the key Thai manufacturing industries. Thailand manufacturing is ranked 14 out of 40 in the world in terms of global competitiveness (OBG, 2017), which is higher than several regional competitors, such as Indonesia, Malaysia or Vietnam (OBG, 2017). This ranking has been achieved due to the country's highly skilled workforce and its labour productivity (OBG, 2017). However, the disadvantage of this skilled workforce is that it comes with a high labour cost compared to other competitors (OBG, 2017). Another advantage held by the manufacturing industry is that it has 20 per cent lower corporate tax rates compared to its regional competitors, which attracts more foreign investors (OBG, 2017). Industrial zones are mostly around the capital city, Bangkok and the Eastern Seaboard; 20 provinces out of 77 within Thailand have industrial zones (Business Sweden, 2015). The key provinces are Ayutthaya, Samut Prakan (this province has the largest airport in Thailand), Chonburi (Chonburi has the largest seaport in Thailand) and Rayong (Business Sweden, 2015). The key, and also the most promising manufacturing industries, are automotive, electronics, electronic appliances and food processing.

Automotive

This section considers the automotive industry, it being the largest manufacturing industry in Thailand (Business Sweden, 2015). Automotive supply chains are considered as being the world's most complicated (Liu & Chang, 2012). Thailand's automotive production is within the top 15 in the world, top 5 in Asia and number 1 in South East Asia (Business Sweden, 2015). Thailand's automotive industry has made a significant contribution to the nation in terms of production value and export (export being 60 per cent of the total production) (Business Sweden, 2015). Furthermore, the demand for cars and trucks is growing rapidly, along with the economies across South East Asia (Business Sweden, 2015). Japanese companies such as Honda, Isuzu, Mitsubishi, Nissan and Toyota dominate the automotive production (Business Sweden, 2015) and western major global car manufacturers in Thailand are Ford, GM, MAN, Mercedes-Benz, Scania and Volvo (Business Sweden, 2015). The 90 per cent of original equipment manufacturers (OEM) production is complete knock-down (CKD) assembly (Business Sweden, 2015) and there are 600 automotive suppliers in Tier 1, and 1700 suppliers in Tier 2 and 3 (Business Sweden, 2015). In addition, the government is supporting the manufacture of eco-friendly vehicles to create new lines of automobiles for car companies and to increase domestic demands (Jones & Pimdee, 2017). Another supporting policy is from the board of investment (BOI) which offers several financial incentives, such as exemptions from imported machines and exemption from income tax for up to eight years (BOI, 2018). However, the eco-cars programs are not very successful since the criteria from the government, such as minimum investments, and production capacity, is not easy to fulfil (Jones & Pimdee, 2017). Furthermore, the main concern for cars manufacturers is the cost of labour and the finding of better solutions regarding energy efficiency, quality and safety control and environmental issues (Business Sweden, 2015; Mahdavian et al., 2021). All these are the main drivers to bring in automation to the automotive industry in Thailand (Business Sweden, 2015; Mahdavian et al., 2021).

Electronics and Electrical Appliance

This section considers the electronics and electrical industry in Thailand. This industry is the second largest in Thailand, coming after the automotive industry (OBG, 2017). Thailand is the world's second-largest maker of hard disk drives (HDDs) after China, with Seagate Technology and Western Digital (WD) as the two leading producers (OBG, 2017). The major products of the electronics industry are computer parts and accessories, integrated circuits (ICs) and equipment for mobile phones respectively (OBD, 2017). The example of leading companies are Seagate, with a factory in Nakhon Ratchasima and Samut Prakan; Western DigitalCorporation with a factory in Pathum Thani and Ayutthaya; Toshiba Storage Device, also in Pathum Thani; and Hitachi Global Storage in Prachinburi (OBD, 2017). Furthermore, the production in Thailand focuses on mainly the assembly and testing of the electronic component for export; the domestic demands are very low, and the equipment used for the production is mostly imported from overseas (Alliance Experts, 2018). Despite the massive production value, export value has been growing slowly since the increase of the regional competition; the manufacturers' relocation to countries where the labour cost is cheaper (OBD, 2017). In addition, the shift in demand with newer technology being used - smartphone and tablet computers – which require smaller and more effective components than personal computers (PC), has required that the manufacturers, such as Samsung, move their factories to Vietnam and begin a new line of production (Reuters, 2015). An example of this is the data storage, which requires HDDs, and is now moving toward solid-state drives (SSDs) that are used in light consumer electronics (OBD, 2017). After all, as the electronics industry places its emphasis on low value-added assembly, the demand for automation solutions is expected to be low (Business Sweden, 2015).

By contrast, electrical appliance industry has greater potential to bring in automation, since there is a demand for solutions to energy efficiency, quality and safety, robots, and tools for metalworks such as injection molding machines (Business Sweden, 2015; Rattanawiboonsom, 2021). A large number of the world's main electrical appliance manufacturers have operations in Thailand; Japanese manufacturers are 50 per cent of the whole industry, with companies such as Canon, Nikon and Sony (OBD, 2017; Rattanawiboonsom, 2021). Furthermore, Thailand is one of the top five manufacturers, producing air conditioning units and refrigerators, followed by washing machines and digital cameras. Domestic suppliers account for about 70 per cent of the total production (OBD, 2017).

Food Processing

This section considers the food processing industry in Thailand. Thailand is the world's leading suppliers of agricultural products, mainly because of the well-established food processing industry, which adds value to the entire food supply chain from field to market (OBD, 2017). As a result, Thailand's food industry is the most advanced, and it is the largest exporter in South East Asia (Business Sweden, 2015). Significant sub-industries are canned fruit, chicken, frozen seafood, rice and sugar processing (Business Sweden, 2015). The leading global markets include Europe, Japan, China, and the US (OBD, 2017). In addition to the export market, the domestic market is also growing rapidly. Most of the processing factories are small firms that serve the domestic market, whereas medium to large firms mostly serve to produce higher valued goods for niche domestic markets (OBD, 2017). The large firms are generally both Thai and Multinational traders, such as Betagro, Charoen Pokphand Group, Del Monte, Dole Thailand, Kraft, Kellogg's, Inter- Holding, Nestlé, Patum Rice Mill & Granary, PepsiCo, Procter & Gamble, Saha Pathana, Royal Friesland Foods, Thai Beverage and Thai Union Unilever Group (OBD, 2017). Despite the advanced food processing factories, about 60 per cent of the advanced food-processing machines and equipment are imported from China, European Union (EU), Japan, Korea and the US (Business Sweden, 2015). The traceability system to track and monitor the whole lifespan of food production, including the processes of cultivating, transporting, processing, warehousing and selling, could ensure the food safety (Lin, Shen, Zhang, & Chai, 2018). Therefore, the demand for automation and innovation depends upon the requirements needed to ensure food safety and standards from each market; generally equipment demands are for refrigerating or freezing equipment, machinery and laboratory equipment for the treatment of materials and machinery for filling, closing, sealing, or labelling food containers (Business Sweden, 2015).

Summary

All high potential manufacturing industries in Thailand - automotive, electrics and electrical appliances and food processing – strive to find solutions and machinery for automation, robotics, energy efficiency, quality and safety and financial control, due to the global rise in competitiveness and standards, as well as an increase in labour costs; regarding labour costs, the producers are known to demand back their products from suppliers (vertical integration) (Business Sweden, 2015). The International Federation of Robotics classifies Thailand as a significant and intensifying market for robotics (BOI, 2018 and Thai manufacturers purchase up to 4,000 industrial robots each year (BOI, 2018). After all, the automation and robotic systems will not be utilised effectively without interconnectivity taking place within the factory. This emphasises the importance of bringing in the IoT in the manufacturing industry in Thailand.

The government are developing the policy, Thailand 4.0, through various government support programmes designed to build the automation ecosystem for manufacturing industries (BOI, 2018). This will boost the growth of the robotics market in Thailand and create a demand for robotics, automation and related technologies (BOI, 2018). With regard to demand, the government is supporting businesses by waiving the corporate income taxes for the first three years, when the tax exemption cap is not more than 50 per cent of the investment capital (BOI, 2018). The firms can be made exempt from the import duty for machinery (BOI, 2018). On the supply side, the businesses that invest in business activities related to the robotics and automation, such as conceptual design solution, engineering design and system integration, such as from IoT, can get eight years of tax holidays, exemption of import duties on machinery and raw material for export manufacturing (BOI, 2018). In addition, those organisations that invest in the robotic and automation sectors within the EEC zone (the provinces of Chonburi, Rayong and Chachoengsao), are eligible for up to 13 years of corporate tax and income tax exemption and they're able to attract foreign investors that have a right to own 100 per cent land (BOI, 2018). Currently, the large companies include ABB from Switzerland, KUKA Robotics from Germany, and Nachi Technology from Japan, and these companies have already settled their operations in Thailand (BOI, 2018). Despite all the benefits of investing automation and robots in the Thai manufacturing industry, the manufacturing industry in Thailand is still facing some challenges with regard to implementing automation: Still, the level of automation is growing but from the low base (Business Sweden, 2015). A majority of the manufacturing SMEs are family run, and the older generation will usually make any final decisions regarding the business; the younger generation needs to convince and help the family to understand the benefit of automation (Business Sweden, 2015). The next section considers the SME sector, which is the focus of this thesis.

2.3 The SME Sector

This section provides an overview of SME sector including discussing its economic importance and contribution. A working definition of SME is also provided.

2.3.1 Overview of SME Sector

SMEs have a significant influence on both the economy and society through employment, innovation and growth (Audretsch, 1999; Floyd & McManus, 2005). High-income economies have the highest SME density, which is measured as the number of SMEs per 1,000 employees; however, it is the Central Asian and middle-income economies in Europe that have experienced the highest growth within the number of SMEs recently (Gonazales, Hommes, & Mirmulstein, 2014). The significant differences between SMEs and large enterprises are that SMEs require a less administrative management process that has more flexibility and a stronger focus on people (Müller, Buliga, & Voigt, 2021; Ghobadian & Gallear, 1997). SMEs do not change the management as frequently as large enterprises; they can then focus on long-term strategies (Müller et al., 2021; Geschka, 1997). They also have specialties in specific areas, but sometimes lack resources, such as highly skilled employees, that are required to expand the operation or control the quality of the products or processes (Geschka, 1997). SMEs account for a significant proportion of all businesses (Jones & Pimdee, 2017). Thus, the definition of SMEs is crucial in order that they may be able to access the finance and support programs, or training (EC, 2016).

2.3.2 SME Definition

This section considers the term SME. According to Kayanula and Quartey (2000), the Bolton Committee (1971) first defined SME in terms of contribution. A business has to fit the following criteria: it has a small market share; the owners manage it in a personalised way, and not through the formalised organisational structure, and it is independent (Abor & Quartey, 2010). Several experts in this field have contributed to the various definitions of SME (Arowomole, 2000). Baumback (1983) defined SME in terms of employment, asset value and dollar sales. The definition of SMEs is varied between countries and industrial sectors. Each country has different criteria for what should be considered a legitimate SME, depending on sectors and size (Moskowitz, 2017). A business that holds a significant market within a sector can be considered small, while another in a small market can be medium or large. The most widely used criteria for a definition of an SME is the number of employees, followed by turnover, and lastly, assets (Gonazales et al., 2014)

The majority of countries that are middle-income and high-income economies in the OECD set the benchmark of having of a certain number of employees within the business in order for it to be classed as an SME; the employee numbers should be fewer than 250 (Abe, 2012). A few countries, such as Japan and the US allow for up to 300 and 500 employees, correspondingly (Abe, 2012). In addition, some countries, such as China, define the SMEs of manufacturing, service and other industries differently (Abe, 2012); the definition is based on industry category, number of employees, annual revenue and total asset. By contrast, the economy in some lower-income countries, such as Botswana, typically define the SME as an enterprise having fewer than 100 employees (Gonazales et al., 2014; Nkwe, 2012). Annual turnover can also be used to define an SME (EC, 2016), the turnover threshold for SMEs being typically between 50 and 70 million dollars (Gonazales et al., 2014) in high-income economies. However, SME turnover is normally limited between one million dollar and five million dollars in lower income economies (Gonzales et al., 2014).

Table 1 provides an overview of the international definitions of SMEs by an upper limited number of employees and turnover as the two most widely used criteria.

Table 1: International Definition of SMEs

Economies	Upper limited number of employees	Turnover	SME literature references
Australia	200	25 million dollars	e.g. MacGregor (2005); Harvie & Lee (2002)
China (industrial sector)	2000	30 million Chinese Yuan	e.g. Xiangfeng (2007); Hall, (2007); Cardoza & Fornes (2011)
OECD	250	50 million Euros	e.g. Fink & Ploder (2009); Coppa & Sriramesh (2013); Beesley & Cooper (2008)
EU	250	50 million Euros	e.g. Will (2008); Dannreuther (2007); Hossain & Kauranen (2016); Durst & Runar Edvardsson (2012)
Japan	300	-	e.g. Honjo & Harada (2006); Harvie & Lee (2002); Shi & Li (2006)

Thailand	200	-	e.g. Shi & Li (2006); Ueasangkomsate (2015); PunyaSavatsut (2011)
US	500	100 million dollars	e.g. Shi & Li (2006); Kalak& Hudson (2016); Altman & Sabato (2005).
Botswana	100	833,333 dollars	e.g. Nkwe (2012); Mapfaira, Mutingi, Lefatshe, & Mashaba (2014).

Table 1 highlights the many different definitions of SMEs that exist globally. The most widely used definition is from the EU, with the 250 limited number of employees as the most frequently used criteria (Casals, 2011; Pickernell, Senyard, Jones, Packham, & Ramsey, 2013). This thesis utilises the EU/OECD definition, as this is the most extensively used by both academia and government. The European Commission (EC) defines an SME by the number of employees, annual turnover and annual balance sheet (EC, 2016). The criteria for the number of employees are mandatory, whereas the two financial criteria are optional.

Table 2 defines Small and Medium Enterprises with European Union standards.

Table 2: European Union Definition

Enterprise category	Headcount	Annual turnover	Or	Balance sheet total
Medium-Sized	<250	≤ 2000 million Baht		≤ 1720 million Baht
Small	<50	≤ 400 million Baht		≤ 400 million Baht
Micro	<10	≤ 80 million Baht		≤ 80 million Baht

These criteria apply to the figures for independent firms only (EC, 2016). A business that holds more than 25 per cent of a larger group, or outsiders, has a stake of 25 per cent or more of the capital or voting right (whichever is higher) . The criteria may need to include / exclude staff headcount / turnover / balance sheet data from the organisation before it can be categorised (EC, 2016).

2.4 Summary

This chapter identifies the key issues and current challenges within the Thai economy as a developing country embracing technology and seeking to compete in a global competitive environment. Regarding the Thailand economy, the main sector in Thailand is manufacturing, which contributes almost 50 per cent of the GDP. Furthermore, the SME sector is recognised as an important factor aiding the economic development within Thailand. However, a current issue is that Thai manufacturing SMEs have a high labour cost in comparison to neighbouring countries such as Vietnam. Thus production facilities often relocate from Thailand to these countries. Therefore, technology adoption in the manufacturing industry is required in order that the business can become more efficient and effective. ICT has been identified as being key to this achievement, especially the IoTs. Successfully adopting the IoT into the manufacturing SME sector will potentially reduce the production cost and increase competitiveness. This chapter also notes the importance of the SME sector as a contributor to the prosperity of the Thai economy. A working definition of SME is thereafter provided. The following chapter will consider the literature that is available regarding ICT and the IoTs, which is the research focus of this thesis.

Chapter 3: ICT and IoT Literature Review

3.0 Literature Chapter

This chapter will provide an overview of the key literature to be considered within this thesis. The key variables of investigation namely IT, internet and IoT are defined as the technological context of this study.

3.1 IT and ICT

This section will provide an overview of IT and ICT including definition, evolution and impact of the technology in relevant context.

3.1.1 Definition and Current Situation of IT and ICT

This section considers the definition of IT and ICT. IT is the application of computer science to better manage information (Grauer, 2001) and is accomplished by collecting, retrieving, transmitting and manipulating information in the form of sound, image or text (Azma, Mostafapour, Rezaei, 2012; Sharma, 2016; Yunis, Tarhini, & Kassar, 2018), and is often applied in the context of business and commercialisation (Sharma, 2016). IT comprises hardware, software and application for transformation information by accepting information firstly as input, then as process and it then sends a new set of information to receivers (Sharma, 2016). IT changes all management processes from paper-based to electronic, which enables the integrated system, fast processing and an ability to handle complicated structure (Azmaet al., 2012). IT is typically used in automation, control systems, data analysis, decision-making, information access, knowledge management, problem solving, robotics and transaction processing (Bag, Gupta, Kumar, & Sivarajah, 2021). The example of IT is supervisory control and data acquisition (SCADA), enterprise resource planning (ERP), customer relationship management (CRM), and product life-cycle management (PLM) (Oliveira, Filipe, & Amorim, 2021).

Normally, the IT focus will be upon encoding and decoding, as well as the processing of information (Yang, 2018), while the broader term of IT is ICT which focuses on sending and receiving technologiesfor message data transmission (Yang, 2018). ICT can often be used as a synonym for IT or the extension of IT concept (Yang, 2018) by stressing the part of unified communications (Murrey, 2011). Furthermore, ICT includes telecommunications technologies such as cell phones, Internet,wireless networks and other communication means (Mahmoud, Amer, & Ismail, 2021; Spacey, 2016; Zuppo, 2012). The advance in ICT enables the hardware and software to deliver information via the Internet (Yang, 2018). As technology evolves rapidly, IT and ICT are gradually linked and merged into one category; the category of ICT (Yang, 2018). IoT, which is the focus technology within this research, is considered to be an ICT.

This section considers the current situation of ICT. The digital revolution has allowed for a large amount of information to be computed and digitally stored, and has increased communication flexibility (Hilbert & Lopez, 2011). Digitalisation has become so important that currently countries are ranked upon their ICT maturation (Iceland, Korea, Switzerland, Denmark, UK are current leaders) (ITU, 2017). At an industry level, **Figure 3** provides the digital-curve; the industries in the first wave are ICT, media and finance, and insurance.

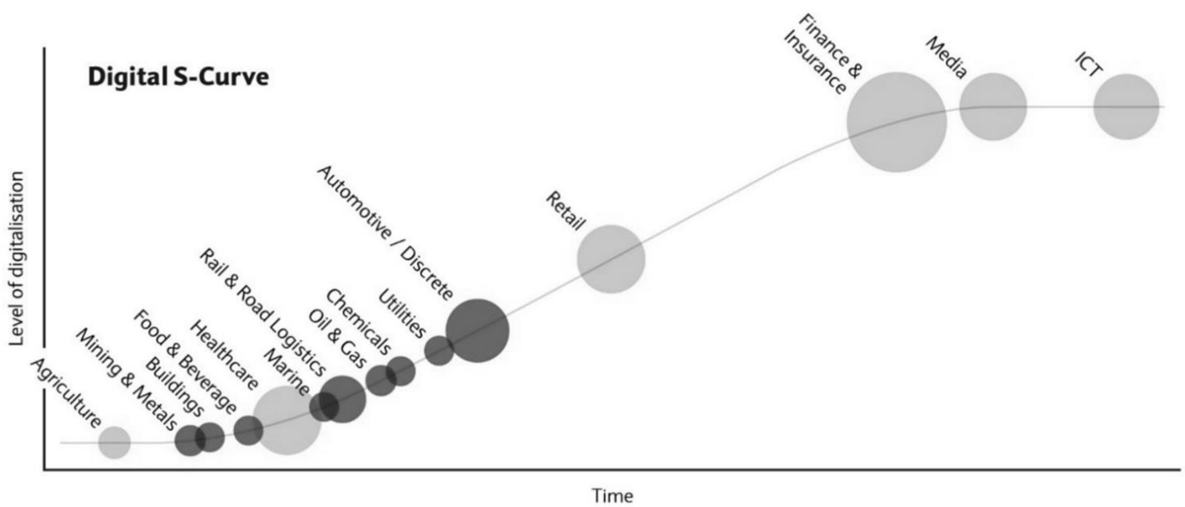

Figure 3: Digital S-Curve

Sourced from Digital S-Curve: Hardtech's, by ABB, 2021 Retrieved March 28, 2022, from https:// https://johntough.com/digital-s-curve-hardtechs-opportunity/. Reprinted with permission.

From a business-level perspective, IT is critical to an organisation's success (Parent, 2019); businesses typically use some form of IT to order raw material, manufacture or assemble it, determine the cost, store, deliver, collect, report on it, as well as using IT to interact with customers and employees within the organisations (Parent, 2019). For example, Toyota uses an Internet-based Web portal called Dealer Daily to link the 1,300 dealers with Toyota factories, part suppliers and distributors. This reduces production costs and cycle time, and increases the amount of new vehicles available to purchase within the market (Oliveira & Martins, 2011). Another example of a web portal is General Motors, which uses design collaboration, product life cycle management and graphics tools to integrate three tiers of suppliers into one network (Parent, 2019). IT and ICT are strategic resources that create competitive advantages within businesses (Oliveira & Martins, 2011). They allow firms to develop a sense of their own environment and respond to both opportunities and risks quickly (Oliveira & Martins, 2011). An example of these technologies is groupware, video conferencing and instant messaging, all of which increase communication frequency and efficiency (Oliveira & Martins, 2011).

Historically, there is rapid growth in programming and ICT skills globally. ICT is growing rapidly worldwide (Pratt et al., 2012). For instance, the internet accessibility had increased from 0.01 to 4.3 per cent of the population in low-income countries; from 0.21 to 23.8 per cent in middle-income countries; and from 11.2 to 51.9 per cent in high-income countries (from 1997 to 2009) (Pratt et al., 2012). The ease by which mobile phone technology can be accessed has increased from 0.05 to 28.9 per cent in low-income countries; from 1 to 71 per cent in middle-income countries; and from 17.9 to 96.3 per cent in high-income countries during the same period (Pratt et al., 2012). Outsourcing software development makes things much easier and more attractive to businesses (Dwyer, 2015) and there is evidence to show that there has been an increase in the level of broadband penetration, in turn leading to an increase in GDP growth rates (Niebel, 2018).

There is evidence that both developing and developed countries have been relatively gaining the same with regard to ICT investments (Cardona, Kretschmer, & Strobel, 2013; Razzaq, An, & Delpachitra, 2021). Although developing countries may lack skilled human capital or finance to support ICT expenditure, they can gain significant benefits from investing in ICT as they still have more room to improve, for example, knowledge in the industry and lower transaction costs compared to developed countries (Keller, 2014; Razzaq et al., 2021). However, the developing countries may need more time to realise the benefit of ICT adoption, and if this is the case, the larger improvement from ICT may be seen to be less abundant within developing countries than within the developed countries (Niebel, 2018).

China and India are the fastest growing markets in the world with regard to mobile technology (Dwyer, 2015); China is the largest ICT products manufacturer and India is dominating the software globally (Dwyer, 2015). In industrialised countries, businesses in both public and private sectors spend about 30 per cent of their R&D budget on ICT (Tarutė & Gatautis, 2014).

3.1.2 IT and ICT Introduction and Evolution

This section considers the introduction and evolution of ICT. The significant technology advancement has been revolutionised and is shown in three types of changes: biotechnology, materials and information (Hallberg & Bond, 2000). Biotechnological advances are mainly in health application for therapeutic and diagnostic, in agriculture to increase productivity and to improveanimal health, and in the environment to provide more efficient waste and water treatment (Achimugu, Oluwagbemi, Oluwaranti, & Afolabi, 2009; Behera, Mishra, & Thatoi, 2021). For the material advances, transport benefits from lighter material. Moreover, healthcare benefits from advanced material such as dynamic images and intelligent prosthetics (Achimugu et al., 2009; Behera et al., 2021). The most significant technology advancements are in telecommunications and information, which allow for digitalisation (Focacci & Kirov, 2021). This research focuses on the ICT revolution in a developing economy context. **Figure 4** provides the s-curve of digital technologies in four different stages: emerging, improving, mature and ageing.

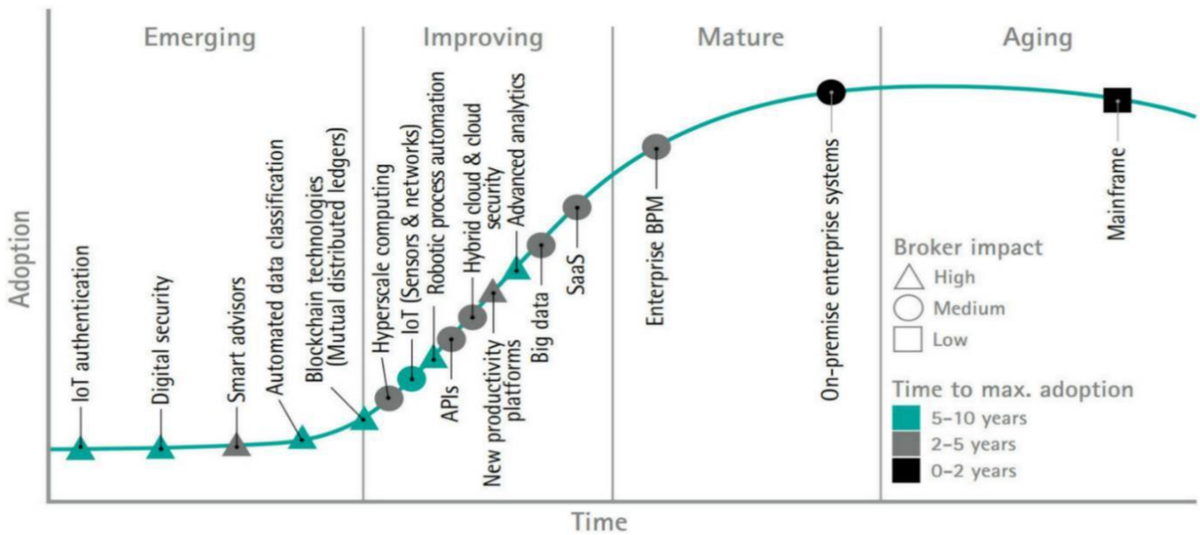

Figure 4: The S-Curve of Digital Technologies in Four Different Stages: Emerging, Improving, Mature and Ageing

Sourced from *State of the UK Economy (May 2018)*, by G. Reilly, 2019. Retrieved March 28, 2019, from https://www.tutor2u.net/economics/reference/state-of-the-uk-economy-may-2018. Copyright 2018 by tutor2u. Reprinted with permission.

Bresnahan and Trajtemberg (1995) identify ICT as a general-purpose technology (GPT), which is comparable to the significant impact that the steam engine and electricity have had upon growth and transformation globally in the past (Vu, 2017). GPTs typically have three characteristics: they are spread out to almost every sector; they continuously improve over time, and they have a significant impact upon creation within innovation and the transformation of sectors (Vu, 2017). In the case of ICT, it generates two distinct and impactful phenomena: network effect and knowledge development (Vu, 2017).

The ICT revolution starts after the IT revolution. IT revolution is mainly driven by the rapid progression of the advancement and application of semi-conductors (Jorgenson & Vu, 2016). The first revolution started during World War Two, with a large automatic, general electro-mechanical calculator called Harvard Mark one (Hernes, 2002). The starting point of IT was a transistor; semi-conductor equipment that can switch and encode data in binary form (Hernes, 2002). Texas Instruments invented the integrated circuit, which comprises several transistors that can store and retrieve data (the storage later known as a memory chip) (Jorgenson& Vu, 2016). Subsequently, there was a large-scale mainframe computer invented (Niederman, Ferratt, & Trauth, 2016) and this is when the term ‘management information systems’, or (MIS) emerged, as the computer’s mathematical calculation was applied in finance, accounting and operation research (Niederman et al., 2016).

The input-output technology evolved from punch cards to magnetic tape, faster printers, and eventually computing languages were developed (Hernes, 2002). In addition, Intel created the first Central Processing Unit (CPU), which acted as the brain of the computer (Jorgenson & Vu, 2016). From here on, computing technology became cheaper, easier to use and smaller, and this was when the term ‘information economy’ was first applied (Niederman et al., 2016).

Then, the first processors to be placed into a microchip became available and magnetic discs were constructed (Hernes, 2002); IBM launched the first PC in 1981 (Hernes, 2002). Following this, the capacities of the computers' main-brain was increased, their applications expanded and the number of people who utilised this technology became more widespread (Hernes, 2002). The PC made electronic data interchange (EDI) possible within the context of SMEs (it was previously only available within large businesses that had large, mainframe computers) (Lacovou, Benbasat, & Dexter,1995). EDI moved from a paper-based exchange of business documents to electronic (Lacovou et al., 1995). Over time, microprocessors were rooted in many products, including aeroplane technology and streetlighting. They become a part of our everyday lives, being adopted for use in the manufacture of video players, credit cards, remote controllers, cameras, hotel room door locks and smart buildings (Hernes, 2002). Microprocessors interpret bar codes into prices at the point of payment for goods, they monitor electronic injection of fuel in our vehicles, and they determine where the elevator stops within a building (Savulescu, 2015).

Internet and mobile technology first emerged in the 1960's (Jorgenson & Vu, 2016), thus beginning the ICT era. This had significant impact upon economic development, particularly in areas where communication and networking, information access, learning, R&D and innovation were driving the economy (Jorgenson & Vu, 2016). More computers were linked and the number of servers were increased, in addition to applications (Hernes, 2002).

The internet is the key technology that allows businesses to integrate electronic technology pertinent to business functions, referred to as E-business (Coltman, Devinney, Latukefu, & Midgley, 2001). E-business includes the use of computer and network systems for internal operations, as well as the internet, for e-commerce and communication with all stakeholders (Coltman et al., 2001). The competitive pressure within industries drove businesses to create e-commerce platforms, emerging in 1990, including business-to-business and business-to-customer applications (Nierderman et al., 2016).

There has been a significant improvement since then in broader computer and communications infrastructure (Niederman et al., 2016); mobile phones were reduced in size and weight and was attended by an expansion of functions and distance (Hernes, 2002). Mobile phones are used not only for holding verbal exchanges, but also to pass written messages, receive news or stock exchange quotes, or even restaurant reviews (Hernes, 2002). To date, mobile phones are now able to send and receive written messages, photos, and can stream music (Hallberg & Bond, 2000). Furthermore, lineless communications can now take place not just through satellites, but also via high frequency, short-range radio transmitters that have coverage of a specific area, or cell, inside buildings by using "Bluetooth" technology, and by utilising infrared light (Hernes, 2002). Currently, new computing devices, as well as communication technology, have emerged, such as a tablet, smartphone, or cloud computing (Niederman et al., 2016). People can now link their devices together; they can access computing resources at any given time (Niederman et al., 2016). In addition to the advancement in telecommunication, powerful computing enables the world of social media, such as Facebook and Twitter (Niederman et al., 2016).

3.1.3 Impact of ICT on Businesses

This section considers the positive impact of ICT on businesses.

Industries and organisations have undergone rapid transformation due to the result of diffusion of ICT within businesses; new technologies enable and ease business activities pertinent to the storage, processing, transmission and reproduction of information (Mikalef & Pateli, 2017). The ICT revolution has created innovations such as the PC, mobile phones and the internet, which increases the productivity gains in several countries (Edquist & Henrekson, 2017) and currently, the IoT as an innovation continues to evolve (Edquist & Henrekson, 2017). ICTs can change the internal processes within businesses by altering organisation, operations and structure (Mikalef & Pateli, 2017); several studies have indeed found that ICT significantly improves the productivity and economic growth at macroeconomic, industry and business level (Jones et al., 2017; Mikalef & Pateli, 2017). **Figure 5** below displays the decrease in computer equipment cost over time:

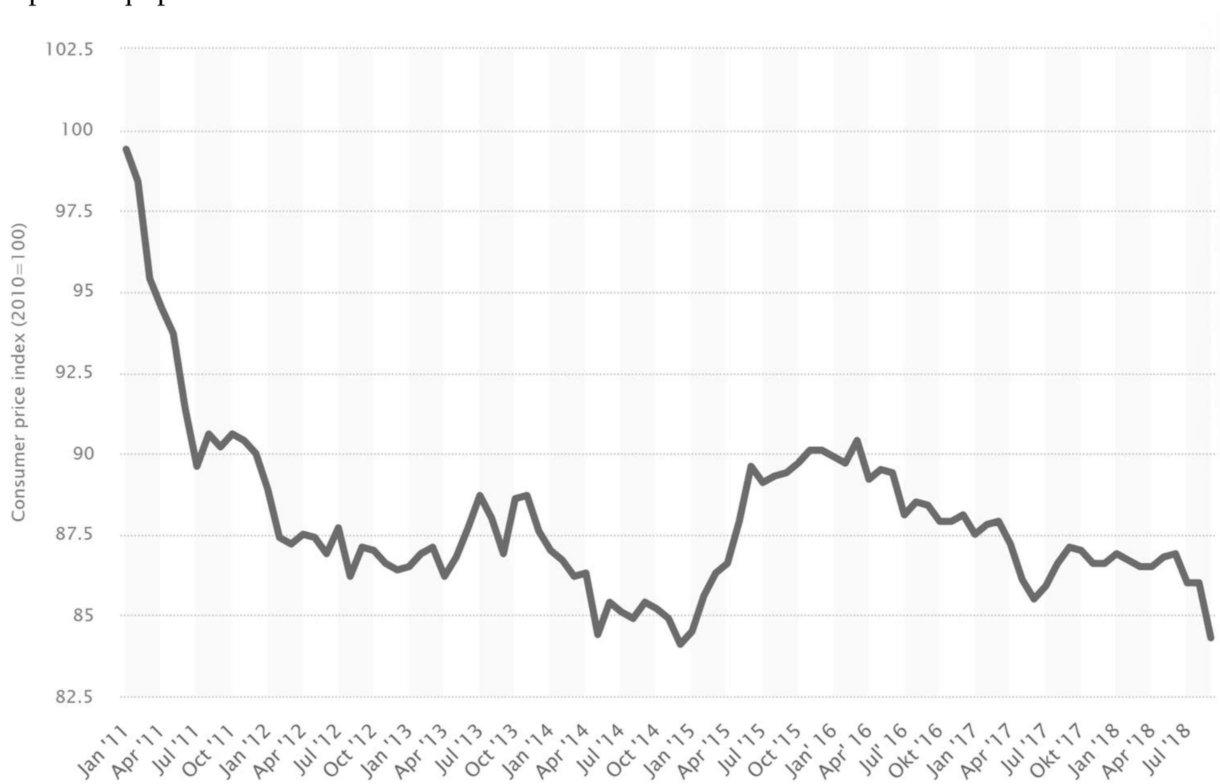

Figure 5: Cost of Computers

Sourced from Monthly Consumer Price Index for Computer Monitors , by Statista, 2018. Retrieved March 24, 2022, from https:/ https://www.statista.com/statistics/485297/monthly-consumer-price-index-pc-monitors-germany/. Reprinted with permission.

From a business level perspective, the areas that are significantly impacted the most by ICT are communication, marketing, networking and resource planning. ICT is globally regarded as a vital tool in terms of increasing the competitiveness of the businesses (Oliveira & Martins, 2011). ICT aids businesses to increase their market shares and improve their productivity – as well as reduce their costs - by expanding the business' efficiency of operation, inventory management and integration of activities (Qureshil, Kamal, & Wolcott, 2009). Furthermore, ICT assists businesses with the marketing of their products or services, develop new products and services, and to hone their customer services (Yunis et al., 2018).

Another benefit of ICT to businesses is that of agility. ICT provides two types of agility, market capitalising and operational adjustment; both improve competitive advantage, especially in the current knowledge-intensive business environment of rapid, highly competitive and unpredictable changes (Yunis et al., 2018). With ICT adoption, businesses are able to detect and capitalise on market change and avoid emerging threat with speed. Firms can constantly adapt and exploit emerging business opportunities (Yunis et al., 2018).

This section considers the negative impact upon businesses. ICT adoption typically creates some additional costs, such as employee training, licensing, organisational restructuring and infrastructure upgrading (Mikalef & Pateli, 2017). Furthermore, ICT will significantly contribute to the performance and sustainable competitive advantage of businesses only if they have sufficient resources; skilled ICT personnel and finance. Organisations are adapted to enable the ICT adoption that requires new infrastructure and internal change, such as re-engineering process and personnel retraining (Tarutė & Gatautis, 2014). By contrast, several firms overestimate the strategic value of IT and financially they have overspent (Melville, Kraemer, & Gurbaxani, 2017). Businesses need to combine existing resources with new ICT resources to enhance business strategies (Melville et al., 2017). In addition to internal factors, external factors such as regulation, and ICT infrastructure such as telecommunication, may limit the IT business value(Melville et al., 2017). A previous study undertaken by Melville et al (2017) has found that trading partners play a significant role when the supply chain is electronically connected. From a human resource perspective, although downsizing effect from introducing ICT in organisations leads to the loss of human capital, it can be off-set through organisational learning improvement by improving communication among employees (Céspedes-Lorente, Magán-Díaz, & Martínez-Ros, 2019), increasing labour productivity and increasing the demand for more skilled labour in problem-solving statistical process controls and computer skills (Céspedes-Lorente et al., 2019). A study undertaken by Céspedes-Lorente et al (2019), suggests that ICT adoption will improve organisational memory, which will result in improved financial performance by increasing problem-solving, and also by generating a solution realised from past experience. (Gong, 2012). Furthermore, it can encourage flatter organisational structure, leaner process and improve the team-based culture within an organization (Céspedes-Lorente et al., 2019).

Several studies found that IT projects often spend 150 per cent of the planned budget, and 20 per cent of IT spending is wasted (Parent, 2019). In addition, 30 to 40 per cent of the IT projects fail to provide any long-term strategic benefit (Parent, 2019). For example, 30 per cent of the information system projects, such as business intelligence, fail to meet their business objective (Saran, 2012). Another example is ERP projects, of which 55 to 75 per cent fail in meeting their intended objectives (Yunis et al., 2018). The first reason behind the failure of the projects is the unclear strategy (Parent, 2019, Wynn, Turner, Abas, & Shen, 2009). Secondly, the budgets are loose, having no specific quotes and milestones, so consequently the business manager underestimates the total cost of the project while overestimating the overall benefits (Parent, 2019). Finally, the initial investment which includes software, hardware development and system integration are large – often 30 to 40 per cent of the total budget (Parent, 2019).

In conclusion, the impact of ICT adoption should be measured in the long term (Consoli, 2012; Bayo-Moriones, Billon & Lera-Lopez, 2013) as it takes some time to realise the benefits after implementation. Several studies indicate that the effect of ICT performance depends on types of technology and the degree of adoption (Bayo-Moriones et al., 2013; Cugno, Castagnoli, & Büchi, 2021; Marcucci, Antomarioni, Ciarapica, & Bevilacqua, 2021; Tarutė & Gatautis, 2014). Bayo-Moriones et al. (2013) found that communication efficiency was increased in businesses that had adopted ICT, operational performance was improved with consequent improvement of financial performance (Tarutė & Gatautis, 2014).

3.1.4 ICT in Manufacturing

This section considers ICT in manufacturing. Currently, subsystems of autonomous systems are enabled by ICT (Sharma, 2016). The growth of automation technology is significantly influenced by communication and networking technology due to the fact that they integrate the dataflow, in both directions, from field level to the operations level (Wollschlaeger, Sauter, & Jasperneite, 2017). Typically, the management of manufacturing businesses comprises two functions; technical and business. Thus the firms need both the operation technologies (OT), e.g. execution systems (MES), SCADA, etc., and IT, e.g. CRM, ERP and PLM to achieve their objectives (Sharma, 2016). The mechanism of OT-IT integration starts from the OT system, which monitors the process in a plant and transmits data pertaining to the condition and status of assets to the IT system in real time. Following this, IT systems will analyse and synthesize the data before generating crucial insight and an automatic reaction relevant to the maintenance and optimisation of operation performance (Sharma, 2016). However, there is still a gap between IT and OT as the life cycle of OT and IT equipment are different. Typically, IT infrastructure, such as computers and software, needs to be upgraded every two to three years, whereas OT infrastructure requires a change or upgrade every 10 to 20 years (Bayo-Moriones et al., 2013). Moreover, the integration of OT and IT needs cooperation from employees on both sides (Sharma, 2016).

The purpose of traditional ICT in manufacturing is to control the information flow of the material in the operational stage. The most commonly used manufacturing ICT are manufacturing resource planning (MRP) and ERP (Lightfoot, Baines, & Smart, 2011). Both technologies are integrated software and hardware and are linked to a central database that keeps and transfers the data (Wei, Chien, & Wang, 2005). MRP II coordinates the whole of the manufacturing production, including finance, human input and materials (Lightfoot et al., 2011). The output of the MRP is a final labour and machine schedule, as well as the production costs, machine and labour time, materials used and production numbers (Wei et al., 2005). The ERP system is the extension of MRP, which can manage the internal and external resources, such as suppliers, customers (Wei et al., 2005). MRP or ERP can capture a small amount of data regarding the asset condition and how it is used in the field (Lightfoot et al., 2011)

As manufacturing businesses typically compete with regard to prices - even for the firms with high-value products such as aerospace and locomotives (Lightfoot et al., 2011) - several firms are trying to differentiate themselves by expanding their focus from production only to include advanced services; spare parts, customer services, periodic maintenance and repair and overhaul, to give some examples (Baines et al., 2009). This servitization aids manufacturers in becoming more competitive, as well as prospering their revenue streams. These intermediate services can enhance the business' relationships with its customers and help the business to receive more revenue throughout a product's lifetime (Baines et al., 2009). However, the advanced product-centric services require manufacturers to take on risk for asset performance, availability and reliability (Lightfoot et al., 2011).

This is where ICT, especially IoT, becomes crucial for manufacturing firms. First, it improves visibility in terms of condition, operating characteristics, location, and its time in use (Miao et al., 2020; Wei et al., 2005). In addition, it enables remote monitoring and interpretation of the information of an offshore factory, leading to responsive maintenance. Furthermore, ICT can identify and predict the conditions of machinery used within the factories responsively (Wei et al., 2005). The result of this responsiveness enables the predictive maintenance for machines (Lightfoot et al., 2011; Tucker, 2019). An example of ICT implementation is the engine management system used by MAN Truck & Bus UK vehicles; this connected the vehicles to data acquisition equipment using cellular communication. The real-time collection of data shows how the vehicle is being driven as well as the real-time fuel consumption (Lightfoot et al., 2009). Another example is the use of ICT in automotive manufacturing. ICT may smooth the flow of the assembling processes by detecting the abnormal speed of the process in real time (Focacci & Kirov, 2021). Indeed, some car manufacturers use an electronic tag for improving inventory management and quality. Furthermore, it can be used to analyse each process to increase the efficiency of the whole processes by reducing failure rate (Uniyal et al., 2021).

In conclusion, manufacturers can implement ICT in order to become more responsive and improve performance, availability and reliability, and also cost. This way, manufacturers can significantly differentiate themselves from traditional manufactures that typically focus on cost, quality and delivery (Sony, Antony, McDermott, & Garza-Reyes, 2021).

3.1.5 ICT in SMEs

ICT adoption within SMEs can be categorised in two ways. The first way uses ICT to both strengthen the day-to-day operational support and the processing activities within the SME (Foong, 1999; Levy & Powell, 1998). SMEs often implement ICT without an architectural plan to integrate with the current business strategy. Therefore, most of the competitive advantage created by ICT adoption is accidental (Hashmi & Cuddy, 1990). The second way utilizes ICT to enhance customer interaction and relationships, especially the micro-businesses, which are typically influenced by customer demand (Qureshil, Kamal, & Wolcott, 2011). Porter (1980) states that the success of SMEs mostly depends on small numbers of customers who purchase a large amount of products, hence they are of paramount importance in order that the company survives and prospers (Qureshil et al., 2011). Matthews (2007) identified three different stages in

IT usage in small businesses: Basic: a minimal usage of IT; Substantial: has several applications and machines in use, and Sophisticated: integrated various systems and constantly developing technology (Tarutė & Gatautis, 2014).

There is currently a trend of implementing new ICT or improving existing ICT within SMEs because they have positive impacts relating to operational efficiencies and increased revenues, or they find better positioning in a niche market (Qureshil et al., 2011). Liang, You and Liu (2010); Santos and Brito (2012) identify two different types of SME performance impacted by ICT adoption: financial and strategic performance. The financial performance consists of profitability, growth and market value, whereas the strategic performance (indirect effect of ICT on SMEs) consists of both customer and employee satisfaction, environmental performance and social performance (Jones, Simmons, Packham, Beynon-Davies, & Pickernell, 2014; Tarutė & Gatautis, 2014). In addition, competitiveness is important in terms of measuring the performance of SMEs. Mateiand Savulescu (2012) states that in a normal situation, the increase of ICT adoption would lead to an increase of competitiveness. Global Competitiveness Reports of the World Economic Forum (Tarutė & Gatautis, 2014) defines 12 key elements of competitiveness that are related to ICT impact on strategic and financial performance. They are Business sophistication, Financial market development, Goods market efficiency, Health and primary education, Higher education and training, Institutions, Infrastructure, Innovation, macroeconomic environment, Market size, Labour market efficiency and Technological readiness (Matei & Savulescu, 2012).

However, ICT adoption within SMEs remains a challenge, both in developed and developing countries (Schreiner & Woller, 2003). SMEs can exploit ICT in smaller firms due to both limited resources and technology and capabilities, even though SMEs have more adaptable to implementing change because of less complicated structure than larger businesses (Jones et al., 2014; Qureshil et al., 2011). The barriers for SMEs to adopt ICT can be divided into Internal factors: Owner/manager characteristics, business characteristics, adoption cost and return on investment, and then the external factor: cultural barriers, infrastructure, political and regulation, and social barriers (Ashrafi & Murtaza, 2008; Jones et al., 2014). More detail of both the use and challenges of IoT in SMEs will be discussed further in the IT, ICT and IoT within manufacturing SME section.

3.1.6 Emerging ICTs

This section considers an overview of emerging ICT. The emerging ICT promotes more efficient communication between humans, it facilitates innovations within organisations and creates competitive advantages (Savulescu, 2015). In particular, the internet and cloud computing has a great impact upon people and organisations; several devices are now connected to the internet, coupled with the cloud (Savulescu, 2015). The interaction with computers is constantly changing, by way of augmented reality, multisensory interface, virtual reality and 3D monitor (Savulescu, 2015). Currently, the emerging ICT is augmented reality, IoT, big data (analytics), cloud computing, and AI. The global digital transformation market, including IoT, cloud computing, Big data, AI and AR/VR is predicted to grow at 17 per cent per year from 2020 to 2025 (Technavio, 2021).

The first emerging ICT is IoT which creates cyber-physical systems (CPSs) (Bauer, 2017). There is great potential, especially for manufacturing firms, to connect physical assets to digital networks and this generates a large amount of data, or big data, which is the second emerging ICT (Tucker, 2019). Data analytics, predictive analytics and social media analytics allow manufacturers to track, measure, predict processes, make a decision in real-time, as well as understanding the customer's needs (Tucker, 2019). This can be strengthened by the third emerging ICT, AI, which uses machine learning - neural networks, deep learning - to make routine decisions, or to augment the human capability with regard to making difficult decisions, for example, diagnostics, or predictive maintenance (Tucker, 2019). It can sense the environment, assimilate and store knowledge, and analyse and define patterns before making a decision (Skinner, 2018).

The fourth emerging ICT is Cloud computing, which enables businesses to store, analyse and access data anytime, anywhere, from any capable devices (Bauer, 2017). The last emerging ICT is augmented reality, which augments the physical world with digital information (Devin, 2019). Within the highly complex world of manufacturing, aircraft manufacturers are using augmented reality to improve accuracy, productivity and control; it enables employees to work virtually with sophisticated moving equipment (Tucker, 2019). Augmented reality, Cloud and IoT require a network which is typically the internet. The most recent network is 5th Generation (5G), the fifth generation of wireless network technology that uses a high-frequency spectrum, small cell antennas and AI- enabled software (Devin, 2019). It aids IoT go beyond the smart home to fully smart cities, in addition to enabling self-driving cars and remote tellers within banking (Devin, 2019). 5G allows augmented reality to fully scale up to enterprise level (Devin, 2019).

The emerging ICT has had a great impact during the last decade. It has significantly influenced the performances of businesses. The next section will consider the internet which is a key factor that enables IT for IoT, our technology focus in this research.

3.2 Internet

3.2.1 Definition and Current Situation of the Internet

The federal networking council (1995) first defined the internet as the global information system that is globally linked by a unique address space based on the internet protocol (IP) (Slater, 2002). Internet is a form of computer networks for the global exchange of data and messages (Slater, 2002) and it provides infrastructure for several computational resources such as databases, or email (Slater, 2002).

The internet is altering the way by which information is both created and shared, the way we work, socialize and organize the flow of ideas, globally (Manyika & Roxburgh, 2011). It contributes to 3.4 per cent of GDP across the large economies, which accounts for 70 per cent of the global GDP (Manyika & Roxburgh, 2011). At the country level, the internet contributes to economic growth only if the countries have the appropriate infrastructure, especially in an era of cloud computing and big data analytics (Manyika & Roxburgh, 2011). The countries need to have an open and highly competitive internet ecosystem in place as well as an environment that encourages innovation and entrepreneurship (Hornsby, Kuratko, & Zahra, 2002). At the business level, large firms clearly benefit from the rise of the internet from the diversified supply chain, global talent sourcing, data analysis and increased engagement with customers; SMEs gain even more benefit by utilising the internet (Manyika & Roxburgh, 2011). A survey found that more than 4800 SMEs in 12 countries that availed themselves of web technologies grew more than twice faster than those that made use of fewer web technologies (Manyika & Roxburgh, 2011). The internet also enables SMEs to become global businesses very quickly, as they can reach customers, and locate suppliers and talent much more efficiently (Bughin et al., 2015)

3.2.2 The Evolution of the Internet

The idea of the internet was born of a universal networking idea in 1963 when Licklider, a computer scientist, first visualized the idea of the intergalactic computer network to colleges at the US Defence Advanced Research Projects Agency (DARPA) (Campbell-Kelly, & Garcia-Swartz, 2013). At that time, DARPA was commissioned to establish a secure network that linked centres that were working on military research, with the condition that the communications would remain active even if some of the centres were attacked (Keefer & Baiget, 2001). Subsequently, DARPA and MIT created a link between the computers at Stanford and University of California, LosAngeles (Glowniak, 1998). The first message sent is the word “login”, but the computers crashed, and just the letters “Lo” were sent successfully (Keefer & Baiget, 2001).

In 1969, the computers at the University of California in Santa Barbara, and the University of Utah were connected, and the data ran on a packet-switching method called Advanced Research Projects Agency Network (ARPANET) (Russell, 2012). In 1970, the ARPANET linked all the nodes with 13 computers across the United States (Keefer & Baiget, 2001), after which the ARPANET was publicized; the original application was an email which separated the user and host names, Telnet, which could be logged on as a local terminal to a remote computer, and file transfer for moving files between computers (Keefer & Baiget, 2001). ARPANET abbreviated the term ‘internet working’ to “internet” in 1974. After that, ARPANET invented the standard of communication protocols called ‘Transmission Control Protocol (TCP/IP) (Glowniak, 1998; Russell, 2012); the messages could be passed along by routers, computer nodes that act as mail sorters (Keefer & Baiget, 2001). The messages are broken down into packages for sending separately through the best path, then aggregated again at their destination (Keefer & Baiget, 2001).

Furthermore, the system is based on an IP address, which starts from the code for a network on the left, to the number of each computer on the right, such as 123.123.414.122 (Keefer & Baiget, 2001). Additionally, the first IP is internet protocol 4 (IPv4) (Ziegler, Crettaz, & Thomas, 2014). However, the growth of the internet has created a need for more addresses than its maximum capacity of IPv4 (Ziegler et al., 2014). In 1998, internet protocol 6 (IPv6), which uses a 128-bit address, emerged (Ali, 2012). It allowed for many more devices and users on the internet by way of allocating addresses and being far more efficient with regard to routing traffic (Ali, 2012).

In 1989, Tim Berners-Lee proposed the World Wide Web, for the use of researchers (Russell, 2012). The domain name, which is the addressing system for the World Wide Web, uses alphabets as codes in order to help ensure that internet users can remember it efficiently (Keefer & Baiget, 2001). With the user-friendly internet service such as the World Wide Web, internet users had been increasing rapidly (Glowniak, 1998). In the same year, the first internet service provider was found (Glowniak, 1998) and thereafter, the internet was entirely used for commercialisation; Amazon was founded in 1995 (Keefer & Baiget, 2001) and a year after, Larry Page and Sergey Brinfounded Google, the most popular search engine in the world (Keefer & Baiget, 2001). The internet market increased speedily until it crashed in 2000 (Leiner et al., 1997), and, four years after recovery, Mark Zuckerberg created the social media site "Facebook" (Hughes, Rowe, Batey, & Lee, 2012). In 2008, the number of mobile devices with internet access exceeded that of desktop computers (Lenhart, Purcell, Smith, & Zickuhr, 2010).

The structure of the internet is integrated with the telephone system (Glowniak, 1998). Large telecommunication firms, or network service providers (NSPs), provide the long-distance data transport service by way of international fibreoptic cables (Glowniak, 1998). The internet service provider links the NSPs with individuals or organisations through modems and standard telephone lines (Glowniak, 1998). The internet generally has four layers, the first layer is the application layer, such as Email, Instagram messaging, which then instructs the second layer, TCP, to establish the connection to a destination (Helmy & Nabhan, 2007). TCP layer splits the data received from the application layer and ensures that the reliability and order of the data is complete before sending it to the third layer; IP (Ziegler et al., 2014). The IP layer carries the data over the internet and sends it to require destinations (Ziegler et al., 2014)

3.2.3 The Impact of the Internet on Industries and Businesses

The internet has born great impact on the economic value of the companies (Porter, 2001) in two ways: industry structure (which determines the average profitability of the competitors); and sustainable competitive advantage (which allows a company to outperform its competitors) (Porter, 2001). The internet has created new industries, such as a global online marketplace (Porter, 2001). Moreover, it has changed the existing industries that have been facing high costs for completing transactions, accomplishing communications and social information (Porter, 2001). Furthermore, it changes the front end of the buying process, such as companies using a website by which customers can order products (Johnston & Mak, 2000).

The influences of the internet on industry structure can be considered by five forces: the intensity of rivalry among existing competitors, the barriers to entry for new competitors, the threat of substitute products or services, the bargaining power of suppliers and the bargaining power of buyers (Porter, 2001). The internet is another channel by which customers can be reached (Kothandaraman & Wilson, 2001) and it increases the industry's efficiency by growing the market size and improving its position relative to traditional substitutes (Porter, 2001). The internet ensures that information is widely available, resulting in ease of purchase, marketing and distribution of products (Rust & Lemon, 2001). In addition, it allows both buyers and sellers to find and transact their business easily (Rust & Lemon, 2001).

However, most of the forces are negative. The bargaining power of buyers increases as it's easier to access information about the product, price and suppliers (Terziu, 2021). New web technologies reduce switching costs (Chen & Hitt, 2002); for example, PayPal, which provides settlement services or internet currency, enables customers to shop at different sites without having to fill in their personal information, or credit card information, thus increasing intensity among competitors (Hapsari, Hartono, & Listiyani, 2021). In addition, PayPal eases the process of finding better, less costly suppliers and accessing channels, thus decreasing barriers to entry (Munker, 2020). The internet allows substitutes that find a new way to meet the needs consequently increasing pressure on existing firms (Johnson & Markey-Towler. 2020). By using the internet, it is made possible for competitors abroad to penetrate the domestic market, increasing competition among businesses (Notani & Jain, 2021).

Internet brands are difficult to build, however, due to the lack of physical presence of a company and also a lack of direct human contact, which may somewhat compromise the service to customers (Kim, Nam, & Stimpert, 2004) However, not every industry that implements internet technology will be unattractive. One example is e-commerce, which benefits from the rise of the internet as these businesses gain more profit when the number of buyers, sellers and substitute products increase (Lin et al., 2020).

Although the internet enhances operational effectiveness by easing and increasing real-time information and it improves efficiency in the supplychain, it creates a more competitive environment (Vadlamudi, 2021). For example, with the rise of e-commerce, customers make a decision based on price, thus undermining profitability (Lin et al., 2020). However, a firm can sustain competitive advantage through strategic positioning as the internet creates unique and integrated system activities within the businesses, making it more difficult for competitors to imitate the system, such as a two-sided platform which creates the network effect (Zhao, Von Delft, Morgan-Thomas, & Buck, 2020). Previously, the majority of businesses were separating internet strategies from the overall strategy instead of tailoring the internet technology to the business' strategy, thus failing to capitalize their assets and creating an easy-to-imitate internet strategy (Kamble, Gunasekaran, Parekh, & Joshi, 2019). However, the Covid-19 pandemic created an intention within several businesses to place more focus their online productivity in order to survive (Shahzad & Imran, 2021; Wang, Hong, Li, & Gao, 2020). The next sections will consider the IoT.

3.3 IoT

3.3.1 IoT Evolution and Definition

This section considers the history, evolution and introduction of the IoT. The use of the term IoT began when Nikola Tesla - the inventor of the alternating-current (AC) electric system -, stressed the wireless implication in 1926, enabling the independent communication capability between the entities by way of mobile networks, social networks and smart components without internet limitation (Bekara, 2014; Li, Tryfonas, & Li, 2016). The ability to connect systems – such as Machine-to-Machine (M2M) communication (Mulligan, Karnouskos, Boyle, Höller, & Tsiatsis, 2018) has been around for about 20 years. Moreover, the availability of sensor equipment and the ability to process information that is generated by different systems are not a new phenomenon (Mulligan et al., 2018; Chen, Xu, Liu, Hu, & Wang, 2014). Over recent decades, there have been developments regarding the Internet Protocol (IP) and the Internet, as well as the significant decreasing in sizes and cost of sensors, chips and actuator parts while still maintaining the same quality (Mulligan et al., 2018). These devices are less power consuming than before and embedded computing technologies can now connect through various radio technologies, such as Bluetooth, cellular or WiFi. All these technologies have paved the way for the creation of IoT devices that are implanted in everyday objects (Mulligan et al., 2018). The IoT augments these various uses of technology and disciplines together, creating new communication modes (Mulligan et al., 2018; Chen et al., 2014). Atzori, Lera, and Morabito (2017) state that IoT can be divided into five eras: tagged objects, interconnection through web technologies, social objects, semantic information visualization and cloud computing technology. The IoT is disrupting almost every industry thesedays due to the fact that many things can be connected to the internet and is a standard of ICT as it is stand out among the technology in the past (Jaafreh, 2018). IoT is a current topic that requires research consideration.

This section considers the term IoT. In 1999, an executive director of Massachusetts Institute of Technology (MIT), Kevin Ashton, first used the term "Internet of Things" for the next step of ICT; connecting things via the internet (Ashton, 2009). The fundamental thought was to enable the objects to communicate with each other via the internet by equipping them with identifiers, wireless networks and the current radio-frequency identification (RFID) technology, since the sensors became less expensive and digitalized to a greater degree (Ashton, 2009).

Keyur (2016) states that IoT is a blend of the following things:

1) Equipment and programming innovations used for the storage

2) Retrieval and processing of data and ICT….

3) ….including electronic systems used for entities communication.

IoT has actually been much improved from SCADA in the Industry 3.0 era, when computers were first used in their masses to create automation, supervisory control and data acquisition. However, IoT is from the Industry 4.0 era. It is SCADA plus the internet, creating cyber-physical systems with no limit to the internet connection. The IoT is a worldwide network of objects that are able to detect, or act, within the surrounding environment, and they are able to communicate with each other (Pundir, Sharma, & Singh, 2016). The intelligence of objects is developed by inserting capabilities for identification, networking and processing them (Kortuem, Kawsar, Sundramoorthy, & Fitton, 2010; Whitmore, Agarwal, & Xu, 2014). However, communicating between objects and acting upon surroundings is called M2M communication which has been around for many years.

The real key advantages of IoT are planning, management and decision-making. The connected objects can create and exchange large quantities of data (often called the Big Data), which can be analysed to improve efficiency and productivity in many areas (Jeschke et al., 2017). Thus, regularly and real-time collecting, analysing and initiating the action by advanced technologies provides a wealth of intelligence; to give example, predictive maintenance to reduce the downtime in factories. As the above-mentioned abilities provide a great deal of intelligence to the objects, the objects implanted in IoT can be called smart objects (Andersson & Mattsson, 2015; Fleisch, Weinberger, & Wortmann, 2014). These smart objects, including common objects with sensors, appliances, robots, cars, trains, and wearable objects have a wide range of sizes and scope, creating significant development over many industries and commerce; smart cities, the environmental economy, energy, health, public safety, transport and the motor industry (Pundir et al., 2016). The smartness that should be highlighted is that the Smart objects have the ability to make decisions by themselves.

A further definition of IoT is objects, including electronic equipment, high technology products, and everyday items: bottles of water, clothing, food, to give examples. IoT can be further defined as items that are recognizable, sensible, locatable and addressable via the internet by using the communication paths (RFID, wireless local area network (LAN), wide area networks (WAN), or other paths) so that they can be connected at any time and any place, with anything and anyone (Vermesan & Friess, 2013, 2014). This definition focuses on simple functions of the IoT objects, but the key intelligence of the IoT is the combination of advanced technologies, such as cloud computing software, data analytic tools and 5G. The IoT enables objects by assigning them a unique Internet Protocol version 6 (IPv6) address linked into an Electronic product code network, in order that they may be able to communicate with each other in the complex system of Cloud computing, and also that they may make decisions themselves based on the aggregated information stored within their network (Graham & Haarstad, 2014; Vermesan & Friess, 2013, 2014). Thus, the evolved cellular mobile communications make the communication between objects in real-time, at any time and any place, possible. In addition, the over cost and more compact chips allow small objects to be implanted with IoT technologies.

The definition of the IoT has been extended and modified significantly. For example, Cisco invented the term ‘Internet of Everything’ to clarify an interconnected network of people, places, and objects (Cisco, 2015). Another example is the Industrial Internet of Things (IIoT) which is used to define IoT applied during the production processes tin order to connect machines (World Economic Forum, 2015). The IoT can be substituted with the word smart systems, including smart devices, smart homes, smart environment and smart firms (Pundir et al., 2016).

There are several papers addressing the definition of IoT. Most of them lack consideration of the overall IoT elements, while some are outdated, not well clarified or imprecise. The most concise and encompassing definition of IoT is that IoT is a concept rather than a technology. It is a worldwide network of communication and cooperation with no limit, connected to the internet, (Bekara, 2014 & Li, et al., 2016) between human to human, human to machine/things, and machine/things to machine/things through the internet and the unique identity of each entity by leveraging the set of supporting technologies (for example, RFIDs, sensor/actuators, machine-to-machine communication devices, gateway, network, cloud computing software, data analytics and tools) to create new applications or services that make human lives easier and more productive (Atzori, Lera, & Morabito, 2010; Patel & Patel, 2016). This definition will be utilised for this thesis. This definition appears in many studies, has been cited many times, offers the widest picture of IoT, covers all the relevant entities and does not change over time.

Table 3 below provides an overview of the various mainstream definitions of IoT:

Table 3: IoT Definitions & Comparison

No.	Definition	Strengths	Weaknesses	Comment
1.	Keyur (2016) states that IoT is a blend of equipment and programming innovations used for the storage, retrieval and processing of data, and ICT, including electronic systems used for entities communication.	-identify overall technologies and system used in IoT and the purposes of using them.	-too broad. -sound like SCADA, the old control system architecture.	-need to clarify the differences or improvement from SCADA.
2.	Pundir, Sharma, and Singh (2016) state that IoT is a worldwide, networks of objects that are able to detect or act on the surrounding, and communicate with each other. The intelligence of objects is developed by inserting capabilities for identification, networking, and processing into them (Kortuem et al., 2010; Whitmore et al., 2014).	-discuss how the intelligence of the objects is developed.	-communication between objects and acting on surrounding is called M2Mcommunication which has been around for several years. -IoT does not have to be worldwide.	-specify the improvement from M2M. -describe the key benefits of the intelligence of the objects in IoT -mention the software, such as data analytic tools which actually creates the intelligence of objects.

3.	Jeschke et al. (2017) state that the connected objects that can create and exchange a lot of data (often called Big Data) which can be analysed to improve efficiency and productivity in many areas. The objects implanted IoT can be called smart objects (Andersson & Mattsson, 2015; Fleisch et al., 2014). Pundir et al. (2016) states that these smart objects, including common objects with sensors, appliances, robots, cars, trains, and wearable objects have a wide range of sizes and scope, creating significant development in many areas from smart cities, environment, energy, health, public safety, transport and vehicle.	-review IoT applications (smart things) and the areas of development. -mention the big data which works well together with IoT to offer analysis and insight.	-does not say how large amount of data can be managed to improve efficiency and productivity. -no clarification of what makes objects smart or different from common objects.	-explain why having a lot of data can be more efficient and productive. - "smartness" should be defined. -big data, as a result of IoT, can be analyzed to create new functions as well.
4.	Vermesan and Friess (2013, 2014) state that the objects, including electronic equipment, high technology products, and common things: food, clothing, bottle of water, forest, etc. that are recognizable, sensible, locatable, addressable via the internet by using the communication paths (RFID, wireless LAN, WAN, or other paths) so that they can be connected anytime, anyplace, with anything and anyone. The IoT enables objects, assigned a unique Internet Protocol version 6 (IPv6) address linked into an	-explain well on how the communication in IoT system works. -give clear information about the evolved communication of IoT objects (can be connected anytime, anyplace, with anyone and anything).	-this definition focuses on only simple functions of the IoT objects. -the only one recent technology mentioned is Cloud computing.	-the advanced and recent technologies, such as 5G and data analytic tools should be stated. -the author should clarify the intelligence of IoT that makes things can be connected anytime, anyplace, with anything. -IoT is limited by objects that require IP address.

	Electronic product code network, to be able to communicate with each other in the complex system on Cloud computing and make decisions themselves based on the aggregated information in their network (Graham & Haarstad, 2014; Vermesan & Friess, 2013, 2014).			
5.	Selected definition (combinedefinitions plus critique) Bekara (2014) and Li, et al. (2016) state that IoT is a concept rather than a technology. It is a worldwide network of communication and cooperation with no limit to the internet between human to human, human to machine/things, and machine/things to machine/things through the internet and unique identity of each entities by leveraging the set of supporting technologies (e.g., RFIDs, sensor/actuators, machine-to-machine communication devices, gateway, network, cloud computing software, data analytic tools, etc.) to create new application or services that make human lives easier and more productive. (Atzori et al., 2010; Patel & Patel, 2016).	-this definition appears in many pieces of research and has been cited many times - offer the widest picture of IoT and cover all the relevant entities -does not change over time.	-IoT does not have to be global/worldwide.	- will be ustilised for this thesis as it it the most concise and encompassing definition.

3.3.2 IoT Architecture and Enabling Technologies

This section considers the IoT architecture and enabling technologies. IoT architecture is a structure of the physical components network that has specific operational principles, configurations, functions, procedures and data formats. This is illustrated in **Figure 6 below:**

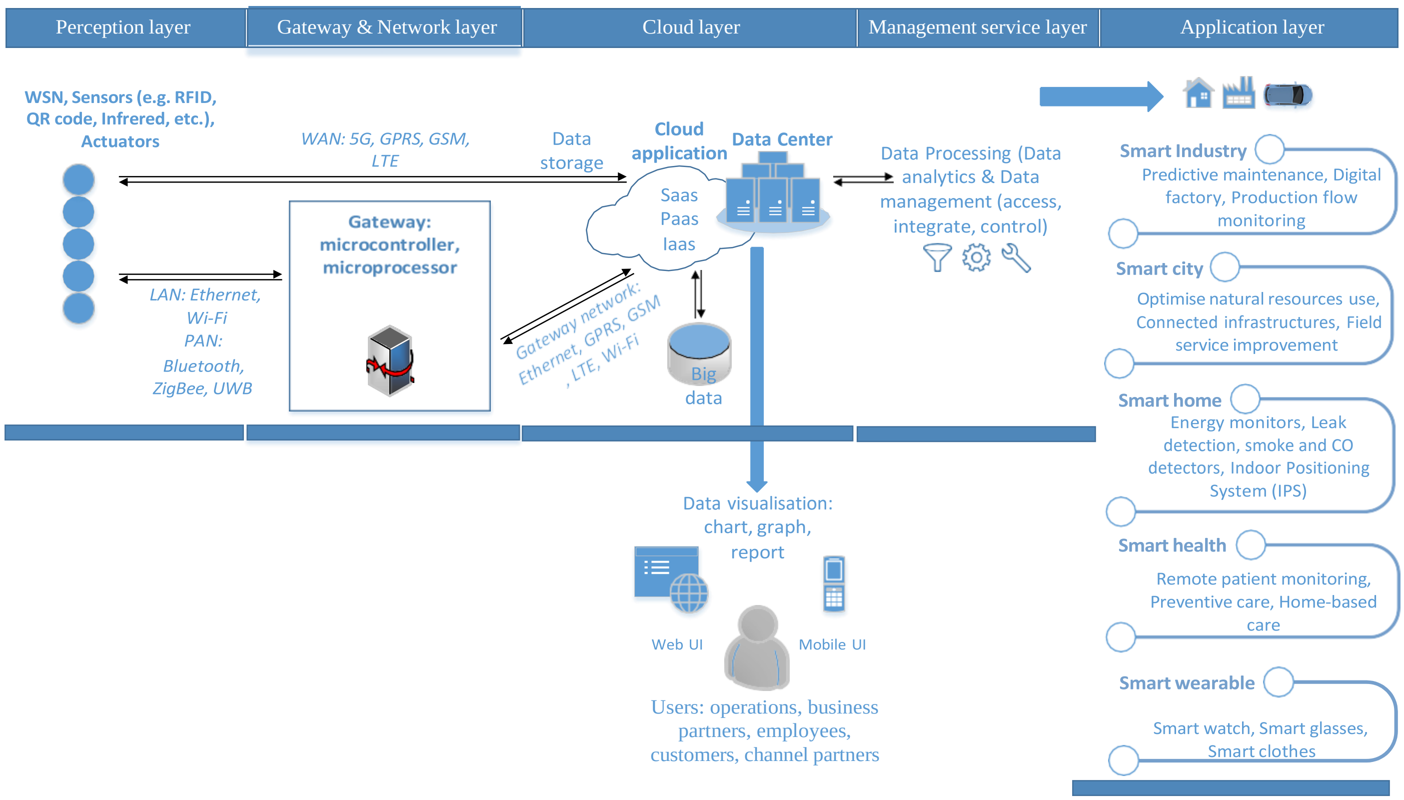

Figure 6: IoT Architecture with Key Technologies

Source: Author's own

Overall, the IoT architecture comprises different layers with various supporting technologies and it illustrates the interrelationship between them (Patel & Patel, 2016; Mahmoud, Yousuf, Aloul, & Zualkernan, 2015). The most widely used and updated IoT architecture in industries and research is a five-layer architecture (Zhang & Tao, 2016; Wang et al., 2013). Three layers out of five are fundamental and required: perception, gateway and network, and application (Wang et al., 2013; IBM think academy, 2015). As implementing the IoT with just three basic layers is not sufficient to be competitive for businesses, the additional two layers, namely the cloud layer and management service layer, provide data storage and analytics solutions, and they have recently become essential parts of IoT solution within businesses (Columbus, 2017). They have the capabilityof interpreting and managing the data collected between objects and systems, and also of enhancing the cooperation between hardware devices and applications (Wang et al., 2013;

IBM think academy,2015). The five layers with the key technologies are discussed as follows.

1) Perception Layer With the Sensors, Actuators and Wireless Sensor Networks (WSN) as Key Technologies

This layer is known as the sensing layer, and comprises smart objects embedded with sensors and actuators (Biliyaminu, Hamdan, Lengyel, & Farkas, 2018; Wang et al., 2013). The sensors, for examples, RFID, QR code, Infrared, enable the real-time data to be detected, acquired, processed, and finally sent to the network layer, thus allowing the interconnection between physical and digital worlds (Atzori et al., 2010, 2012; Patel & Patel, 2016). For the sensors that require low batteries and low-power rate wireless connectivity, they can form the network called WSN which allows multi-hop communication between sensor nodes, covering large areas (Gubbi, Buyya, Marusic, & Palaniswami, 2013). The sensors can be grouped by their purposes, such as environmental sensors, sensors in factories and appliance sensors (Vashi, Ram, Modi, Verma, & Prakash, 2017). Some of them have an ability to record a number of measurements before sending to the gateway, server or applications (Patel & Patel, 2016).

2) Gateway and Network Layers With Gateways and Wired or Wireless as Key Technologies

The purpose of this layer is to provide the means of transferring the collected information from the perception layer to the cloud or application layer directly (Biliyaminu et al., 2018; Vashi et al., 2017), as well as to be the mean of aggregating, processing and transferring information between the IoT nodes from different sensors (Leo, Battisti, Carli, & Neri, 2014). As massive data (often called big data) produced by the sensors in the first layer requires advanced and high performance wired or wireless network infrastructure to be able to securely transfer and keep the sensitive information confidential from sensor devices to the central information processing system (IBM think academy, 2015; Patel & Patel, 2016; Wang et al., 2013), the recent technologies in the network, such as 5G, Bluetooth, LTE, WiFi, and Zigbee are crucial (Leo et al., 2014; Patel & Patel, 2016). Most sensors require connectivity to the sensor gateways (e.g. microcontroller, microprocessor, etc.) and then from the gateways to applications. This connectivity is in the form of a LAN, such as Ethernet and Wi-Fi connections, or Personal Area Network (PAN) such as ZigBee (Patel & Patel, 2016). However, for sensors that do not require connectivity to sensor gateways, they can connect directly to applications via WAN such as Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS) and Long-Term Evolution (LTE) (Patel & Patel, 2016).

3) Cloud Layer with Cloud Computing Technologies

This layer simply provides a space for aggregated big data that has been sent from the sensors or sensors gateway (Biliyaminu et al., 2018). The cloud layer can process and store a large quantity of data that has been generated from the devices connected to the internet in real-time and keep it readily available to be used by the management service layer, or application layer (Biliyaminu et al., 2018; Gubbi et al., 2013). Cloud computing is a recent technology for a shared pool of configurable computers,

networks, storage, software and applications, with on-demand access (Lee & Lee, 2015). This enables the capability of high-speed processing, resulting in real-time decision-making for humans and IoT devices. There are commonly three types of cloud service to compare and choose: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS)(Lee & Lee, 2015). This layer provides a platform for the management service layer to store and manage data.

4) Management Service Layer with Data Analytics and Management Tools as a Key Technology

This is a software layer and is used in order that the software developers can perform communication and input/output (Lee & Lee, 2015). The major role is to simplify the integration of different technologies into new ones and ease the development and deployment of new services or applications; IoTcreates a complex infrastructure with many heterogeneous devices (Patel & Patel, 2016). The result is that software developers are required to make less programming effort (Lee & Lee, 2015). Various analytics and management tools are used to extract relevant information from a large amount of raw data before being processed at a much faster rate. The data will be accessed, integrated, stored and controlled and analyzed in this layer (Patel & Patel, 2016), then the software will make a decision based upon the computing results., It will then initiate both interactive and automated processes to enable a more responsive IoT system (Vashi et al., 2017). One of the important features in this layer is that of the business rule system; a software system that executes one or more business rules in a runtime operation environment (Patel & Patel, 2016). For instance, the rules come from the policy within a business; "All clients that buy more than 3 pairs of shoes per month gets 20 per cent off the next pair of shoes". A business rule system enables these organisational policies and other operational decisions to be defined, tested, executed and maintained separately from the application code (Patel & Patel, 2016).

5) Application Layer with the IoT Application Software as a Key Technology

This is the last layer for the use of end-users, the companies or their customers. It enables the interaction between human to device and device-to-device (Biliyaminu et al., 2018). The aim of this layer is to create a smart environment by presenting the output processed data from the management layer as services, applications or features (Biliyaminu et al., 2018; Mahmoud et al.,2015). The IoT applications can be a smart city, smart factory, smart health, smart car, smart glasses or smart transportation (Patel & Patel, 2016). To exploit the full potential of IoT application, the data on the IoT devices needs to be received and acted upon properly in time, or real-time in an ideal situation (Lee & Lee, 2015). To be able to track down all the processes from the lower layers to IoT applications, executives and functional managers might consider employing the data visualization through web UI (web user interface) or mobile UI (mobile user interface) because it can present the practical graphs, flow process chart and operating reports based on both the data received from the layers and the effective data analysis process, which allows the interaction with the environment (Vashi et al., 2017). This will help the companies to make more precise decisions regarding business strategies and milestones.

3.3.3 The IoT: Its Usage and Purposes

This section will consider the prediction of IoT and explain why IoT is so important to both societies and businesses. Gartner predicts that the IoT installation will create revenue above $300 billion by 2020 even though there are still many unfixed issues, such as data security, privacy, organisation change and standardisation, and there are many unregulated problems in many industries (Al- Qaseemi, Almulhim, Almulhim, & Chaudhry, 2016; Dlodlo, Foko, Mvelase, & Mathaba, 2012; Stankovic, 2014; Mckinsey and company (2015); Saleem, Adebisi, Ande, & Hammoudeh 2017). The IoT is experiencing a high rate of technology change, which is affecting the entire world (Dutton, Law, Groselj, Hangler, & Vidan, 2014).

From a firm-level perspective, many industry leaders expect IoT to have a significant impact on the growth and productivity of the companies (Gilchrist, 2016) by way of creating new lines of business, increasing value or collaborating between partners from different industries (Mourtzis et al., 2016; Turber, Brocke, Gassmann, & Flesich, 2014). Although knowing that IoT implementation is complicated, Bsqua (2017) states that almost 73 per cent of businesses plan to invest more in IoT, and several firms have already realised the profitability offered when IoT is implemented. The manufacturing industry would face the greatest change; the factories could be developed to fully automation (Tomic, 2017) in Europe and the US markets where most of the vehicle OEM headquarters are situated (Manyika et al., 2015).

The Small and medium-sized enterprises (SMEs) would benefit from IoT as well as the large corporations since they can easier access or sell products globally and reach the customers quickly via their marketing strategies (Manyika & Roxburgh, 2011). The IoT will affect societies by changing the way that humans and machines work together in order to increase productivity (World Economic Forum, 2015). It will assist and guide our daily activities via AI, simplifying our lives by making things more convenient, more productive and less stressful. For instance, Google Home allows users to control their smart homes with their voices (Islam, Kwak, Kabir, Hossain & Kwak, 2015). The next section will specifically consider the IoT in manufacturing.

3.4 IoT in Manufacturing

3.4.1 Evolution and Introduction of IoT in Manufacturing

This section considers the evolution and introduction of IoT within the manufacturing industry. The introduction of steam and water power into manual production at the end of the 18th century started the first industrial revolution (Bauer & Horváth, 2014; Schlick, Stephan, & Zühlke, 2014). Mass production through electrical power and Frederick principle of labour division and assembly-line production began the second industrial revolution (Bauer & Horváth, 2014; Schlick, Stephan, & Zühlke, 2014). The third industrial revolution was constituted by the adoption of automated production, computers, IT-systems and robotics in 1970 (Bauer & Horváth, 2014; Schlick, Stephan, & Zühlke, 2014). The smart factory, autonomous systems, IoT, and machine learning led to the recent industrial revolution, or Industry 4.0: a term invented by the German government in order to provide a framework for the integration of cyber-physical systems (Anonymous,2015). Industry 4.0 is triggered by digital technologies that have a significant impact on the manufacturing industry. These include:

(1) CPSs as intelligent solution in manufacturing (Sztipanovits et al., 2013);

(2) IoT as communication platform for (CPSs);

(3) Cloud solutions for decentralized services (Verl et al., 2013);

(4) Big Data solutions for high-performance processing of big data with large amounts of volume, variety, speed, variability or veracity within manufacturing (Kagermann, Wahlster, & Helbig, 2013; Lee, Lapira, Bagheri, & Kao, 2013);

(5) they impact upon cellular internet, such as 5G, which is essential for a connected manufacturing devices;

(6) Edge computing, which brings computation and data storage closer to the sources of data such as IoT devices (Wynn, 2021):

(6) Fog computing which uses edge devices to conduct computation (edge computing), storage, and communication locally (Wynn, 2021).

Traditionally, IT, such as distributed control and secure software, for examples. and operational technology (OT) such as robots, conveyor belts, smart meters and generators in the industrial scope are not integrated (Monostori, 2014). IT starts with data and their models and moves toward data infrastructure (Monostori, 2014), whereas OT starts with physical assets and objects and moves toward industrial control systems.

The evolution of manufacturing and information technologies created CPSs within the industry (Monostori, 2014). CPS connects information and software technologies with mechanical and electrical components (Sztipanovits & Ying, 2013). This combination makes it possible for IT to inject IT ideas into OT, resulting in advancements in the manufacturing scope (Serpanos & Wolf, 2017). We then have IoT, which enables the connection of the physical and the virtual world and thus creates the network both across and within manufacturing businesses (Frazzon, Harmann, Makuschewitz, & Scholz-Reiter, 2013). IoT enhances the CPS by allowing the mutual interconnection of these entities by applying communication technologies - the internet - (Kagermann et al., 2013), which then leads to the connection of the virtual and the real worlds (Spath et al., 2013). CPSs applying IoT in manufacturing leads to the production of big data with a large amount of this data found in volume, velocity and variety (Kagermann et al., 2013).

Data from the manufacturing industry has been growing rapidly, reaching more than 1000 Exabyte (EB) annually (Yin & Kaynak, 2015). The sensing and actuator advancement is still in the early stages of development and many more forms of IoT equipment can still be deployed (Stankovic,2014). Collecting, storing, transferring, analysing and visualizing data from machines and equipment is not new. It has been around for approximately 40 years (Yin & Kaynak, 2015). However, since the data is growing rapidly, it requires special manipulation and analysis in order to get the economic value through industry re-shaping (Mourtzis et al., 2016). To achieve this goal, manufacturing systems are now transformed into digital manufacturing. IoT in manufacturing currently embraces advances in sensor technologies, connectivity, analytics and cloud computing that will ultimately help the manufacturers to utilise data for their performance management.

Physical objects implanted with tiny electrical components have a capability to network and integrate within the resulting cyber-physical infrastructure (Kagermann et al., 2013). The manufacturing industry is the largest market for IoT (Sadeghi, Wachsmann, & Waidner, 2015). With the globalization of the world's economy, manufacturing companies have to cope with increasing competition from their worldwide counterparts in terms of a volatile market, product price, feature, quality and cost, not forgetting higher manufacturing standards (Wright, 2014). Furthermore, consumers demand more diversified and customized products, which leads to more product and process complexity (Bauer & Horváth, 2014). In addition, the shortened technology and innovation cycles result in a more competitive environment (Ramsauer, 2013). These challenges put pressure on the manufacturing enterprises to become more flexible, efficient and adaptable in production and logistics systems (Bauer & Horváth, 2014); this is accomplished by embracing new technologies to maintain competitiveness and meeting the client demands of the client. IoT, which has potential to transform the manufacturing sector, has gained significant attention from both academia and industry (Bi, Xu, & Wang, 2014). The integration of IoT in manufacturing will generate a significant market potential of between $900 billion and $2.3 trillion USD annually by 2025 (Alexakos, Anagnostopoulos, Fournaris, Koulamas, & Kalogeras, 2018). Currently, 31 per cent of manufacturers are implementing IoT to enhance their internal operations. Meanwhile, another 56 per cent are exploring this option so that they may reduce operational costs, improve supply chain efficiencies and increase predictive maintenance ability (Bond, 2017).

3.4.2 Concept, Key Technologies, and Architecture of IoT in Manufacturing

This section considers the concept, key technologies and architecture of IoT in manufacturing. IoT in manufacturing is an advanced innovation that transforms common production objects into smart manufacturing objects (SMOs) that are able to sense, interconnect and communicate with each other to automatically and adaptively make a decision and act upon it, based on manufacturing logics (Tao, Cheng, Xu, Zhang, & Li, 2014). In addition, on-demand use and an efficient sharing pool of resources in the factory are enabled by IoT technologies. The connection between human-to-human, human-to-machine, and machine-to-machine are possible through recent advanced technologies within the network (Zhong, Dai, Qu, Hu, & Huang, 2013). For manufacturers, IoT has become a full ecosystem where software, cloud computing (or local servers) and analytics tools are integrated to turn raw information into significant and useful information or predictions that can then be presented on user interfaces (such as a web portal or mobile application). This enables users to monitor, take actions or remotely control machines or systems in the manufacturing enterprises.

Soldatos, Gusmeroli, Malo and Orio (2016) state that the scope of future IoT in manufacturing can be classified into two categories. The first one is IoT-based virtual manufacturing applications, which utilizes IoT and cloud technologies to connect stakeholders, products and the business in the form of a virtual manufacturing chain, which enables connected supply chains, informed manufacturing plants that are made up of informed people, informed products, informed processes and informed infrastructures (Soldatos et al., 2016). The second one is IoT-based factory automation, which places emphasis on the plant automation by integrating new systems, including production stations and recent technologies such as sensors, RFID and 3D printing, empowering manufacturing quality and performance. It also increases the rate of responsiveness, needs and customer demand (Soldatos et al., 2016).

Yang, Shen and Wang (2016) state that the manufacturing enterprise can be divided into five different levels: sensor-actor-machine, shop floor, factory, enterprise and supply chain (Yang et al., 2016). The IoT increases the efficient information flow both downward and upward between any two levels. This can flatten out the organisational structure (Yang et al., 2016). Factories that implement IoT can be more efficiently managed and scheduled by only one integrated management system (Yang et al., 2016) and IoT will also enable automation by reducing the number of workers and layers of hierarchy within the businesses (Yang et al., 2016).

The key technologies of IoT within manufacturing are the same as those of IoT in general, but for specific use in manufacturing. An integrated network of RFIDs and WSNs is one of the main components of IoT infrastructure within manufacturing (Wang et al., 2012). A manufacturing system is comprised of several sensors, such as vibration sensors, temperature sensors, and force sensors (Gowtham, Haribalaji, Kavinprabu, & Karuppuswamy, 2017) in order to acquire data in real-time from conveyors, machines, actuators and fixtures (Wang et al.,2012). For wired and wireless technologies,Wifi and Bluetooth can be used so that sensors are able to send the data to a central computer in real-time (Gowtham et al., 2017). Wired networks, such as Transmission Control Protocol/Internet Protocol (TCP/IP) and Recommended Standard 232 (RS232) can be used for communicating between machines, robots and central computers, and physical devices (Gowtham et al., 2017). Radio waves are used for data transaction between RFID readers and tags (Gowtham et al., 2017).

Finally, cellular communication technologies, such as 5G, can be used for communication between users, or between management and inter-factory networks (Wan et al., 2016). Furthermore, operations in manufacturing are required to use multiple computing resources such as servers, and this results in expensive investment and unbalanced resources allocation, low productivity and inefficiency (Wang et al., 2012). Cloud manufacturing can provide a solution for these problems by storing massive amount of data in private or public cloud servers and solving problems by using superior cloud computing. In addition, big data analytic tools in cloud manufacturing are used in order to manage big data, allowing manufacturers to offer more business opportunities, readily adapt to changes and improve decision-making in different manufacturing stages (Matsas, Pintzos, Kapnia, & Mourtzis, 2017).

IoT in manufacturing architecture is similar to general IoT architecture. However, to be specific for the purpose of using IoT in manufacturing, more detail and layers need to be added. From a functional perspective, the physical layer should be added to the architecture (Wan et al., 2016). It is responsible for specific physical activities, such as mobility, production, transportation and logistics, to give examples (Wan et al., 2016). This layer consists of various devices, such as automated guided vehicles (AGVs), manipulator, conveyors, production equipment and machines. (Wan et al.,2016). The flow of the work begins when the AGV carries the raw material with the RFID tag from the warehouse to conveyor systems based on cloud manufacturing instructions (Wan et al., 2016). The RFID tags have key manufacturing data and also the data of the progress that has been made (Wan et al., 2016). The manipulators and machines can then process the raw material in conveyor and production systems and the finished products are sent to the warehouse by AGV. During thewhole process, sensors have the capability of recording real-time information necessary for monitoring and analysing (Wan et al., 2016).

It is not only the physical layer that should be added, but also the data visualization in general IoT architecture should be emphasized as one separated layer, because it is important for the workers in the factory, or the management team, to interact with the manufacturing systems. For instance, they can monitor the status of both the process and the machines and observe the workers that operate the machines in real-time (Gowtham et al., 2017). Furthermore, management is able to analyse the statistic report of the updated information regarding the products: procuring process, quality and movement, for example, and provide key parameters according to their requirements (Wan et al., 2016). **Figure 7** below details the architecture of IoT within manufacturing:

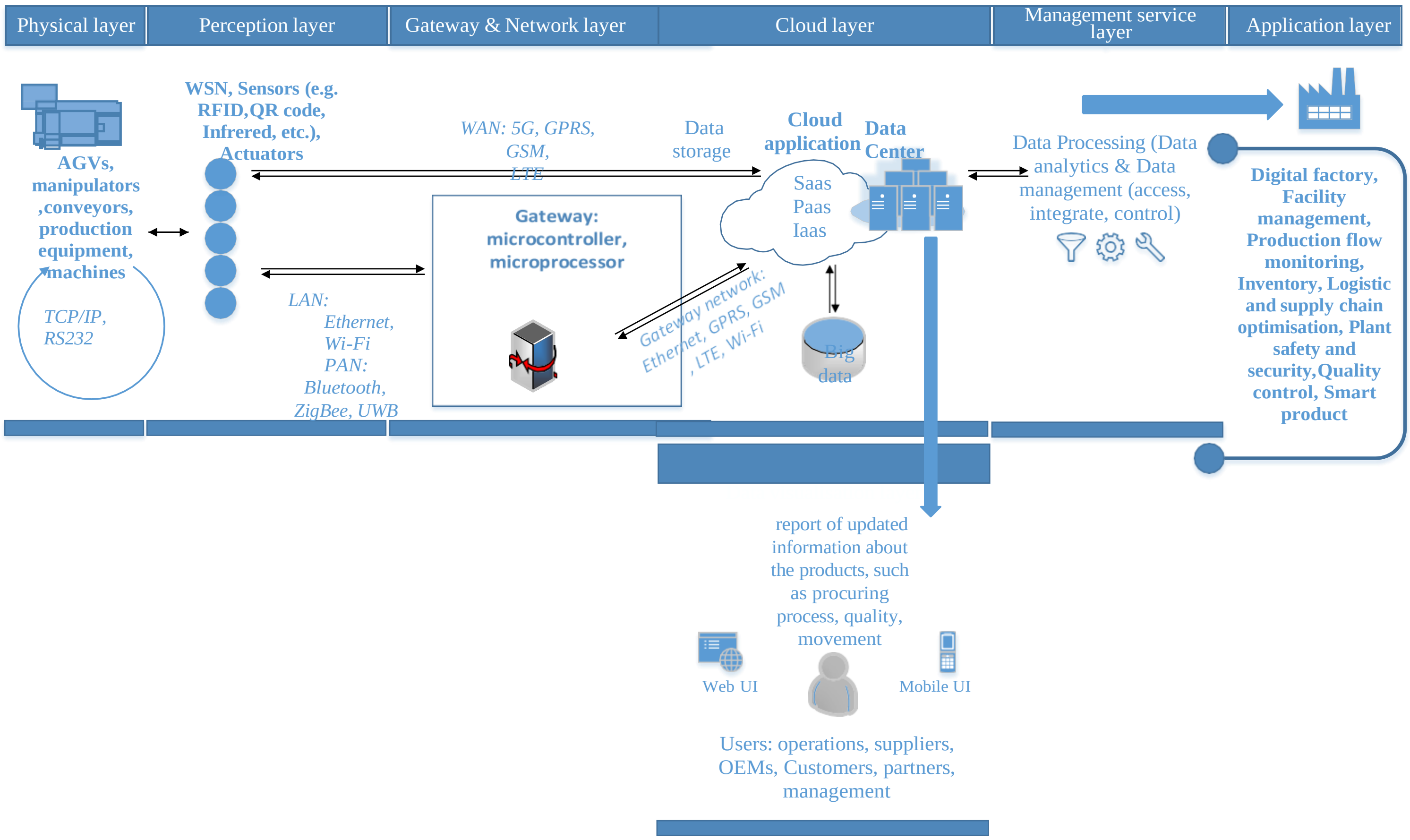

Figure 7: IoT in Manufacturing Architecture with Key Technologies

Source: Author's own

The IoT found in manufacturing architecture provides an effective way to enhance the distribution and decentralization of manufacturing resources (Wang, He, & Wang, 2012). The architecture of IoTis dynamic, so therefore, a system's components can be reconfigured at anytime (Wang et al., 2012).

The virtual enterprise arising from the result of implementing IoT can be used for a specific project by the host enterprise and can be adapted and made ready for other projects (Wang et al., 2012). In addition, interaction between humans, machines and equipment within the manufacturing environment causes a waste of time (Tao, Jin, Wang, & Li, 2014). With IoT implementation within manufacturing, all interactions can be performed under the same roof and all parties can focus upon their own tasks, rather than concerning themselves with the interactions (Tao et al., 2014).

3.4.3 Applications and Challenges of IoT in Manufacturing

This section considers the applications and challenges of IoT within manufacturing. IoT based manufacturing enterprises allow higher agility and adjustability that can shift the manufacturing sector from product oriented to customer-oriented (Tomic, 2017). The adoption of the IoT in manufacturing leads to increased resources and operational efficiency, nearly zero defects and a shorter time to becoming available on the market (Jeschke et al., 2017). The interconnectivity and digitalisation between all entities - customers, machines, products and workers - will create a more competitive environment, a sustainable operation and will eventually increase the overall profits in the industry (Tomic, 2017). **Figure 8** below provides an overview of the benefits and applications of the IoT in manufacturing context:

Overall benefit of IoT in manufacturing
- offer more analytical information to managers. - enable agility in autonomous processes. - systems are independent and can be configurable on their own. - enable robots to be more autonomous, interconnected and cooperative in a more safe andproductive way. - physical assets in the factory have unique IDs, intelligently connected to the network. - coordinating product and information flows will be no longer required.

Application	Practices
1.7.1. Digital/ Connected factory	- vertical integration between all parties. - reduce the need for intermediaries. - sharing real-time and graphic-intensive information globally. - manage the factory unit remotely. - reduce the transaction costs related to international production. - move back operations from Low labour countries to the countries having high innovation. - decentralized IoT-based factory automation.

1.7.2. Facility management	- maximize the machine uptime and minimise equipment failure. - enable predictive maintenance. - accurate operating condition in manufacturing environments, such as temperatureand humidity which leads to energy saving.
1.7.3. Production flow monitoring and Quality control	- horizontal integration of many manufacturing resources and capability used in the various stage of manufacturing. - eliminate wastes and unnecessary work. - increase operational efficiency. - improve production quality.
1.7.4. Inventory, logistic and supplychain visibility and optimisation	- realise the flow of material, production cycle time, in real-time. - vertical integration between all parties. - reduce the need for intermediaries - enable autonomous warehousing. - reduce the work in process inventory. - eliminate data asymmetry issues. - precise estimates of available material, work in process, and arrival time of newmaterial. - lower safety stock levels and reduce shared costs in the supply chain. - improve the flexibility, integration, agility, and responsiveness of their logisticsprocesses.
1.7.5. Plant safetyand security	- improves the safety condition in the factory by monitoring key performanceindicators (KPIs) of health and safety. - prevent potential accidents before it occurs.
1.7.6. Smart product/proc ess	- quickly respond to market trend, identify new customer segments, create a new design, update existing designs, and test the market at less time and cost - increase new products. - create more customized products and more agile factory. - extract customer needs in order to improve customer satisfaction rate. - enables mass customization. - enable 3D printing. -

Figure 8: Benefits and Applications of IoT in Manufacturing

Source: Author’s own

Nevertheless, there are several challenges which manufacturers need to overcome. For example, data from different parties in supply chains is required to be integrated (Sadiku, Wang, Cui, & Musa 2017). Another challenge is initial investment cost as the manufacturer has to invest in the IoT and ensure its integration into the current operating systems

(Sivathanu, 2019). In addition, management in manufacturing firms need to convince their employees to accept the technology (Tomic, 2017). **Appendix 9** provides the detail of applications and challenges of IoT in manufacturing. The next section considers IoT usage in manufacturing industries.

3.4.4 IoT Usage in Manufacturing Industries

This section will provide an overview of the key IoT usage in manufacturing industries that are considered within this thesis. These includes:

(1) IoT usage in stone mining and manufacturing.
(2) IoT usage in coal mining and processing.
(3) IoT usage in gas production.
(4) IoT usage in food processing.
(5) IoT usage in precast concrete manufacturing.
(6) IoT usage in shop floors.
(7) IoT usage in textile manufacturing.
(8) IoT usage in rice manufacturing.
(9) IoT usage in automotive manufacturing.

Regarding the IoT usage in the stone and coal manufacturing sector, the IoT could enable automation, remote monitoring, and location tracking to reduce accident frequency (Laskier, 2017). Pre-alarm parameters could alert if any sensor recognises beyond the safety pre-alarm value (Yinghua et al., 2012). The examples of underground conditions as pre-alarm parameters related to health risk factors are high physical workload, fire, high temperature, humidity and exposure to dust and gas-phase hazardous substance (Chehri et al., 2019). An example use of the IoT technology in mine is active RFID-based wireless for safety and traceability of the mining areas. RFID transmitter devices are mounted on headlamps belts or badge cards of miners to enable tracking of workers in real-time (Yinghua et al., 2012). Regarding the IoT usage in gas production, real-time monitoring application is utilised to detect where and when exactly the leakage in gas pipelines are (Toma & Popa, 2018). Infrared sensing is used to monitor through the video camera throughout the pipeline (Rahmati et al., 2017). For food processing, IoT systems including gas, temperature and humidity sensors are utilised to monitor the food conditions in real time to maintain quality (Popa et al., 2019). Regarding precast concrete manufacturing, RFID could track and locate precast products in real-time achieving accuracy and efficiently within inventory and logistics management (Han & Ye, 2018). For textile manufacturing, the IoT enables mass customised products design (Puranikmath & Babu, 2020). Real-time data and feedback from customer preferences allows textile manufacturers to promptly review the design, make changes, and finalise the product design (Suuchi, 2019). For example, IoT usage in rice manufacturing, is typically used in polishing processes to control the size and colour of rice (Chantima, Polpinit, & Khunboa, 2016). Lastly, the automotive manufacturing sector uses real-time monitoring functions of the IoT to improve the quality and reduce failure rates (Khaleel et al., 2015) of each process which often causes a bottleneck as automotive production comprises several processes which continue from each other (Wanjari, 2020).

Appendix 10 provides the detail of IoT Usage in Manufacturing Industries. The next section considers IoT in SME manufacturers.

3.5 IoT in Manufacturing SME

3.5.1 IT, ICT and IoT in SME

This section considers both the uses and challenges of IT and ICT within manufacturing SMEs. ICT technology supports real-time information sharing among partners to create and manage both dynamic and non-hierarchical networks of SME, responding to market opportunities, collaborating design and manufacturing customized products (Ferreira, Shamsuzzoha, Toscano, & Cunha, 2012). The use of traditional communication technologies – e-mail, telephone and fax - are not able to obtain real-time data sharing, and are often both ineffective and time-consuming (Shamsuzzoha, Toscano, Carneiro, Kumar, & Helo, 2016). By contrast, the use of recent ICT has had a significant impact on SMEs in terms of productivity and innovation capacity (EC, 2016). The European Commission (2016) emphasises that increasing use of ICT is an important factor for European firms, especially SMEs, in order that they may become increasingly competitive. The use of ICT in firms potentially results in digital transformation, which creates organisational optimisation by using technologies that increase performance, reduces administrative overhead costs and allows them to focus on their core business and increasing employee productivity (EC, 2016). ICT helps SMEs to gain improved access to new market opportunities, or wider market opportunities such as obtaining their sources from a more extensive network of suppliers and gathering customers in new areas. Furthermore, SMEs can gain information regarding their customers so that they may be more able to offer an improved standard of customer satisfaction and enhance new product development processes more effectively (Bayo-Moriones et al., 2013). In addition, implementing ICT in SMEs can lead to improved process efficiency by reducing time and cost and quality improvement by decreasing defects and errors (Bayo-Moriones et al., 2013).

However, compared to large organisations, SMEs are limited in their ability to invest in ICT or IT due to less available and accessible resources and skills. The most critical limitation is financing, as SMEs need to identify, develop, purchase and integrate ICT solutions (Dai et al., 2015; Wynn, 2009). Outsourcing the IT advanced solution from large businesses such as IBM, SAP and Siemens are too expensive for SMEs that have a limited budget for R&D investment; therefore, SMEs require a more realistic and attainable solution with high-customized functionalities and flexibility (Dai et al., 2015). Furthermore, a department that is skilled in fixing technical problems, or providing professional services that ensures day-to-day operations should manage the IT solution adoption. However, most of the SMEs are not willing to support this type of professional service (Zhong, Dai, Zhou, & Dai, 2008); they do not consider them as 'value adding' employees compared to the workers within operations (Zhong et al., 2008).

In addition, firms are facing several challenges regarding the digitalisation of their operations because they need to reconfigure the business (Tarute, Duobiene, Kloviene, Vitkauskaite, &

Varaniute, 2018). The major external challenges faced are having to constantly adjust both their products and services in order to adapt to external conditions and having to continuously optimise their supply chain due to the fact that the wider use of ICT and IT within the manufacturing industry creates an ever-changing customer need, global competition, or technological changes (Lederer, Knapp, & Schott, 2017). For internal challenges, implementing ICT and IT at a significant level can create critical management problems; mainly the changes of processes and operations management to ensure the interoperability between key partners in the value chain, such as standards and format used for electronic data exchange (Dremel, Wulf, Herterich, Waizmann, & Brenner, 2017; Horlacher & Hess, 2016).

This section considers the uses and challenges of IoT in SMEs. In order to make the transition from the use of traditional ICT infrastructure to IoT, the firms require cost-effectiveness and business value drivers which are comprised of technological oriented services and agility. To do this, they need to reduce their business expenses and reinvest their monetary savings to the technology-oriented services, IT and business architecture such as networking capability and IoT applications (Abazi, 2016). IoT is one of the advanced forms of IT that creates significant impacts on SMEs, as large firms are looking for innovative, smaller partners to be their suppliers (Suleman, 2016). Lund, MacGillivray, Turner and Morales (2014) state that SMEs and entrepreneurs need to collaborate with other SMEs and large firms in order to utilise IoT in their organisations. IoT brings a new era of ways of conducting business and how interaction takes place with customers, as the customers tend to communicate with the businesses via the internet Abazi, 2016) (Abazi, 2016). In addition, collective data from the IoT can create a significant advantage in competition compared with other SMEs that do not use IoT (Abazi, 2016). From a business model perspective, Leminen, Rajahonka and Westerlund (2015) state that it is not possible to build the IoT solution completely by solely using SMEs; they need to outsource and integrate systems with their partners. However, there is no study that determines how SME should select the IoT service providers. SMEs that want to fully utilise the IoT and create digital transformation in a service- driven environment have to overcome some barriers, otherwise products or services can be delayed (Lueth & Glienke, 2017). The largest obstacle in the way of the SMEs adopting IoT is a lack of internal talent and technology expertise, as well as ability to create some specific policies for implementation; therefore, they should consider looking for external means of transformation and innovation (Kulkarni, 2018).

3.5.2. IoT Implementation in Manufacturing SMEs

This section considers the IoT implementation within manufacturing SMEs. Before implementing IoT, SMEs should first understand the key aspects of the business model change caused by the IoT (Varaniute, Vitkauskaite, & Tarute, 2018). The most significant changes are value propositions, key resources, key partners and cost structure (Varaniute et al., 2018). For the key resources change, the implementation requires improving the production workers' qualifications, or changing the existing workers, as the IoT needs a more advanced skilled and knowledge set to ensure that value is added after adoption (Dassisti et al., 2017; Kleindienst & Ramsauer, 2016; Moeuf et al., 2017; Müller, Maier, Veile, & Voigt., 2017; Müller et al., 2018; Nylander et al., 2017; Sommer, 2015). Some firms may need to reorganize their production if they were too obsolete (Dassisti et al., 2017; Kleindienst & Ramsauer, 2016; Moeuf et al., 2017; Müller et al., 2017; Müller et al., 2018; Nylander et al., 2017; Sommer, 2015). Dassiti et al. (2017) state that selected IoT solution should be able to rest on existing systems, such as ERP, MES, SCADA, and multi-modal assistance systems can be useful to workers with their often-diverse tasks. In addition, SMEs should plan to scale up the overall systems in advance by ensuring the possibility to reutilize all the existing components (Varaniute et al., 2018). Furthermore, upgrading the existing production line machines is required to enable big data collection (Varaniute et al., 2018).

For the key partner change, manufacturing SMEs should make sure that the use of technology solutions and systems align with their partners (Kleindienst & Ramsauer, 2016). For key activity change, the adoption of IoT solutions enables manufacturing SMEs to improve their information flow management, thus resulting in increased effective management and control in the factory (Moeuf et al., 2017; Müller et al., 2018). The improved information flow will reduce the costs and errors at several stages in the supply chain (Dassisti et al., 2017; Müller et al., 2017; Sommer, 2015). In addition, more efficient exchange of information with key partners allows collaboration in distributed production networks (Varaniute et al., 2018). This will increase the trust and strengthen the partnerships among them (Kleindienst & Ramsauer, 2016; Moeuf et al., 2017). Furthermore, increasing information flow efficiency between SME manufacturers and their suppliers and customers will increase the holistic productivity within the production networks of the value chain. For the value proposition changes, the use of IoT creates more customised products for the customers, which in turn strengthens the nature of SMEs: they provide a product or service to particular target groups (Kleindienst & Ramsauer, 2016; Leiting, De Cuyper, & Kauffmann, 2022; Müller et al., 2017). In addition, IoT increases product quality from the capability of real-time monitoring and analysing (Moeuf et al., 2017). Also, they can reduce the transportation time within the supply chain. **Table 4** below provides an overview of the key aspects of business model change caused by IoT:

Table 4: The Key Aspects of Business Model Change Caused by IoT

Key aspects	Key changes due to implementation of IoT
Key activities	- improve information flow management. - increasing effective management and control.
Key partners	- increase the trust and strengthen the partnerships among SMEs and their partners. - increases the productivity of the whole production networks of the value chain. - allows the collaboration in distributed production networks.
Value propositions	- create more customized products for the customers. - increases product quality.

Key resources	- requires improving production workers qualifications or changing the existing workers. - may need to reorganize their production ifthey were too obsolete.
Customer relationships	- increase information flow efficiency between SME manufacturers and their customers.
Customer segments	-possibilities to target new Business to Business (B2B) customer groups.
Channels	- reduce transportation time in the supply chain.
Cost structure	- reduces the costs because of increased efficiency and reduced errors at several stages in the supply chain.

Revenue streams	-increase in revenue. -possibility to change payment method and processes to be more convenient.

3.5.3 The Use and Challenge of IoT in Manufacturing SME

This section considers both the use and challenges of IoT within the manufacturing SME. IoT presents a new era for SME in manufacturing (Hansen, Malik, & Bilberg, 2017). It helps them to improve customer relations (Abazi, 2016). A major enabling technology is RFID, which is an electronic barcode that is used to transfer information between manufacturing objects (Gubbi et al., 2013). RFID tags can be used in material movement, resources planning and logistics to obtain production feedback in real-time (Hansen et al., 2017). Sena Ferreira, Shamsuzzoha, Toscano and Cunha (2012) note that most SMEs do not have reliable data; therefore, operation managers usually do not regard data as a valuable resource. They use IoT with RFID technology only to manage and monitor flows of data and material and to facilitate the adoption of lean manufacturing. However, with the implementation of IoT in the factories, the data flow is reliable and the target improvement in production is more attainable and swifter than using the traditional value stream mapping (Moeuf et al., 2017). SMEs can gather data from a production machine to evaluate its performance and variance, resulting in continuous improvement within the factories (Xia, Li, Zhang, & De Silva, 2016).

Constantinescu, Popescu, Muresan and Stana (2016) suggest that, as IoT provides data that is too large to be processed effectively by SMEs, the SMEs can use the concept of JITIR (Just-In-Time Information Retrieval) to monitor any requirement for change in the factory and to enhance the decision-making process and reduce the risks (Schönsleben, Fontana, & Duchi, 2017). JITIR comprises of three stages:

1) Analysis of the need via employees' interview.

2) Recovery of data.

3) Regular review of the employees' environment (Constantinescu et al., 2016).

IoT enables several advanced technologies that, in the past, only large enterprises have been able to use (Hansen et al., 2017). For instance, AGVs used for internal transport are more flexible in solutions; they are less expensive and easier to programme, allowing SMEs to implement them in their warehouses, or on shop floors (Hansenet al., 2017). Another trend in production automation is collaborated robots, or 'cobots', which can integrate the strength from workers and robots within the factory setting (Grigorescu, Vatau, & Dobra, 2010; Malik, Bilberg, 2017). With IoT, cobots are safer and more effective in the interaction between themselves and worker (Grigorescu et al., 2010; Malik & Bilberg, 2017). Even though most SMEs have a low production volume with a high variety of products, with theconcept of lean automation the routine and less ergonomic tasks in the production can be achieved by using cobots (Grigorescu et al., 2010; Malik & Bilberg, 2017).

Actually, SMEs realise the potential benefits of IoT but they dislike the incurring costs from acquiring new machines, or adjusting their existing machines, in addition to the integration of sensors and software (Müller, Buliga, & Voigt, 2018). Thus, they lack accurate and consistent data that is necessary in order to analyse and improve manufacturing performances (Müller et al., 2018). The most important challenge for SMEs regarding the implementation of IoT in manufacturing are resource scarcity, unstructured processes, competencies of the employees, the need for partnership and support from the government and innovation systems (Nylander, Wallberg, & Hansson, 2017; Warrian & Southin, 2017). In addition, it can be more challenging for SMEs that products and processes are not related to IT (Wallberg et al., 2017).

SME manufacturers require significant investment to handle big data from IoT implementation (Schönsleben et al., 2017); however, cloud computing and Hadoop systems can be the solutions, in term of investment and number of employees required to manage and evaluate the data (Hansen et al., 2017). The entire IoT platform can be maintained in the cloud, which is better than building from zero in the firm's own data centres; SMEs can meet their business goal faster than in a traditional data centre and can avoid or minimise the software technical debt or incompatibilities of technologies (Illa & Padhi, 2018). There are several outsourced cloud platforms with big data (Illa & Padhi, 2018). However, SMEs should acknowledge that there is no single cloud service provider that can provide end-to-end IoT solutions (Illa & Padhi, 2018). They have to select particular products from various providers and integrate them to meet both the firms' and the industry needs (Illa & Padhi, 2018). Furthermore, they should be concerned with their organisation's expertise, capability and execution within the cloud (Illa & Padhi, 2018). SME's will eventually utilise this data to optimise the customer demands and production process at a lower cost (Moeuf et al., 2017). Currently, there are few studies on how to make big data analysis more assessable to SMEs and what implementation steps or technologies are required (Moeuf et al., 2017).

An example of the impact of IoT within manufacturing SMEs in different countries is a comparative study between IoT adoption in German and Chinese SME manufacturers, undertaken by Beier, Niehoff, Ziems, and Xue (2017). They found that currently, German SMEs expect a higher impact from IoT than in China. However, China SMEs expect to have a higher impact by 2023 than Germany (Beier etal., 2017). Regarding the benefits, the study found that German SMEs expect more operational benefits, such as financial profits, time efficiency and overall equipment effectiveness, whereas Chinese SMEs expect both strategic and operational economic benefits (Müller et al., 2018). For its challenges, China sees financial resources, job losses and skill shortages, correspondently, as the top three challenges, while skill shortages, cooperation and financial resources are the top three challenges for Germany respectively (Müller et al., 2018).

From the literature review, it was apparent that there exists only limited literature examining IoT within SMEs. Some literature has examined the challenges, but there is no clear relationship between the requirements of IoT implementation in manufacturing SME and what the SMEs lack. Furthermore, before implementing IoT, not only the challenges that the firms face should be identified, but also the drivers or motivation. However, there is no robust study on this; this raises several questions; why did manufacturing SMEs decide to invest in IoT even though they have limitations, how should the SMEs balance the IoT investment with the firm's objectives and capacities, what obstacles do they have while adopting and how do they change the attitude/ways to overcome them? Moreover, the study regarding the benefits/impacts is still nascent. A study about the benefits/impacts after IoT implementation within German SMEs and Chinese SMEs is questionable to generalise the findings and does not provide significant detail. This raises further questions; which applications from IoT implementation should manufacturing SMEs focus on and what are specific benefits/impacts after installing those applications?

3.6 Summary

Geographically, it is evident from the literature review that the level of adoption of ICT in developing countries is inferior when compared with developed countries.
However, the majority of existing studies are focused on ICT adoption in developed countries. Therefore, there is a need for a further research regarding the adoption of emerging ICTs such as the IoT in developing countries such as Thailand. This chapter identifies the key benefits and current challenges of IoT adoption in manufacturing SMEs which were identified in chapter two (**section 2.2)** as the most important sector for the Thai economy. The IoT usage in various manufacturing industries is considered. The benefits of using the IoTs include the development of improved communication and connectivity between devices, such as factory automation, logistics and business management, and smart transportation of assets and goods. Nevertheless, there are several challenges to adopt the IoT such as the compatibility with existing systems and the initial and on-going costs of investment. However, there is a lack of the study covering all the relevant factors affecting IoT adoption; for example, technological, organisational and environmental factors; there are limited studies considering the drivers, motivators and challenges that firms will encounter when IoT is adopted.

In summary, it is apparent that there is a need for further research, to explore the usage and adoption of the IoTs in developing countries such as Thailand, based on the gaps in the existing literature and the importance of this topic to the manufacturing SME community. Therefore, the aim of this study is to examine the factors affecting IoT adoption within manufacturing SMEs in Thailand. The objectives are to identify factors relating to the adoption intention of the IoT in the manufacturing sector, clarify the factors relating to IoT adoption intention in SMEs in Thailand, and explore factors and inter-relationships relating to the adoption intention of the IoTs in manufacturing SMEs in Thailand. The next chapter considers the theoretical frameworks utilised within this thesis.

Chapter 4: Theoretical Framework

4.0 Theoretical Framework Chapter

This chapter provides an overview of the key theoretical frameworks to be considered within this thesis. A conceptual framework together with research questions are proposed at the conclusion of this chapter.

4.1 Theory Models and Relevant Factors

There are several theories typically used in IS research (Wade, 2009). However, there are few studies considering the IT adoption models, with regard to IT, undertaken at a business level perspective (Hsu & Lin, 2016b; Hwang, Kim, & Rho, 2016; Singh, Gaur, & Ramakrishnan, 2017; Tu, 2018; Yang, Lee, & Zo, 2017a). An employee cannot adopt a new innovation until it has firstly been adopted within an organisation (Roger, 2003). This study will focus on the IoT adoption at the business level. The most widely used theory in innovation diffusion and adoption in organisations is the DoI (Oliveira, Thomas, & Espadanal, 2014; Rogers, 1983). The DoI theory by Rogers is a prominent adoption model used in IS research (Dedrick & West, 2004; Ifinedo, 2011; Mora, Monge, Azadegan, & Teich, 2010; Shah, 2009; Zhu, Dong, Xu, & Kraemer, 2006). In addition to DoI, the TOE by Tornatzky, Fleischer and Chakrabarti (1990) is another important theory that strengthens DoI as it is genetic and can be combined with other factors, making it highly adaptable in various contexts. Furthermore, TOE considers both the internal and external factors within the organization. The value of combining the TOE with a view to strengthening the DoI theory is well-accepted (Chau & Tam, 1997; Hsu, Kraemer & Dunkle, 2006; Oliveira & Martins, 2011; Wu et al., 2013).

Other related technology acceptance theories such as the technology acceptance model (TAM) (Davis, 1986; Davis, 1989; Davis et al., 1989), the theory of planned behaviour (TPB) (Ajzen, 1985;Ajzen, 1991) and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003) will be used as complimentary theories and combined with the DoI and TOE theory. Several researchers have combined more than one theoretical perspective in order to understand the IT adoption of emerging technologies (Fichman, 2004; Lyytinen & Damsgaard, 2011; Oliveira & Martins, 2011; Wu, Cegielski, Hazen, & Hall, 2013; Wynn, 2021). To understand the organisational decisions relating to the adoption of technological innovation, variables from several theories and literatures will be tailored to the specific needs of the innovation.The next section considers the evolution and concept of the selected theories and model, the evolution of DoI as the main theory in relevant context, followed by the section that will provide the description of relevant factors from literature and selected theories affecting IoT adoption in manufacturing SMEs. The relevant factors are then extracted, analyzed and synthesized, resulting in the conceptual framework.

4.1.1 Evolution and Concept of DoI, TAM and UTAUT

This section considers the evolution of theories concerning technology acceptation. The evolution of theory and model of technology adoption began when Roger (1960) first developed the DoI, which is well established and the most utilised theory in the field of innovation (Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004; Légaré, Ratté, Gravel, & Graham, 2008; Tornatzky & Klein, 1982). The technology acceptance research began when the development of computers over the past four decades made it important for people and organisations to understand why they should accept or reject a technology (Rondan-Cataluña, Arenas-Gaitán, & Ramírez-Correa, 2015). The technology acceptance theory began with Theory of Reasoned Action (TRA) by Fishbein and Ajzen (1975), and it was developed further using the various models of Technology Acceptance Model such as TAM; it was recently updated with UTAUT by Venkatesh et al. (2003). The evolution of technology acceptance models is shown in **Figure 9** below. The next section will consider the evolution and the concept of TRA, which is one of the first models to study acceptance of technology, and also considered are the DoI, TAM and UTAUT which will be utilised within this study (Rondan-Cataluña et al., 2015)

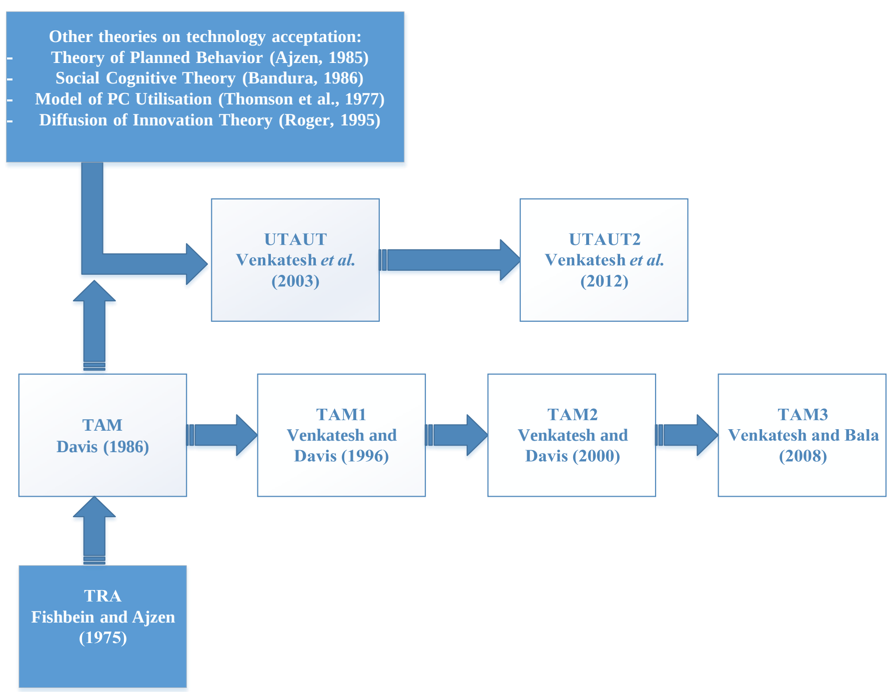

Figure 9: Evolution of Theories About Technology Acceptation

Source: Author's own

Diffusion of Innovation Theory

This section considers the evolution and concept of DoI. The first concrete study to be undertaken with regards to DoI was in 1943 by Ryan and Gross (Evol & communication, 1999). In order to gain knowledge and apply it to the diffusion of various farm innovations, they investigated the relatively rapid diffusion of hybrid seed corn taking place on lowa farms (Evol & communication, 1999). In 1958, Everett and Rogers conducted research on the diffusion of agricultural innovation and later generalized the diffusion model before publishing their work, "DoI", in 1962. Rogers synthesized studies from over 500 diffusion models in several areas. Over the past decades, the general model of diffusion of innovation has been expanded to various areas, such as communication, education, economics, internet, marketing and public health (Pelto, 1973; Rosen, 2000). In the original model of DoI by Rogers (1983), the innovation characteristics, which can determine the rate of technology adoption, are of relative advantage, compatibility, complexity, trialability and observability. Rogers believed that these five qualities determine between 49 and 87 per cent of the variation in the adoption of new products (Robinson, 2009).

In addition to Rogers (1983), Tornatzky and Klein's (1982) meta-analysis was marked as a significant contribution in this literary field. They examined IT innovations by discussing the use of Rogers'innovation contributions throughout the IT world (Kapoor, Dwivedi, & Williams, 2014a). In addition to the five attributes listed by Rogers, they identified 25 other innovation features (Tornatzky & Klein, 1982) and these may be included within this study. Tornatzky and Klein, Moore and Benbasat (1991) subsequently undertook a significant study in this area and developed an instrument to measure individual perceptions of adopting an IT innovation (Moore & Benbasat, 1991). They identified eight features, three out of which were studied either by Rogers, or by Tornatzky and Klein, and ease of use was considered to be an exact opposite measure of the complexity attribute from Rogers. The remaining four newly identified features are image, voluntariness, visibility and result demonstrability (Moore & Benbasat, 1991).

In total, 32 innovation attributes influence the adoption, and adoption intention (Kapoor, et al., 2014a). However, a study was found that 19 of these 32 attributes were either no longer in use, or had been utilised by less than five publications, and therefore should be removed (Kapoor, et al., 2014a). The 32 innovation attributes were then narrowed down to only 13 - relative advantage, compatibility, complexity, trialability, observability, cost, risk, image, visibility, voluntariness, result demonstrability, social approval, and communicability (Kapoor, et al., 2014a). **Table 5** below shows the final 14 innovation attributes:

Table 5: The Final 14 Innovation Attributes

Innovation attributes	Definitions	Sources
Relative	Degree to which an innovation is perceived as better than advantage the idea it supersedes	Roger (2003)
Compatibility	Degree to which an innovation is perceived as consistent with existing values, past experiences and needs of potential adopters	Roger (2003)

Complexity	Degree to which an innovation is perceived as relatively difficult to understand and use	Roger (2003)
Trialability	Degree to which an innovation may be experimented with limited basis	Roger (2003)
Observability	Degree to which the results of an innovation are perceptible to others	Roger (2003)
Cost	Relates to the costs associated with the use of an innovation. Lower costs increase the rate of innovation- adoption	Tornatzky and Klein (1982)
Risk	Multidimensional component involving performance, financial, social, physical, psychological, time loss, product breakdown and the like types of risks	Tornatzky and Klein (1982)
Image	Degree to which the use of an innovation is perceived to enhance one's image or status in one's social system	Moore and Benbasat (1991)
Visibility	Degree to which the use of a particular innovation is apparent	Moore and Benbasat (1991)
Voluntariness	Degree to which the use of an innovation is perceived as being voluntary or of free will	Moore and Benbasat (1991)
Result demonstrability	Dimension concentrated on the tangibility of the results of using an innovation, including their observability and communicability	Moore and Benbasat (1991)
Social approval	Non-financial aspect of reward	Tornatzky and Klein (1982)
Communicability	Degree to which an innovation can be clearly and easily understood	Tornatzky and Klein (1982)

It was considered appropriate to use the fifth edition of the book from 2003, as it is the most updated version. However, the fourth edition (1995) is the most cited version (Kapoor et al., 2014a) but most of the studies citing this fifth edition of Rogers' book also cite the fourth edition of the same book from 1995 (Kapoor et al., 2014a). Nevertheless, it was found thatthere was no significant difference between the fourth and fifth editions. (Kapoor et al., 2014a).

Theory of Reasoned Action

This section considers the evolution and concept of TRA. TRA was the first model to study acceptance of technology. Psychologically, TRA examines the determinants of conscious behavior (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). According to this theory, the specific behavior of a person is determined by a person's intention to carry out behavioral intention (BI) (Rondan-Cataluña et al., 2014). In addition, BI is determined by attitude (A) and the subjective norms (SN) relating to the conduct in question (Rondan-Cataluña et al., 2014). **Figure 10** below provides the conceptual framework of TRA:

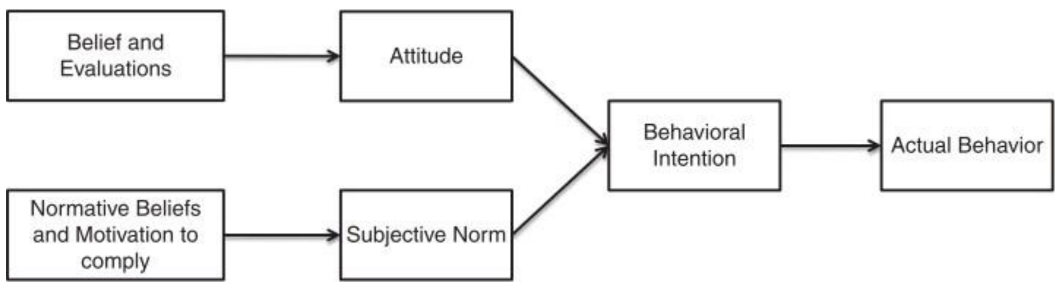

Figure 10: Theory of Reasoned Action

Source: Fishbein and Ajzen, 1975 (p.261)

Technology Acceptance Model

This section considers the evolution and concept of TAM. TAM, developed by Davis in 1986, has been adapted from TRA in order to be specifically used for modeling user acceptance of information systems (Rondan-Cataluña et al., 2015). **Figure 11** provides the conceptual framework of the TAM.
TAM is based on two particular beliefs:

1) Perceived usefulness (PU)
2) Perceived ease of use (PEOU), as the main antecedents of technology acceptance (Rondan-Cataluña et al., 2015)

In the same way as TRA, TAM indicates that the use of computer is determined by BI, even though BI in TAM is determined by PU and Attitude, which is different from the TRA (Rondan-Cataluña et al., 2015). Furthermore, TAM does not include SN used in TRA, as it has an uncertain theoretical status (Rondan-Cataluña et al., 2015).

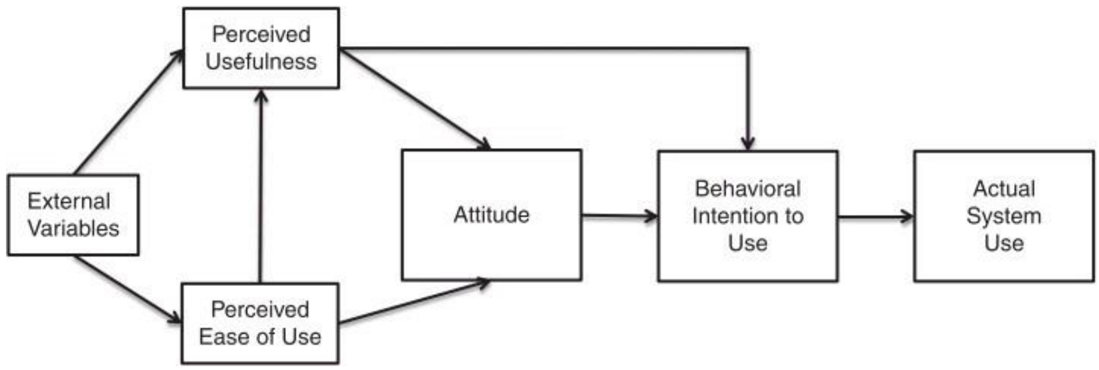

Figure 11: Technology Acceptance Model

Source: Davis, 1986 (p.985)

In 1989, Davis found that PU and PEOU have a strong impact on BI, and the effect of A decreases over time; therefore, Davis excludes A in the TAM (Rondan-Cataluña et al., 2015. When Venkatesh and Davis (1996) analyzed the antecedents of PEOU, they no longer included Ain the model (TAM1) (**Figure 12** below). Since then, TAM1 has been used in various technological contexts, and not only for computers within the workplace (Rondan-Cataluña et al., 2015).

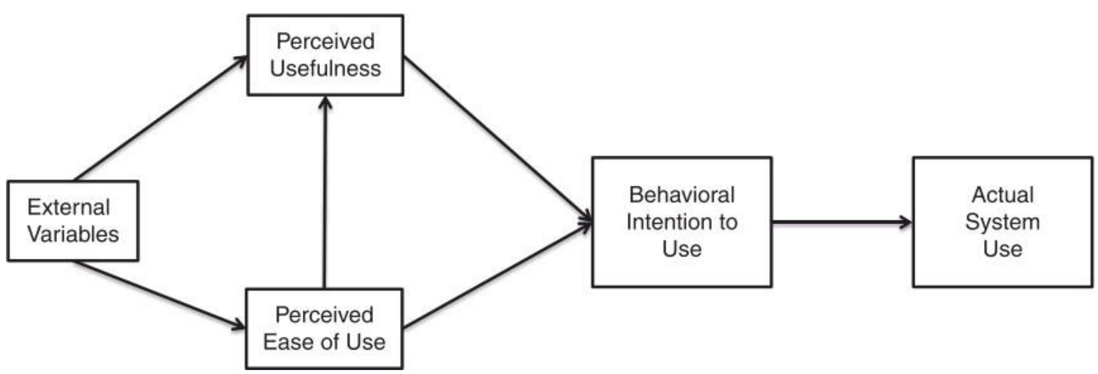

Figure 12: Technology Acceptance Model 1

Source: Venkatesh and Davis, 1996 (p.188)

The first extensions of TAM - called TAM2 - by Venkatesh and Davis (2000) expanded upon the antecedents of PU. They added constructs on social influence processes (SN, voluntariness, and image) and cognitive instrumental processes (job relevance, output quality and result demonstrability) (Venkatesh & Davis, 2000) as shown in **Figure 13** below:

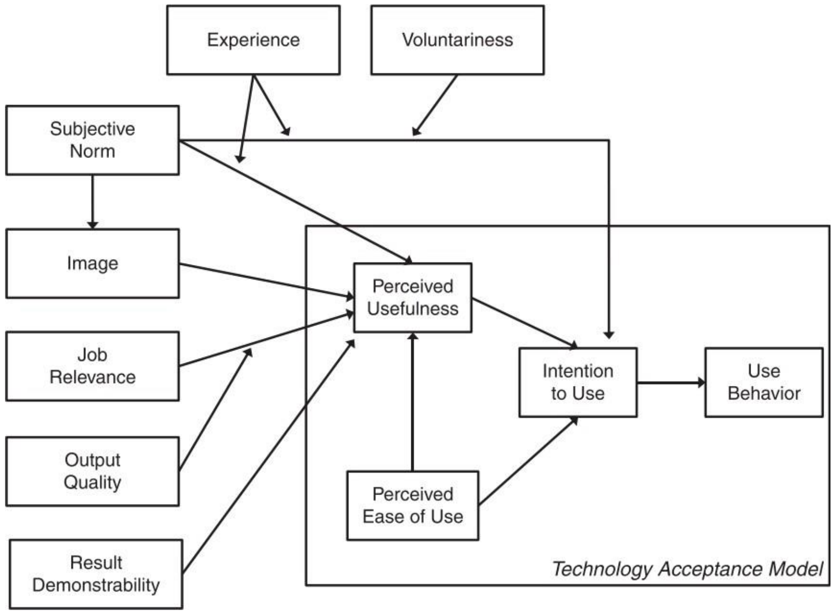

Figure 13: Technology Acceptance Model 2

Source: Venkatesh and Davis, 2000 (p.346)

The most recent TAM is TAM3 (**Figure 14**) by Venkatesh and Bala (2008). They expanded upon the antecedents of PEOU (Venkatesh & Bala, 2008), paying particular attention to building upon the anchoring (computer self-efficacy, computer anxiety, computer playfulness and perceptions of external control) and adjustment framing (perceived enjoyment and objective usability) of human decision-making. TAM3 suggests that there are three relationships that have not been empirically tested in previous TAM models. Venkatesh and Davis (2008) suggested that experience would moderate the relationships between:

1) Perceived ease of use and perceived usefulness

2) Computer anxiety andperceived ease of use

3) Perceived ease of use and behavioral intention

TAM models in the last decades have been widely used, extending their application to a multitude of technologies, especially to web site applications (Venkatesh & Bala, 2008).

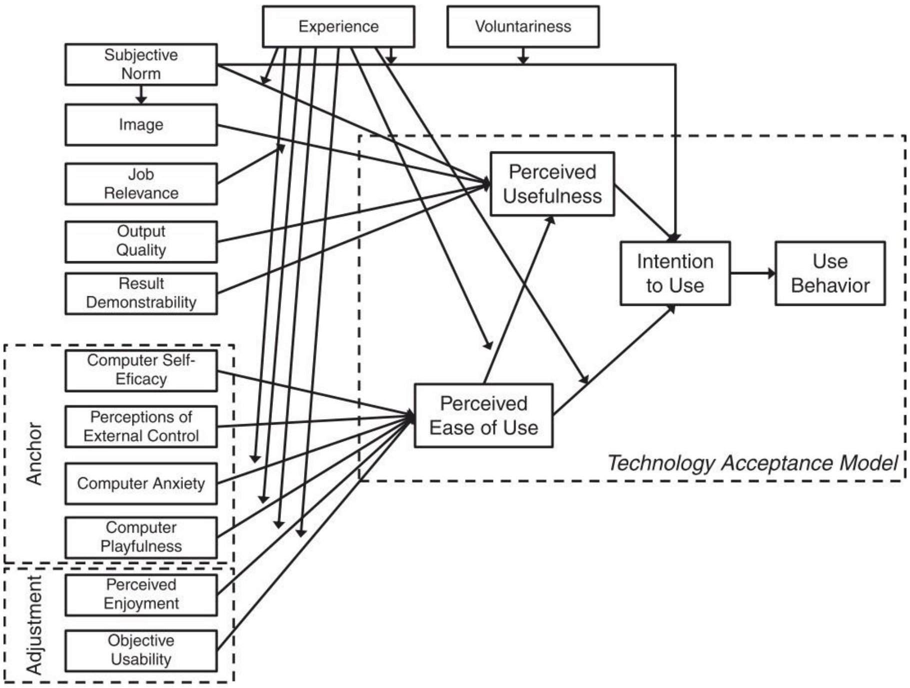

Figure 14: Technology Acceptance Model 3

Source: Venkatesh and Davis, 2008 (p.276)

Despite the development of TAM, a study notes that the TAM1, TAM2, TAM3 do not significantly improve from the original TAM (Rondan-Cataluña et al., 2015). In fact, they have less power of explanation than the original TAM (Rondan-Cataluña et al., 2015). More specifically, a number of studies indicate that when the attitude (A) is removed from the TAM model, the R-square of BI of use drops significantly, while the R-square of use remains constant (Rondan-Cataluña et al., 2015). It is likely that when TAM models are not applied to consumers, but to employees who are obliged to use such a technology, attitude does not play an important role (Rondan-Cataluña et al., 2015). However, when TAM models are applied to final consumers, attitude gains weight within its relationship with BI of use (Yousafzai et al., 2007a). Regardless of the potentials of development of TAM models a decade ago (Lee et al., 2003), these results demonstrate that there have been no significant improvements, at least to applying the methods with voluntary users.

Unified Theory of Acceptance and Use of Technology

This section considers the evolution and concept of UTAUT. After TAM, UTAUT has become one of the main lines of research within the literature of information systems. In addition to TRAand TAM, many models have appeared. This is because many researchers publish informal models, mixing concepts of various theories, or using only those most favorable to their objectives, without considering the contributions of other alternatives (Rondan-Cataluña et al., 2015). Consequently, Venkatesh et al. (2003) affirmed that there is a need for a review and synthesis to progress toward a unified view of user acceptance. Therefore, Venkatesh et al.(2003)reviewed and compared the acceptance literature and discussed eight prominent models: TRA, TAM, the motivational model, TPB, which is a model combining TAM and TPB, the model of PC utilization, the innovation diffusion theory and the social cognitive theory. They then framed a unified model called UTAUT that mixes elements across the eight models (Venkatesh et al., 2003). **Figure 15** below provides the conceptual framework of UTAUT:

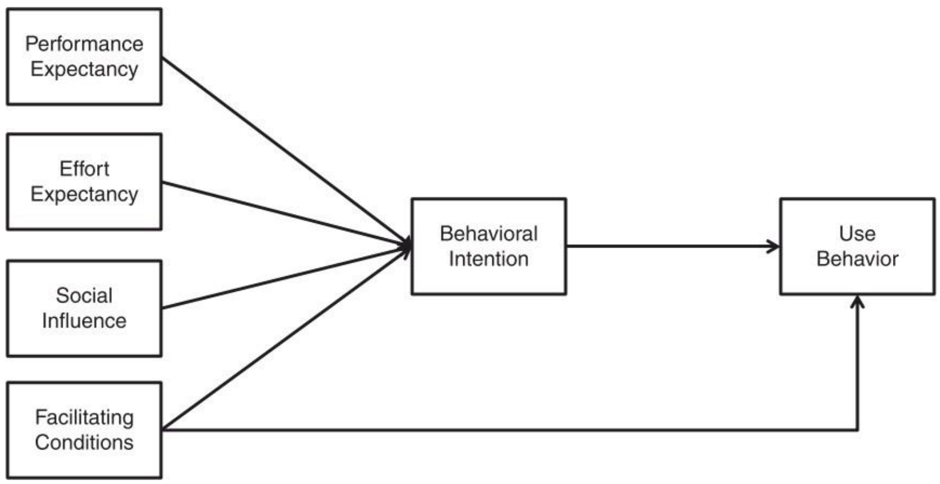

Figure 15: Unified Theory of Acceptance and Use of Technology

Source: Venkatesh et al., 2003 (p.447)

UTAUT has four constructs, which directly determine the user acceptance and usage behavior. The four constructs are:

1) Performance expectancy

2) Effort expectancy

3) Social influence

4) Facilitating conditions (Venkatesh et al., 2003)

These four constructs directly affect BI (Venkatesh et al., 2003).

Similar to the TRA and TAM framework, BI directly also affects the behavioural use (UB) (Venkatesh et al., 2003). In contrast to TRA and TAM, BI is not the only direct antecedent of UB but it also facilitates the conditions that directly determine UB (Venkatesh et al., 2003). After the original UTAUT, Venkatesh et al. (2003) adapted the model for consumer use in 2012. This model, called UTAUT2, added three determinants of BI:

1) hedonic motivation,
2) price value,
3) habit (Venkatesh et al., 2012).

Furthermore, the habit construct is related to UB (Venkatesh et al., 2012).

The next section considers the evolution and concept of the TOE framework.

Figure 16 below provides the UTAUT2 conceptual framework. UTAUT2 is the most recent technology adoption and acceptance theory:

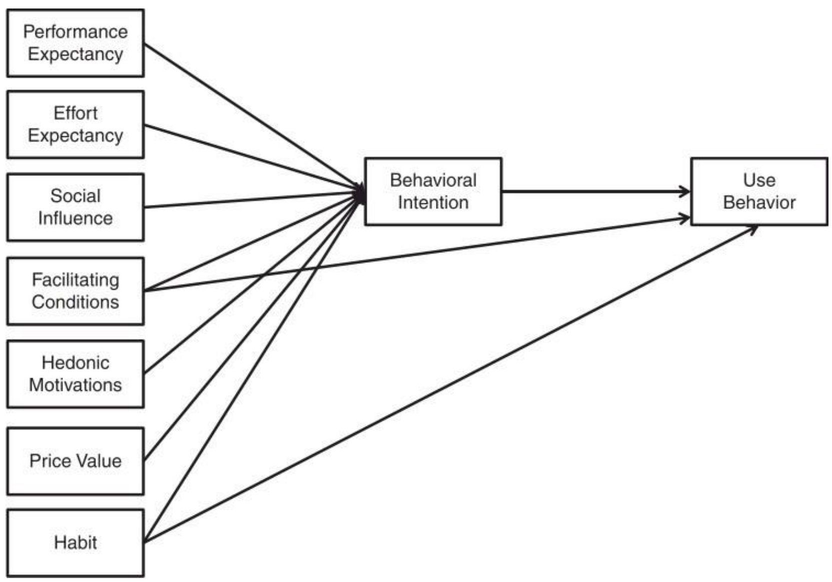

Figure 16: Unified Theory of Acceptance and Use of Technology 2

Source: Venkatesh et al., 2012 (p.160)

4.1.2 Evolution and Concept of TOE

Tornatzky and Fleischer developed the TOE framework in 1990. It identified three aspects of organisation that have an effect upon the adoption of technology:

1) Technological context
2) Organizational context
3) Environmental context (Tornatzky & Fleischer 1990)

Figure 17 below provides the technology, organisation and environment framework (Tornatzky & Fleischer 1990):

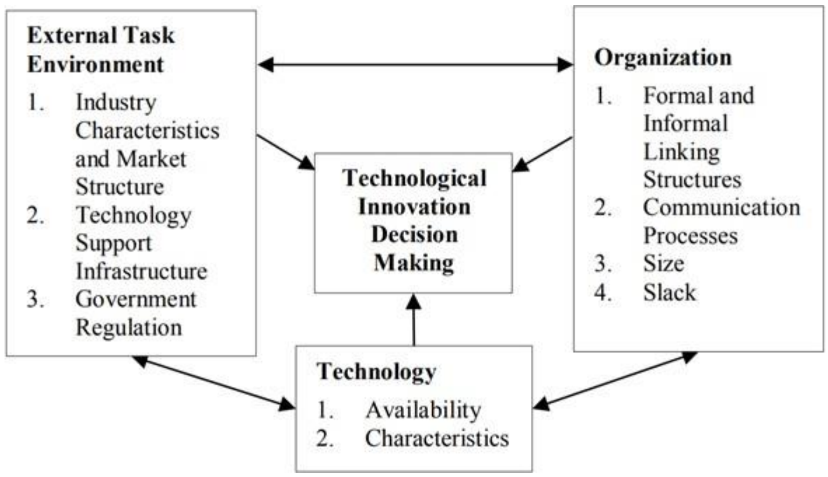

Figure 17: Technology, Organisation, and Environment Framework

Source: Tornatzky & Fleischer, 1990 (p.154)

The technology aspect of TOE considers the availability and characteristics of the technologies (Tornatzky & Fleischer, 1990). The technology aspect of DoI by Rogers (2003) is the same as in TOE(Roger, 2003). The organisational aspect identifies characteristics and resources of the organisation, including the size, structure and communication process (Tornatzky & Fleischer, 1990). In addition, the individual features, such as top management support, are not defined by TOE but this study will consider it as recommended by DoI theory (Asiaei & Rahim, 2017). Lastly, we will consider the environmental context, which explains the industry, competitors and governmental regulations related to the firms (Tornatzky & Fleischer, 1990). This includes trading partners' readiness, industry characteristics and market structure, government encouragement, and technology support infrastructures such as access to quality ICT consulting services (Al-Qirim, 2006; Jeyaraj, Rottman & Lacity, 2006). These three contexts provide the details regarding the opportunities and constraints for the adoption of technology innovation (Tornatzky & Fleischer,1990). TOE has been successfully integrated with other famous models such as DoI (Rogers, 1995), TAM (Davis et al., 1989) and it has also it has been applied successfully in several IT studies, such as RFID adoption (Wei, Lowry & Seedorf, 2015), e-business adoption (Zhu & Kraemer, 2005), electronic data interchange (Kuan & Chau, 2001), and information systems (IS) (Thong, 1999). The next section considers evolution of DoI theory as the main theory of this thesis in relevant context.

4.1.3 Evolution of DoI in Relevant Context

This section considers the evolution of DoI in relevant context. Several studies regarding the use of DoI found that relative advantage, compatibility and complexity significantly affect the use of technology, whereas the trialability and observability are less significant (Kapoor, Dwivedi, & Williams, 2014b). It was found that two features from Roger's (2003) five innovation attributes – observability and trialability - were the least used (Kapoor et al., 2014b). The reason for this is because trialability does not identify well as an innovation attribute with some specific studies, so it was therefore considered irrelevant; for example, a study undertaken on the adoption of ISO 9000 standards indicated that ISO 9000 was a whole system innovation that could not be pretested in parts (Hashem & Tann, 2007). A study on the adoption of distributed work arrangements (DWA) considered observability the least important attribute to the management, as theimpact of DWA was long term and the extent of their adoption was very limited (Sia, Teo, Tan, &Wei, 2004). In addition, trialability was eliminated because DWA required considerable organisational restructuring, making it impossible to reverse its effects (Sia et al., 2004).

Observability has received significant criticism within the literature. Moore and Benbasat (1991) argued that observability was complexly defined by Roger's (1983), and Tornatzky and Klein (1982) stated that it was unclear if the definition for observability was referring to cost or to compatibility. A few studies did not utilise trialability by reasoning that the level of diffusion of an innovation in significantly high already. For example, Li, Troutt, Brandy berry and Wang (2011) explained that the use of their online sales channel was at a level where most of the SMEs werewell educated about it being in use by most of their peer organisations. However, Roger's (1983) stated that trialability should be used only where early adopters were present, and peer adopters were not found. This is the case of IoT; Rijsdijk, Hultink, and Diamantopoulos (2007), in their study on product intelligence, stated that observability and trialability were less significant in comparison to Roger's (2003) other three attributes, and also that observability and trialability became insignificant when the consumers that had already gained experience of using an innovation were involved. But this is not the case with IoT adoption in Thailand.

Another observation is that many studies elected to cite the meta-analysis by Tornatzky and Klein (1982) in order to justify their use of only three of Rogers attributes: relative advantage, compatibility, and complexity out of the total five. There were many studies citing Tornatzky and Klein (1982), studies which concluded that these three attributes were consistently related to adoption and use behavior (Agarwal & Prasad, 1997; Agarwal & Prasad, 1998; Agarwal & Prasad, 2000; Carter and Belanger, 2004; Teo & Pok, 2003; Truman, Sandoe, & Rifkin, 2003). Furthermore, Yi, Jackson, Park, and Probst (2006), in their study on acceptance of IT innovations, also cited many studies from the literature (Agarwal & Prasad, 1998) to conclude that these three attributes were the only key innovation characteristics. However, numerous studies (Boyne, Gould-Williams, Law, & Walker, 2005; Hashem & Tann, 2007; M'Chirgui & Chanel, 2006; Zhu et al., 2006) chose to study the influence of these five attributes on adoption as the dependent variable. This thesis will utilise all the five factors from Rogers (2003).

Ramdani and Kawalek (2007) cite a number of studies in order to identify relative advantage as the most common characteristic influencing the adoption of IS innovations (Ramdani & Kawalek, 2007).They also cite even more studies to affirm that compatibility and complexity significantly determine IS innovations adoption in small business contexts (Ramdani & Kawalek, 2007).

In term of dependent variables, there have been various studies undertaken with regard to understanding the effects of Roger's (2003) innovation attributes concerning adoption intention as the dependent variable (Carter & Belanger, 2004; Sia et al., 2004; Van, Lou, Belanger, & Sridhar, 2010). The studies often, focused on the effect of innovation attributes on adoption intention, and then the effect of adoption intention on the actual adoption itself. There has been research that focuses on the effects of these innovation attributes about attitude, followed by the study of the influence of attitude upon the adoption intention, such as Agarwal and Prasad (2000) and Vishwanath and Goldhaber (2003). There have also been a number of studies embarked upon that strive to understand the effects that complexity and compatibility have on relative advantage as the dependent variable (Yang, Lay, & Tsai, 2006). Yang and Choi (2001) also looked at the effect of social influence on relative advantage, and ease of use as dependent variables. Furthermore, research has used compatibility as the dependent variable to better understand the influence of different attributes on this variable; for instance, Sia et al. (2004), in researching the operation of DWA in a complex environment, found that complexity had a significant negative impact on compatibility. Huh, Kim, and Law (2009), in their study on IS within hotels, found that complexity had a significant negative effect on relative advantage as the dependent variable. Moreover, Lee and Kim (2007) looked at the influence of various independent variables on implementation as a dependent variable on the internet-based IS. IS studies have also studied the effect of complexity, compatibility and relative advantage on attitude as a dependent variable; Agarwal & Prasad, 2000; Huang & Chuang, 2007). In contrast, Cho and Kim (2002), during their work on object-oriented programming languages, studied the influence of the same three attributes as Roger's regarding assimilation as a dependent variable. The following sections will consider the use of DoI theory in both developed and developing countries, manufacturing industries and SME sectors. Thereafter, discussion of the use of DoI theory, with a different model and with reference to recent technologies, will take place.

Diffusion of Innovation in Developed and Developing Countries

This section considers the characteristics of both developing and developed countries that have an affect upon the diffusion of innovation. First, we will look at the external factors, such as the economic and political environment, which is not the main concern for developed countries (Zanello et al., 2016), but for developing countries, political instability and weak law enforcements discourage both foreign investments and the opportunity of diffusion of innovation from abroad (Zanello et al., 2016). Moreover, diffusion of innovation in developing countries is also limited by weak interaction and cooperation between private and public sectors, such as universities (Zanello et al., 2016). Second, the efficiency and quality of communication, which depends not only upon the development of infrastructure, but also the geographical and cultural distance; this also has an effect upon innovation diffusion (Zanello et al., 2016). Developed countries, in contrast to developing countries, have efficient transport systems that can facilitate the movement of goods and knowledge diffusion (Zanello et al., 2016). Cultural differences, such as language and social and individual characteristics, also affect the diffusion of innovation (Zanello et al., 2016).

Third, the communications between firms (Zanello et al., 2016). There is less collaboration between organisations found in developing countries, as they typically have less diversified sectors, fewer large businesses and limited intra-firm workers mobility (Zanello et al., 2016).

The majority of businesses in developed countries are formal firms, whereas a large number of firms in developing countries are informal (Zanello et al., 2016). This creates the two levels of innovation diffusion, thus hindering the diffusion between two levels (formal and informal) (Zanello et al., 2016). Fourth, we have the internal factors within the firms, such as limited financial resources and a lack of advanced and specific skills (Gulati, 1999; Zanello et al., 2016). These constraints have a stronger impact on developing countries where the knowledge and financial gap are greater (Persaud, 2001).

Fifth, the nature of the innovation that determines the spread and speed of diffusion (Zanello et al., 2016). Where the technological gap between developed and developing countries is significantly large, better implementation of basic technologies can have greater impact within the developing countries than the adoption of new technologies (Prahalad, 2012). The low-tech innovations do not require many channels of transmission and capacity (skills and capital) (Persaud, 2001). Therefore, the diffusion in developing countries, which mostly implement low-tech innovations, tends to be faster than the diffusion of high-tech innovations in developed countries. Moreover, low-tech innovations are easier to diffuse within developing countries than between developing and developed countries, as is the case for imported innovation (Zanello et al., 2016). This is because developing countries may not have the capability to effectively utilize advanced innovation from host countries (Zanello et al., 2016). Furthermore, those advanced innovations may not address the needs of developing countries (Zanello et al., 2016).

Lastly, the characteristic of innovation adopters and innovation adoption in developing countries is influenced by the acumen and skills of entrepreneurs, which can be seen less than in developed countries (Zanello et al., 2016). Entrepreneurial skills and attitude, such as curiosity and a leaning toward personal relationships, are important factors in the diffusion of innovations (Zanello et al., 2016); in less structured establishments, innovation is driven by people with characteristics that make them overcome the constraints (Zanello et al., 2016)

To summarise, most firms within developing countries still have the capacity to increase their innovation advancement, so therefore small improvements in their activities can create greater impact than within developed countries. Given the current state of the capacity within the developed countries, low-tech innovations are more likely to be adopted and have greater chances of success. In addition, over the decades, ICTs have been spreading rapidly in most developing countries, allowing more reliable, and quicker, communications. This can create greater integration of private and public sectors, such as research institutes and universities.

The Use of Diffusion of Innovation Theory within SMEs

This section considers the diffusion of innovation within SMEs. For SMEs, individual decision processes are more relevant, as the owners are usually the primary decision-makers (de Guinea et al., 2005). The organisational decision processes - including agenda-setting, matching, re-inventing, clarifying and routinising - are less appropriate, because they assume that SMEs typically have formal structure, which is not true (Burke, 2005). By contrast, there is some argument that owner-decision might be influenced by family and employees (Parker & Castleman, 2009). Moreover, Roger's (2003) individual decision process does not consider how the knowledge is acquired (Rogers, 2003). The know-how about complex innovations is gained by experiencing the innovation directly when firms adopt innovation (Attewell, 1992). However, many firms do not have sufficient time and resources to experience the innovations (15: MacGregor & Vrazalic, 2007) and this problem can be solved by using change agents within Roger's (2003) DoI Theory (Parker & Castleman, 2009). Change agents create and build know-how, and they operate between innovation creators and potential adopters (Parker & Castleman, 2009); they provide services, which facilitate adoption and require minimal how-to knowledge, which, in turn, increases rate of diffusion (Parker & Castleman, 2009).

The examples of change agents are application service providers and internet service providers. In the context of the SME, DoI theory purely may not explain the adoption of innovation, as SMEs are part of multiple social systems; a family, a business network, a local community or an industry) (Parker & Castleman, 2009). They usually have different norms, behaviours and beliefs (Parker & Castleman, 2009). The DoI theory does not examine these complex social and relational dimensions (Parker & Castleman, 2009). Small firms' e-business adoption suggests the integration of DoI theory with the social network theory (SNT) which takes into account the structural, interpersonal and interaction aspects of a small firm's owner/manager's social network that influences their decision-making (BarNir & Smith, 2002).

Another example of papers that applied DoI theory to SME sector is the attributes of innovation adoption and its effects on the performance of Malaysian manufacturing SMEs (Mamun, 2018). The study argues that innovation behavior at the SME level should be categorised as authoritarian innovation behaviour by which is meant that the decisions are made by a few individuals who have power, or technical knowledge (Mamun, 2018). The finding suggests that all attributes from the DoI theory – relative advantages, compatibility, complexability, trialability and observability - affect the adoption of innovation in manufacturing SMEs in Malaysia (Mamun, 2018).

The Use of Diffusion of Innovation theory in Manufacturing Industries

This section considers the use of DoI theory within manufacturing industries, which is one of the predominant industries that use this theory. One example of the most recent studies about DoI in manufacturing is regarding the adoption of 3D printing technology within manufacturing (Schniederjans,2017). The results provide evidence that top-management adoption category impacts the potential speed of adoption (Schniederjans, 2017). The analysis suggests that individual characteristics of top management play a role in the impact that these perceptions have on the intention to adopt 3D printing in manufacturing (Schniederjans, 2017). Furthermore, there have been a number of studies undertaken regarding cloud computing; for instance, Low et al. (2011) used DoI to examine the adoption of cloud computing within a high-technology industry. However, they did not incorporate the key factors, such as cost savings and security concerns; these are essential factors to be considered by a firm when making the decision of whether or not to adopt cloud computing. Moreover, there are limited studies such as Oliveira et al. (2014) that validate the both the direct and indirect effects of the innovation characteristics and the technology, organisational and environmental contexts of cloud computing in manufacturing. A further study undertaken within the manufacturing context is e-commerce adoption in electronic manufacturing companies (Alam, Khatibi, Ahmad, & Ismail, 2007). Roger's five innovation diffusion characteristics were used as factors within the study, and security and confidentiality were considered as an additional factor (Alam et al., 2008). The result is that relative advantage and compatibility have a positive and significant influence on e-commerce adoption, whereas complexity and security have negative effects (Alamet al., 2008). This study also revealed a non-significant relationship between trialability and e-commerce adoption within manufacturing (Alam et al., 2008).

The Use of Diffusion of Innovation Theory With Different Models

This section considers the use of DoI theory with different models. DoI theory has been integrated with several models, such as TOE, task technology fit model (TTF), technology to performance chain (TPC), TAM, UTAUT and social network theory. A number of extensions, for example, firm antecedents - prior condition, knowledge and risk orientation, image, perceived risk, strategic orientation (such as consumer, market and entrepreneurship) and trust – have been integrated with DoI theory.

The Use of Diffusion of Innovation Theory in Most Recent Technologies

This section considers the use of DoI theory in most recent technologies. The example studies of DoI in most recent technologies are the Barriers to Innovation Diffusion for Social Robotics Start-ups (Wood, 2017), Diffusion of Surgical Innovations, Patient Safety and Minimally Invasive Radical Prostatectomy (Parsons, Messer, Palazzi, Stroup, & Chang, 2014), Adoption of 3D Printing Technologies in Manufacturing (Schniederjans, 2017) and Modelling Adoption Timing of Autonomous Vehicles (Shabanpour, Shamshiripour, & Mohammadian, 2018). There is minimal literature applying the DoI theory to IoT, which is the focus technology in this study. However, most of them are not robust; one study tried to determine the factors that need to be considered when adopting IoT by integrating DoI with a technology performance chain (combination of the utilization aspect and task-technology fit model). However, further research needs to be conducted in order to both verify the finding model and be able to generalize. A further study of DoI on IoT tried to understand the IoT diffusion focusing on value configuration of RFID and sensors (Hwang et al., 2016). However, the research undertaken was from business cases between the years of 2008 and 2012; IoT had not been implemented in the industries significantly as of that time. Therefore, there was distinct lack of research within the area of DoI theory on IoT. The next section will consider the determinants from DoI as the main theory of this thesis in relevant context.

4.1.4 The Determinants from DoI Theory in Relevant Context

This section considers the innovation determinant from DoI theories, mainly from Roger's

(2003) theory, as it is well established and the most utilised theory in the field of innovation (Greenhalgh et al., 2004; Légaré et al., 2008; Tornatzky & Klein, 1990). Roger's innovation determinants that are found relevant to IoT adoption are: relative advantage, compatibility, complexity, trialability and observability. Thereafter, the relevant innovation determinants from Tornatzky, Klein's, Moore and Benbasat's: cost, security and privacy risk, and image, which were developed after Roger's, will be analyzed. The detail of the innovation determinants in relevant context are as follow:

Relative Advantage

Relative advantage is defined as the degree to which a technology is perceived as being more effective and efficient than the current technology (Rogers, 2003). Previous studies demonstrated that relative advantage and PU from TAM model are closely related (Shin, 2015). Typically, the natural qualities of the technologies determine the specific type of relative advantage, for example, economic, social, convenience, and satisfaction (Rogers, 2003). Therefore, Rogers (2003) stated that relative advantage can be measured by economic benefit, convenience, increased efficiencies and prestige. Several studies have suggested that relative advantage can be divided into two concepts:

1) perceived usefulness
2) image (Karahanna, Straub, & Chervany, 1999; Mao & Palvia, 2006; Moore & Benbasat, 1991).

Moreover, Rogers (2003) stated that relative advantage is the strongest determinant to influence adoption of innovation. Relative advantage is found to be one of the important factors considered for SMEs to adopt technology (Alshamaila, Papagiannidis, & Li, 2013; Sin, Choy, Lin, & Cyril, 2009). McMullen, Griffiths, Leber and Greenhalgh (2015) claimed that relative advantage offers value to an organisation, such as process improvement and cost effectiveness; for example, a study by Chiu, Chen and Chen (2017) on broadband mobile application adoption showed that relative advantage is a predictor for adoption to take place, and Premkumar, Ramamurthy and Nilakanta (1994) found that relative advantage is an important factor in determining EDI adoption within an organisation. The adoption of IoT offers superior functionality and increased efficiencies for organisations and employees alike (Balaji & Roy, 2016), and IT managers should consider adopting IoT because of its relative advantage (Kamin, 2017). Ahsan, Talib, Sarwar, Khan, and Sarwar (2016) state that several organisations should adopt IoT, because the existing technology may not be able to solve problems.

For most businesses, gaining benefits from IoT is the most important factor that incentivizes them to invest in projects (Christensen & Huang, 2018). In the IoT context, relative advantage is pertinent to an activity that can enhance existing products/services, enable competitive advantages and gain efficiency, which would be easier with IoT (Christensen & Huang, 2018). For manufacturing firms, one of the relative advantages of IoT is that it tracks the individual users and targets them based on information supplied by the devices (Gao & Bai, 2014). It can offer more complicated and real-time information to managers within the workplace, enable agility in the autonomous process and connect assets to the centre network. Industrial IoT can provide benefit to businesses such as higher productivity, reduced downtime and predictive maintenance (Whitmore et al., 2014; Li, Hou, Liu, & Liu, 2012; Bandyopadhyay & Sen, 2011). It has also been found that relative advantage is one of the important predictors for the adoption of technology within SMEs (Alshamaila et al., 2013; Sin Tan et al., 2009). In summary, further study of relative advantage is required with regards to IoT within manufacturing SMEs in Thailand.

Compatibility

Compatibility refers to how well the business integrates new technology with current practice, or value systems (Rogers, 2003). Several studies confirmed that compatibility is positively related to the adoption of technology and negatively related to complexity in DoI theory (Shin, 2015; Rogers, 2003; Sinha & Mukherjee, 2016). Compatibility can be defined as a measure of consistency between existing values, past experiences, and requirements (Rogers, 1962). Existing values can be norms, strategies, goals, or best practices (McMullen et al., 2015). An example of existing value is a business having skilled employees, who are sustained with technology adoption (Sung & Choi, 2014). Past experience is the accumulation of the adopter's past experience with the technology (Roger, 1962) and it is correlated with the adoption. Finally, the requirements refer to the needs of the businesses regarding the adoption of new technology (Gluhak et al., 2011). There are many studies (Premkumar, 2003; Daylami et al., 2005; Zhu et al., 2006; Sophonthummapharn, 2009; Ghobakhloo et al., 2014) that support the theory that compatibility is an important factor with regards to the adoption of technology. Indeed, previous studies have found that compatibility plays an important role in determining the user's perception regarding communication-oriented services (Islam, 2016). The existing technological infrastructure and its ability to easily integrate with IoT systems (Rosas, Brito, Brito Palma, & Barata, 2017; Tornatzky & Fleischer, 1990) is another critical determinant. IoT infrastructure comprises five elements:

1) Access Technologies
2) Platforms
3) DataStorage & Processing
4) Security and Data analytics (Leuth, 2015)

It is vitally important for the manufacturing industry that IoT be implemented effectively (Whitmore et al., 2014; Chan et al., 2012). The IoT consists of a myriad of networks made up of unique objects based on a set of communication protocols (Shin & Jin, 2017). Therefore, because there are a number of various different standards, compatibility between the communication standards can be somewhat difficult (Shin & Park, 2017). This means that compatibility provides the manufacturing industry with a critical challenge with regard to IoT adoption (Gubbi et al., 2013).

Compatibility of IoT involves sensors, networks and applications from different suppliers, which are important factors to consider if IoT adoption is to be implemented (Haddud, DeSouza, Khare, & Lee, 2017). Compatibility is essential for bringing together various data sets and for developing IoT (Shin & Park, 2017). Open standards set a framework for data that can be joined across organisational boundaries (Shin & Park, 2017). One of the issues that was found within the IoT system was that it failed to communicate between IoT devices, and this can hinder the IoT adoption process (Stočes, Vaněk, Masner, & Pavlík, 2016). Furthermore, compatibility can minimise the switching cost from traditional systems to new IoT system (Asimakopoulos, G., & Asimakopoulos, S., 2014). The IT managers within the businesses need to consider compatibility as a critical determinant for IoT adoption as compatibility affects the functional requirements and is instrumental in security, privacy and reliability strategies that play an important part in successfully adopting the IoT devices (Kamin, 2017). Compatibility between systems and applications are an important aspect of IoT devices because compatibility is required to make the transition from previous technology to the IoT system (Islam et al., 2015: p4). In addition, the integration of various networks of IoT would require new security, privacy and reliability standards (Jing, Vasilakos, Wan, Lu, & Qiu, 2014). In summary, further studies on compatibility in IoT adoption are required within manufacturing SMEs in Thailand.

Complexity

Complexity is defined as the degree of difficulty that an innovation is perceived to have with regard to both understanding and using it (Rogers, 2003). Rogers (1962) stated that complexity depends on the level of knowledge and expertise of an organisation. In addition, familiarity may be one of the reasons that complexity negatively relates to the adoption (Kamin, 2017. Frambach, Barkema, Nooteboom and Wedel (1998) stated that perceived complexity negatively affects the adoption of service technology and in the study of mobile banking services, Chen (2013) found that users are reluctant to use the service if they need to use more mental effort than they do for the existing service. A further study is the perceived complexity of e-government, which is found to be a significant factor hindering the intention to use (Lean, Zailani, Ramayah & Fernando, 2009). Furthermore, Brumec (2006) foundthat complexity had a direct negative influence with regard to the intention of adopting the internet.

For the IoT, complexity is measured by usability, learnability and utilization of the technology/devices (Penjor & Zander, 2016). Boos, Guenter, Grote, & Kinder (2013) refer to the complexity of IoT as the degree of control needed to achieve accountability at organisations. Complexity might be a critical factor for technology that requires a high learning curve (Kamin, 2017), which it does in the case of IoT; IoT may require a high learning curve for both end users and IT resources (Kamin, 2017). As the development of IoT devices is high and the functionalities are varying, the complexity will increase (Bi, 2017). Moreover, the variety of IoT devices raises the complexity during product selection and planning (Zhong, Xu, & Wang, 2017). In addition, more complex technology, such as IoT, will require more time for businesses to adopt and adjust their existing business model or product (Christensen & Huang, 2018). All this complexity arising from the IoT has a negative effect upon adoption (Haddud et al., 2017). Several studies demonstrated that IoT capability requires further effort in order to control it, because of the automation aspect of the technology (Kamin, 2017). Therefore, as the complexity of IoT is high, making adoption difficult, businesses need to consider decreasing the complexity of IoT before they adopt it (Safari, Safari, & Hasanzadeh, 2015). Furthermore, IoT may be difficult to integrate, maintain or upgrade due to the complexity of it (Kamin, 2017). The adoption of IoT for smart cities has demonstrated that IoT infrastructure is both complex and risky, as the security and reliability are vulnerable (Kamin, 2017). The executives within the businesses must have strategies to decrease complexity and reduce the risk caused by IoT (Sanchez et al., 2014). In summary, further studies on complexity in IoT adoption are required within manufacturing SMEs in Thailand.

Trialability

Trialability is the degree that an innovation is experimented upon, within a limited basis, to test its qualities, understand how it works and assess its usefulness before adoption takes place (Roger, 2003). Trialabilityis positively correlated with technology adoption (Pashaeypoor, Ashktorab, Rassouli, & Alavi-Majd, 2016; Rogers, 2003). Technology that can be tested and costs nothing, or very little, is likely to be rapidly adopted (Chiyangwa & Alexander, 2016; Rogers, 2003). In addition, the more that the technology is tested, the more the adopter will become confident about it's strengths and robustness (Savoury, 2013). In an organisation, technology may be tested to analyse feasibility before presenting a business case to top management (Hsu & Yeh, 2016; Shin & Jin Park, 2017).

Organisations that can test the technology before adoption takes place may see both the benefits and the risks in advance (Kamin, 2017). Trialability enables organisations to plan for the features and risks alike, and to discern if there is benefit to be gained (Fang et al., 2015). Several studies undertaken have indicated that trialability decreases uncertainty about adoption of techonology (Wang, 2014). In the software industry, users can install software called 'trialware' for a limited time to learn about the functionality before purchasing it if they feel that it is useful (Li & Cheng, 2014). In addition, Trialability also enhances the confidence of employees within hospitals and this will lower the risk of them making mistakes (Hayes, Eljiz, Dadich, Fitzgerald & Sloan, 2015). Furthermore, Lee, Hsieh,and Hsu (2011) found that trialability significantly affects the employees' intention to use the e-learning systems. Odumeru (2012) claimed that trialability is an important factor that can be positively correlated with the attitude towards online learning technology.

In the context of IoT, trialability may play an important role when planning to adopt the technology within a business. However, Sanchez et al. (2014) state that IoT experimentation is difficult to conduct, as IoT architecture is complicated and both hardware and software resources are required. A study on cloud adoption within SMEs found that trialability affects the decision positively (Alshamaila et al.,2013 and. IoT may change an organisation's infrastructure, especially if the current systems are incompatible with IoT (Boo et al., 2013). Organisations may be reluctant to adopt IoT because they feel it may disrupt their business (Islam et al., 2015). Therefore, trialability may be important for organisation IT managers when consider adopting IoT (Kamin, 2017). The opportunity to test IoT security, reliability and privacy issues may decrease the risk for an organisation (Kamin, 2017) and the IoT adopter may value the innovation. However, they will realise the benefit only when the technology is successfully integrated with systems that are already in place within the organisation's infrastructure (Atzori et al., 2010). In summary, further studies on trialability in IoT adoption are required within manufacturing SMEs in Thailand.

Observability

Observability is the degree to which the result of adopting a technology is visible to others (Rogers, 2003). Moore & Benbasat (1991) stated that observability could be divided into two constructs: visibility and result demonstrability. Observability helps to ensure that a technology will provide benefits to an organisation (Ju, Kim, & Ahn, 2016) and it can be positively correlated with technology adoption (Rogers, 2003; Wang & Wang, 2016). Visible results may provide evidence to stakeholders, especially the top management within the firms, that the technology is indeed beneficial.

Therefore, observability helps promote the technology to stakeholders while they are making the decisions (Kamin, 2017). When the usefulness and reliability of a technology can be demonstrated, the uncertainty is removed and the adoption process is faster (McMullen et al., 2015). In the study of technological products, Vishwanath and Goldhaber (2003) found that observability significantly affected the intention to adopt. There have been several past studies of the observability factor upon technologies, such as agricultural technology (Ajili, Salehi, Rezaei-Moghaddam, Hayati & Karbalaee, 2012) and mobile banking technology (Al-Jabri & Sohail, 2012). In contrast, several previous studies have indicated that observability did not significantly impact the technology adoption (Kamin, 2017). Kapoor et al. (2014a) reviewed 226 innovation articles and found that only relative advantage, compatibility and complexity had any influence regarding the adoption.

In the context of IoT, organisations need to observe the IoT to ensure that its benefit is in alignment with their objectives (McMullen et al., 2015). Furthermore, Sanchez et al. (2014) state that firms may consider observing IoT adoption within other oganistations that have adopted the technology and see how it provides value to those businesses.

The successful implementation of IoT within organisations is easier to observe than the individual experimentation with IoT, due to the limitations upon revealing the data in this competitive environment (Nysveen & Pedersen, 2014). It is crucial for IT manager to observe a successful result of IoT adoption so that they can be confident about the security, privacy and reliability of the technology (Kamin, 2017). In summary, further studies on observability in IoT adoption are required within manufacturing SMEs in Thailand.

Cost

Perceived cost is defined as the concerns a business may have regarding the costs of buying, using and repairing a system or service (Shin, 2009). There are several studies regarding the relationship between the user perception on innovative and recent services, and cost (Park et al., 2017). For instance, cost is found to be a significant influencing factor of e-commerce adoption within SMEs (Riemenschneider &McKinney, 2002; Pearson & Grandon, 2005). Al-Debei and Al-Lozi (2014) found a significant connection between economic value and the adoption of a wireless service. Moreover, 3G, which is one of the main components of IoT, had undergone slow adoption in the past and this was due to the cost (Ong, Poong & Ng, 2008). For the IoT technology, several studies have found that cost is a significant factor in determining whether adoption of IoT should be implemented (Al-Momani et al., 2016; Chong & Chan, 2012; Chao & Lin, 2017; de Panizza, Lindmark & Rotter, 2010). The implementation of industrial IoT requires infrastructure such as middleware and a network of cloud-based data center (Sivathanu, 2019). The indirect cost of training people to use industrial IoT and the cost of executing the technology are necessary for the businesses (Love & Irani, 2004). In addition, Kim and Shin (2015) found that the cost significantly affects the adoption of IoT services in Taiwan, and furthermore, Acquity Group (2014) demonstrated that one of the most predominant concerns for users of the IoT service in the US is the cost. However, a study by Nikbin and Abushakra (2012), on consumer acceptance, found that price value does not significantly affect IoT adoption intentions; users feel that IoT services may not be costly and it is not a major factor, and this contradicts the findings of several past studies. In summary, further studies on the cost of IoT adoption are required within manufacturing SMEs in Thailand.

Security and Privacy Risk

Security and risk is defined as the degree to which the use of applications/systems will be risk-free (Shin, 2015). Hsu and Lin (2016) also divide these concerns into four dimensions: collection, unauthorized secondary use, improper access and errors. Berdykhanova, Dehghantanha and Hariraj (2010) state that transaction security is a concern of users when they undertake online activities. To increase the adoption rate and the level of IS usage, users need to feel safe when interacting with systems (Alghamdi & Beloff, 2014). Therefore, there should be a clear contract between users and providers that states the liability and privacy-preserving guidelines (Hsu & Lin, 2016). In the case of IoT systems, IoT security concerns are from the embedded connected devices found within network heterogeneity (Sahraoui & Bilami, 2015; Xu, Qu & Yang, 2016). The weaknesses of the IoT systems may be insecure web interfaces, software and firmware vulnerabilities, and a lack of transport encryption (Airehrour, Gutierrez & Ray, 2016). The security and privacy concerns include data protection, organisation, and system security (Tao et al., 2014; Medaglia & Serbanati, 2010; Chen et al., 2014; Chan & Chong, 2013; Weber, 2010; Oliveira & Martins, 2008). The most extreme presentation of a security risk is that of a cyber-attack; cyber criminals taking control of physical devices (Weinberg, Milne, Andonova & Hajjat, 2015). In addition, service providers may access and use information without permission (Hsu & Lin, 2016).

The current studies considering IoT security are mostly regarding a person's comprehensive sense of security and well-being within the IoT environment (Shin, 2013). In the US, lack of security and privacy are the barriers preventing the adoption of the IoT services (Acquity Group, 2014). In addition, they affect the willingness to provide information for IoT services, thus they cannot fully utilise the system (Kowatsch & Maass (2012). In the UK, Coughlan et al., 2012 found that privacy and security are critical factors to be considered when planning on implementing IoT throughout the country. Specifically for the manufacturing industries, security is one of the critical components of IoT infrastructure and it is of major concern for the firms (Sivathanu, 2019). Several studies regarding IS and IoT mention the concerns about data security, institution and system security (Tao et al., 2014; Medaglia & Serbanati, 2010; Chen et al., 2014; Chan and Chong, 2013; Weber, 2010; Oliveira & Martins, 2008); for example, Saedi and Iahad (2013) found that security and privacy are adoption factors that need to be considered for cloud computing within SMEs. Evans (2015) stated that privacy concerns are one of the major concerns when considering adoption of the IoT. In addition, Kshetri (2014) stated that security concerns are a key barrier that hinders adoption of new big data, which is a significant part of the IoT system. In summary, further studies regarding relative advantage are required within manufacturing SMEs in Thailand.

Image

Image is defined as the degree to which the use of a technology is implemented to enhance image or status in a social system (Moore & Benbasat, 1991). This attribute is positively related to technology adoption (Moore & Benbasat, 1991). Rogers (2003) stated that image significantly motivates individuals to adopt an innovation in order to gain social status. Therefore, image should be included as one of the innovation determinants. There have been many studies undertaken - such as a study on mobile internet (Hsu, Lu, & Hsu, 2007) and internet banking (Gounaris & Koritos, 2008) - that show how image positively affects technology adoption intention. As IoT has been identified as a trendy emerging technology, IoT can help businesses to promote their identity as a creative and innovative firm (Christensen & Huang, 2018). If a firm perceives IoT as a consistent technology with their organisational value and culture, they can enhance their image by naturally adopting IoT (Christensen & Huang, 2018). For the industrial sector, of which firms often promote their unique attributes and specialties of the products or services, adopting IoT can both enhance the image of a business and distinguish the business positively from their competitors (Christensen & Huang, 2018).

In summary, further studies regarding image are required within manufacturing SMEs in Thailand.
The next section considers the determinants from TOE as the main theory to strengthen DoI theory within this thesis.

4.1.5 The Determinants from TOE Theory in Relevant Context

This section considers the determinants from TOE theory. Existing technology systems may need to change when adopting new technology such as IoT, and therefore different aspects of the technology context will be analyzed. The technology context in TOE is based upon the same idea as DoI (Oliveira et al., 2014). In this thesis, eight factors that have been found to be significant in relevant context are included in the technology element: relative advantage, compatibitliy, trialability, observability, security and privacy risk, cost and image. Organisational context refers to descriptive measures about the organisation (Tornatzky & Fleischer, 1990), including top management support, organisational readiness, organisational structure and size. The external pressure is referred to as the degree of which the same industry of business partners affects the technology adoption within a firm (Tornatzky & Fleischer, 1990). It is not only the influence from business partners; competitive pressure and technology support from vendors are also significant factors of external pressure (Hsu et al., 2014). Several studies concerning IoT have demonstrated the impact of external pressure on organisational intention to adopt this technology (Matta, Koonce & Jeyaraj, 2012; Chong & Chan, 2012; Pan, Nam, Ogara & Lee, 2013; Lin, Lee, & Lin, 2016). The details of the determinants from TOE theory in relevant context are as follows:

Top Management Support

Top management are the key decision-makers concerning investing in, and adoption of, technology; it is a critical antecedent of adoption intention within businesses (Daylami et al., 2005; Jeyarajet al., 2006). Top management allocates resources for the adoption of new technology (Vahtera, 2008). Seyal et al. (2007) found that management support is one of the significant predictors that have influenced SMEs to adopt IT. Tushman and Nadler (1986) identified six methods that top management can use in order to foster technologies; first, they can create and communicate the organisation's strategy and core value by incorporating the innovation into the strategy (Tushman & Nadler, 1986). Secondly, they are the role models for their employees within the organisations; they are able to send out messages pertaining to how important technology is to their subordinates (Tushman & Nadler, 1986). Third, they can reinforce the technology by using both formal and informal rewards (Tushman & Nadler, 1986). Fourth, they can create an innovative culture by emphasizing the competitive condition (Tushman & Nadler, 1986). Ultimately, they can re-shape the executive team so that they may have the correct conceptual and technical skills for their tasks (Tushman & Nadler, 1986). Lastly, they set up a clear vision strategy and direction on innovation (Tushman & Nadler, 1986). Chan and Chong (2013) found that top management support is an important factor for mobile supply chain management systems that are considering adoption. For the IoT, top management support is crucial, as IoT will have a great impact on organisation, and top management are the staff within a business who will decide how to implement IoT (Vukicevic, 2018). Top management guides the allocation of resources for IoT adoption, the integration of service and the re-engineering of process within the organisations (Hsu & Yeh, 2016; Wang & Wang, 2016). Without the top management support, the organisation may resist adopting IoT (Wang & Wang, 2016). In summary, further studies regarding the behavior of top management are required within manufacturing SMEs in Thailand.

Organisation Readiness

Prior studies that have been undertaken on IS adoption found that organisational readiness affects the adoption of IS technology (Jedermann & Lang, 2008). For example, Hsu and Yeh (2016) found that IoT adoption within Logistics in Taiwan is significantly affected by organisational readiness. Generally, businesses are required to have surplus of resources for innovations (Depietro, Wiarda & Fleischer, 1990). The gap between their total resources and their total required expenditure is defined as the slack of an organisation (DePietro et al., 1990). There are two types of organisational slack; financial and human resources (DePietro et al., 1990). Human resources are required to adopt an innovation, but can also be employed if there is sufficient financial slack (DePietro et al., 1990). Usually, organisational slack is dependent on the priority of the organisation (DePietro et al., 1990). If the organisations view particular technologies as being important - such as IoT - they may allocate some slack from other departments to the IT department (DePietro et al., 1990). The organisation should be informed regarding specific technology and assess the opportunities of them by cleaning information from early adopters (DePietro et al., 1990). Cyert and March (1963) stated that SMEs typically have less available resources than large businesses, indicating that they have been late to invest in this new technology.

Furthermore, firms that tend to be data-driven and have adopted the IoT system may be required to develop knowledge and skills for their employees (Bughin et al., 2015; Holdowsky, Mahto, Raynor, & Cotteleer, 2015; Manyika et al., 2015; Papert & Pflaum, 2017). Currently, very few organisations have sufficient knowledge about IoT and the use of it (Ericsson, 2015). The analytic advantage that IoT provides is another challenge (Bughin et al., 2015; Manyika et al., 2015; Risteska Stojkoska & Trivodaliev, 2017) as IoT may generate a lot of data, but it is usually limited to control and monitoring (Manyika et al., 2015). Some organisations lack understanding of the potential use of data (Ericsson (2015) and therefore cannot convert the data to provide a meaningful insight. In addition, businesses require algorithms in order to make decisions whereby managers set policies and monitor metrics (Ericsson, 2015). This lack of knowledge is evident, even in top management positions (Ericsson, 2015). Wainwright, Green, Mitchell & Yarrow (2005) emphasized that managerial ICT skills, ICT knowledge, and ICT practices are important determinants of IT adoption intention by SMEs and Ndubisi and Jantan (2003) found that computing skills and technical backing are a critical factor pertaining to the perception of usefulness in Malaysian SMEs. The businesses within industry or geographic regions with high quality and low cost suppliers of technology-related training and consulting, have more option and flexibility concerning the technology. The knowledge factor has been proved to be significant by Vukicevic (2018) and Ericsson (2015) stated that in order to close the knowledge gap, firms should provide training to staff, recruit IoT talent, or use external IoT consultants. Vukicevic (2018) stated that there is almost zero chance that one firm will manage to implement all aspects of IoT; the firms should therefore create a stable ecosystem in which enterprises collaborate together on their IoT projects Vukicevic (2018). Most businesses trust the potential of IoT, but are unable to determine its true value (Ericsson, 2015; Wang, Zhang, & Lin, 2013). This is mainly due to a lack of knowledge regarding the project (Ericsson, 2015; Wang, Zhang, & Lin, 2013). Some organisations will wait until they see competitor movement, customer demand, or regulations. This can increase the risk of competitors taking over the market (Ericsson, 2015) and Vukicevic (2018) stated that IoT can increase existing competitive advantages. It is important for businesses to understand what impact IoT can have on the whole value chain of the industry and on the organisation itself (Vukicevic, 2018). The firms can determine how they will fare with regards to market positioning, marketing mix and strategy (Vukicevic, 2018). Furthermore, organisations should ask these three questions of themselves; should I invest now, or wait, should I invest big or small and should I develop internally or externally? (Vukicevic, 2018). In summary, organisational readiness is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Organisational Structure

Burns and Stalker (1961) found that organisations that are more flexible and have changing conditions adopt technology more readily than organisations that have stable conditions and set rules. Furthermore, Burns and Stalker's (1961) study found that formalisation (more rules and specific procedure) and centralisation have a negative effect on the adoption of technology. This is supported by Rogers (1983) who posited that system openness (the linkage degree between members of a system and others that are external to the system) has a positive relationship with the organisational innovativeness. Regarding IoT, Ericsson (2015) found that traditional governance structures are likely to deny IoT adoption and this is evident from the study by Vukicevic (2018); this study showed that IoT required significant organisational change, particularly for large firms because they are not dynamic and are more likely to be resisted by stakeholders. IT departments need to become involved and collaborate with many other departments (Bughin et al., 2015). For instance, departments may be required to change from office automation to a critical part of the product development within manufacturing (Vukicevic, 2018). In summary, organisational structure is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Organisational Size

DePietro et al. (1990) and Rogers (1983) state that the size of an organisation is one of the most crucial factors with regards to adopting technology. Vukicevic (2018) distinguish the larger firms from SMEs regarding the adoption of IoT; larger firms usually have an R&D, or strategy department, which routinely researches what future innovations are they are likely to come into contact with (Vukicevic. 2018). Furthermore, larger firms have more of an advantage than the smaller firms because they have more resources and can take increased risks relating to technology adoption (Carcary, Doherty, Conway, & McLaughlin, 2014); management then has to make decisions on what to do with the findings of R&D. This is often a critical issue for large businesses, as adopting IoT will not only require significant organisational change (Vukicevic, 2018), it will create a great impact within the larger businesses. In contrast to the larger firms, SMEs typically find new technologies only when the market confronts them (Vukicevic, 2018). Even though SMEs are more adaptable and the people working on technological innovations work closely to operational work (Vukicevic, 2018), they do not have sufficient resources and knowledge to readily adopt emerging technologies such as IoT (Carcary et al., 2014). Furthermore, Vukicevic (2018) found that the organisational changes within large businesses also happens within SME's; SMEs are more flexible but are mostly less effective in handling changes (Vukicevic, 2018). In summary, organisational size is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Competitive Pressure

Competitive pressure is the degree to which the firm perceives their competition within the industry (Oliveira & Martins, 2010). The organisation should be agile and adaptable in order to respond to competitive pressures (Mourtzis et al., 2016). An organisation that fails to innovate typically expands less and will often fail (Rosas et al., 2017; Taneja, Pryor & Hayek 2016). Prior studies have found that competitive pressure affects the intention to adopt technology within an organisation (Raymond and Uwizeyemungu, 2007; Wang et al., 2010; Leminen et al., 2012; Chan and Chong, 2013). Organisations adopt IoT in order that they may become more competitive (Rosas et al., 2017). Hsu and Yeh (2016) found that the competitive pressure affects the adoption within logistical firms. This competitive pressure therefore has a positive influence on IoT adoption. In summary, competitive pressure is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Technology Support from Vendors

Prior studies have demonstrated that the IoT support from the industry affects the decision to adopt the technology within a firm (Bassi & Horn, 2008; Chen, Zhang, & Zhang, 2010). Implementation of new IS within SMEs typically demands expertise and support from vendors (Thong, 1999). In addition, it is found that support from technology vendors positively influences the adoption of IS within SMEs (Al-Qirim, 2007; Mirchandani & Motwani, 2001; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011). Approximately 40 per cent of the value of IoT requires communication and data integration between different IoT systems (Bughin et al., 2015; Manyika et al., 2015). The entire ecosystem of an organisation needs to be integrated (Bughin et al., 2015). Therefore, for IoT implementation, manufacturing SMEs require support from the IoT vendors. However, for the SMEs, it would be difficult, as they do not have power to enforce this with their IoT vendors (Bughin et al., 2015). In summary, technology support from vendors is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Business Partners Influence

The business partners may affect the technology adoption within a firm (Premkumar et al., 1997). Furthermore, DePietro et al. (1990) state that dominant players in the market can occasionally dictate what technologies should be used by the enterprises that work for them. In the case of manufacturing SMEs (OEM), in which some of their customers are dominant players, the influence or pressure would affect the technology adoption intention. In summary, business partners' influence is required for further study in IoT in manufacturing SMEs in Thailand. The next section considers the determinants from related theories and relevant literature.

4.1.6 The Determinants from Related Theories and Relevant Literature

This section considers the determinants from related theories and from relevant literature. For IoT to be accepted, two models have been widely referred to and used: UTAUT by Chong et al. (2015) and TAM by Gao and Bai (2014). These models provide a clear explanation about the determinants of IoT adoption by users (Lu, Papagiannidis, & Alamanos, 2018). The next section will provide details of relevant factors from these two alternatives, as well as the relevant factors from the literature. The detail of the determinants from related theories and relevant literature in relevant context are as follows:

Perceived Usefulness

Acceptance studies mostly use the intention of the users and behaviour towards IoT as dependent variables, and perceived usefulness is one of the most widely used determinants, first being proposed byTAM (Gao & Bai, 2014). One of the main reasons that hinder the adoption of IoT technology applications may be the failure to communicate its clear benefit to potential users (Gao & Bai, 2014). In the context of TAM, this view is reflected by the perceived usefulness (Gao & Bai, 2014). In addition, perceived usefulness is similar to performance expectancy of the unified UTAUT and the relative advantage of DoI (Venkatesh et al., 2003, 2012). It refers to the users' feelings of improved performance when they use the technology (Gao & Bai, 2014). IoT offers many potential benefits for companies, such as vertical and horizontal integration, decentralised IoT-based factory automation, managing the factory unit remotely, reducing the need for intermediaries advanced facility management, enabling autonomous warehousing and mass customization (Shin & Jin Park, 2017). Therefore, the perceived usefulness of IoT technologies is likely to be high (Gao & Bai, 2014). Evans (2015) found that the barriers that hinder the successful adoption of the IoT are the use of big data (Al-Momani, Mahmoud, & Ahmad, 2018a). However, the majority of studies support the positive effect of perceived usefulness on the intention towards technology adoption (Shin & Jin, 2017). For instance, Kim and Shin (2015) investigated the intention to use smart watches and the findings show that the quality and relative advantage of smart watches are found to be associated with perceived usefulness (Al-Momani et al., 2018). Furthermore, Acquity Group (2014) found that one of the most important factors for the adoption of IoT services in US is the usefulness of the technology (Al-Momani, Mahmoud, & Ahmad, 2016). Likewise, Coughlan et al. (2012) suggested that perceived usefulness is a significant determinant of the intention to use IoT services in the UK (Al-Momani et al., 2016). The TAM indicates that perceived usefulness is a significant determinant of behavioural intention to use IT (Davis, 1989; Hart & Porter, 2004; Lee et al., 2012; Lu & Su, 2009; Song et al., 2008). In summary, perceived usefulness is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Ease of Use

Perceived ease of use is one of the most used determinants in an acceptance study, first purposedby TAM (Lu et al., 2018). Perceived ease of use is similar to effort expectancy of UTAUT and the complexity of DoI (Venkatesh et al., 2003). It is concerned with users' perceived effortswhen using the IoT technologies/services (Gao & Bai, 2014). For potential IoT users to adopt IoT, they need to feel that IoT is easy to use (Gao & Bai, 2014). Extensive previous studies state that perceived ease of use is a significant determinant of behavioural intentions towards the technology (Davis, 1989; Davis et al., 1989; Lee, Park, Chung, & Blakeney, 2012). Users may consider adoption of IoT based on how easy and convenient it is to use (Shin & Jin, 2017). IoT requires technologies for processing and analysing large amounts of heterogeneous data. An organisation may consider that IoT is either easier or more difficult to use depending on the degree of knowledge the organisation itself possesses about the use of technologies (Shin & Jin, 2017). Furthermore, according to TAM and UTAUT, perceived ease of use also positively affects perceived usefulness (Kuo & Yen, 2009; Lee et al., 2012; Venkatesh et al., 2012). In summary, perceived ease of use is ready to undergo further studies with regards to IoT within the manufacturing SMEs in Thailand.

Experience

Prior studies indicate that previous experience is a significant predictor variable, or moderate variable of technology adoption (Speier & Venkatesh, 2002). The experience influences the IS adoption intention through perceived usefulness (Dong et al., 2017). Previous experience can be either a cognitive experience or an affect experience (Rose, Clark, Samuel & Hair, 2012). Specifically, cognitive experience involves the inner workings of thinking and mentality and the affect experience involves personal emotional systems or feelings (Dong et al., 2017). Users who have more experience know how to utilise the systems more effectively and reduce risk in the future (Dong et al., 2017). In the case of IoT, cognitive experience strengthens the relationship between perceived ease of use and perceived usefulness and undermines the relationship between perceived privacy risk and perceived usefulness, as the knowledge about IoT systems enhances both usability skills and the capability of reducing risks (Dong et al., 2017). The affect experience undermines the relationship between perceived privacy risk and perceived usefulness (Dong et al., 2017). In summary, the effect of experience is ready to undergo further studies with regards to IoT within the manufacturing SMEs in Thailand.

Social Influence

Social influence is defined as the users' perception of whether other important people believe that the users should be utilising the technology (Chong et al., 2015). It is similar to Subject

Norm in TRA theory (Venkatesh et al., 2012). When evaluating the acceptance of technology, social influence should be included (Williams, Rana, & Dwivedi, 2015; Gao and Bai, 2014). The social context of the decision-maker within the business is important to the decision process (Hse & Lu, 2004), especially for technology that is still in an early stage of development or diffusion (Gao and Bai, 2014), including IoT. This is because they still have insufficient amounts of reliable information regarding the usage details. Therefore, the opinions of social network influences individual evaluation of the technology (Gao & Bai, 2014). Allowing the users to experience the products/technology may help them increase the perceived ease of use and perceived usefulness (Bao et al., 2014). Social influence has been studied in several IS fields (Gao & Bai, 2014). Davis et al. (1989) emphasized the importance of social influence upon IT acceptance and usage behavior. A study by Nikbin and Abushakra (2019) found that social influence significantly affects IoT adoption. It means that when competitors have adopted IoT, entrepreneurs will have a higher intention to adopt the technology (Nikbin & Abushakra, 2019). For IoT, influence from peers, family or media might affect the users' intention to adopt the technology (Gao & Bai, 2014). Gao and Bai (2014) found that social influence significantly affects the behavioral intention to adopt IoT service. In summary, social influence is ready to undergo further studies with regards to IoT within the manufacturing SMEs in Thailand.

Performance Expectancy

Performance expectancy refers to the expected benefits and usefulness of IoT within organisations (Peņicina & Kirikova, 2013). The performance expectancy of IoT is improved integration and connectivity, as IoT can connect different devices through embedded sensor and actuator networks (Caron, Bosua, Maynard & Ahmad, 2016). A key development trend is that of IoT's integration with existing network systems (Xu et al., 2016) and interorganizational integration (Ferretti & Schiavone, 2016). IoT is one of the key sources of big data (Botta, De Donato, Persico & Pescapé, 2016) that enables real-time data visibility and sharing (Neisse et al., 2014). Sharing of data across networks of devices provides opportunity for smart services, such as connected marketing and reality-augmented customer services (Lee & Lee, 2015). With the embedded business analytic tools found in IoT devices, dynamic drill down and querying and analysis of data is enabled (Borgia, 2014) and also the ability to facilitate complex problem solving (Ng, 2014; Qiu, Luo, Xu, Zhong, & Huang, 2015). It enables real-time decision making (Sambasivan, Patrick Wemyss & Che Rose, 2010) autonomously. IoT provides the weakness and strengths throughout organisations and reacts to unexpected events on time (Qin et al., 2016). The nearly real-time performance monitoring and control are also a key benefit of IoT (Peņicina & Kirikova, 2013). IoT also enables remote control capabilities, such as predictive maintenance (Pye, 2014). Another important benefit of IoT is that of enhanced organisational efficiencies by way of system and procedure improvement (Lee & Lee, 2015), which results in increased speed and accuracy (Santoro, Vrontis, Thrassou & Dezi, 2018), reduced labor, transaction and process failure cost (Qin et al., 2016), reduced waste (Borgia, 2014), improved energy consumption usage (Weinberg et al., 2015) and supply chain responsiveness (Valmohammadi, 2016). Finally, IoT can enhance organisational productivity by coordinating all IoT devices (Bradley, Thibodeau & Ng, 2014). For instance, it can improve value chain productivity across product design, inventory management, manufacturing, logistics and customer service (Murray, Papa, Cuozzo & Russo, 2016; Weinberg et al., 2015). The studies have demonstrated that performance expectancy is a significant factor effecting adoption of IoT by entrepreneurs (Nikbin & Abushakra, 2019). Entrepreneurs will consider IoT if it is useful within their organizations' operations (Nikbin & Abushakra, 2019). In summary, performance expectancy is ready to undergo further studies with regards to IoT within the manufacturing SMEs in Thailand.

Facilitating Condition

Facilitating Conditions is defined as the degree to which an individual believes that current organisational and technical infrastructure support the use of a system" (Venkatesh et al., 2013) For the facilitating conditions, four determinants are identified from literature: First, lack of organisational support and awareness, this refers to availability of a specific group or person that has knowledge, commitment and the skills needed to handle the system problems/difficulties effectively (Ferretti & Schiavone, 2016). In addition, the organisational infrastructure that is required for IoT systems may be difficult to set up due to social change and potential resistance to changes in daily basis work practices (Dutton, 2014). Secondly, lack of a unified interconnection standard; this is necessary for IoT devices to be integrated (Valmohammadi, 2016). Several standardizations are required, including those pertaining to data format, data interfaces, protocols and architecture (Borgia, 2014). Third, data management and scalability, which is the ability to manage the large amount of data generated from IoT devices efficiently (Dutton, 2014). Current data centre architecture is inadequate and unable to handle data volumes of a heterogeneous nature (Lee & Lee, 2015). IoT requires distributed data centre management to improve data processing efficiency and response time (Bradley et al., 2014). New algorithms and technologies, such as indexing methods and data mining tools, are required (Saint, 2014). A study by Nikbin and Abushakra (2019) found that facilitating conditions significantly affect IoT adoption by entrepreneurs. In summary, facilitating conditions are ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Behavioural Control (PBC)

PBC is defined as users' perceptions regarding skills, abilities and resources in order that easily and natural systems and services can be implemented (Lu, Zhou & Wang, 2009). PBC is similar to facilitating conditions from the UTAUT framework, which describes the users' perception if they have sufficient resources, capability and control to successfully perform the behaviour (Gao & Bai, 2014). There are several studies that support the positive relationship between PBC and behavioural intention such as Lu et al. (2009) and Mathieson (1991). Coughlan et al. (2012) found that knowledge and awareness of IoT is one of the critical factors that has significant impact on the adoption of the technology. In addition, Han et al. (2014) stated that technology awareness is one of the most important factors for the adoption. For the manufacturing firms, they need to provide the user-friendly interface, allowing employees to maximize their control skills. In the case of IoT, PBC is the users' perception of how they can perform activities by using IoT (Park, Baek, Ohm, & Chang, 2014). Therefore, users need to have at least very basic skills in order to utilize the systems/devices (Gao & Bai, 2014). For instance, when the railway employees use mobile IoT equipment to maintain the engine parts of the trains and monitor the wheel status, they need capability to operate the IoT systems; otherwise concern of control and negative evaluation of the IoT could be provoked (Gao & Bai, 2014). In summary, perceived behavior control is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Intelligence

Perceived intelligence also refers to the degree to which IoT systems are automatically adjusted during the operation; IoT systems contain sensors, memory systems, data processing and reasoning and communication capacity (Dong, Chang, Wang, & Yan, 2017). Perceived intelligence means that IoT systems can store memory through constant self-learning (Ritter et al., 2011) and it is different from intelligence (Dong et al., 2017). In terms of the technical standards that the manufactures consider, IoT systems should satisfy the standards of intelligence (Dong et al., 2017). Perceived intelligence is a subjective existence (Dong et al., 2017). The smartness, intelligence and the abilities that the IoT system is equipped with are considered from the users' subjective assessment (Lee et al., 2007). These features are reflected in the automation and simplification of product usage. IoT systems can analyse, judge, act and handle the data obtained from the environment (Dong et al., 2017). Furthermore, intelligent systems will be able to save on the human workforce and time via machine e-learning (Dong et al., 2017). In summary, perceived intelligence is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Convenience

Perceived convenience is defined as the agility, availability, and reachability of services (Dong etal., 2017). For IoT systems, perceived conveniences refers to how users can connect at any time and within any location, which are the characteristics of IoT (Dong et al., 2017) through the wireless of mobile phone or PC (Brown, Pope, & Voges, 2003). From Yoon and Kim's (2007) study, convenience can be divided into three dimensions: time, place dimension and execution. Previous studies have proposed that perceived convenience is a significant quality attribute in theperceived usefulness of wireless LAN and internet-based banking (Liao & Cheung, 2002; Yoon & Kim, 2007). An IoT system makes everything more effective and efficient, which enhances the performance of its users (Dong et al., 2017). Furthermore, execution dimension represents anew type of IS service that is simple to use (Dong et al., 2017). In summary, perceived convenience is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Connectivity

Connectivity is defined as the connection from human-to-human, or human-to-objects (Dong et al., 2017). For IoT systems, connectivity can be from objects to other objects, which is an important characteristic that makes the IoT system more advanced than traditional IS (Dong et al., 2017). Studies on connectivity of human-to-human or human-to-objects have usually focused on the connection quality (Chae et al., 2002). When users of IoT have stable IS service without connection break downs, high connection quality is achieved (Dong et al., 2017). Furthermore, a speedy response from the systems is also another important characteristic of the IoT systems. IoT systems can also minimise connection errors (Dong et al., 2017). Teo et al. (2003) confirmed that connectivity significantly influences effectiveness, which in turn improves the performance. In IS research, effectiveness is related to perceived usefulness of the TAM as introduced by Davis (1989). Furthermore, from a study on user acceptance of IoT in the smart home, IoT provides a large number of functions, with wireless connections between users and home network (Lee & Lee, 2015). Therefore, people can conveniently use their appliances and products without physical interaction (Park & Kim, 2014). This means that perceived connectedness might affect ease of use (Park, Cho, Han, & Kwon, 2017). In the case of IoT in manufacturing, it offers various applications that can bring convenience to users, such as sharing real-time and graphic-intensive information globally and management of the factory unit remotely. In summary, perceived connectivity is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

Perceived Trust

Trust is defined as a person's perception of the integrity and ability of a third party who is providing a service (Al-Momani et al., 2018). For IoT, trust is defined as the user's confidence in the IoT system that is provided by the IoT service provider (Al-Momani et al., 2018). Studies in the adoption of a new technology have demonstrated that trust is an important factor regarding IoT adoption (Al-Momani et al., 2018; Gefen, Karahanna & Straub, 2003; Wharton & Brunetto, 2007; Siegrist, Cvetkovich, & Roth 2000). Studies have found that trust is a significant variable that affects the attitudes and intentions of employees towards the acceptance of IT products (Flavián, Guinalíu, & Gurrea, 2006). Gao and Bai (2014) stated that trust in the IoT services is a significant variable that affects the behavioural intention to adopt the services. Furthermore, Kowatsch and Maass (2012) stated that trust is an important factor for the adoption of IoT services in Spain. In addition, Gao and Bai (2014) stated that the users' trust of IoT technology and service providers is believed to significantly affect the IoT adoption intention.

New technologies typically come with risks, which negatively affect the users' intention and behaviour to adopt them (Gao & Bai, 2014). Two important characteristics of the IoT system, which are intangibility and high level of various IT involvement, may increase a level of perceived uncertainty and risk for the users (Gao & Bai, 2014). Lin (2011) stated that trust is one of the most effective tools for decreasing uncertainty and risks and generating a sense of safety. The lower the technology uncertainties, the more confident participants will become, as they can anticipate the technology benefits (Tu, 2018). Many participants considered that the scanner without line of sight and the bulk reads of tagged items as significant benefits of IoT technology under the assumption of having 100 per cent reading rates. If IoT technology cannot guarantee 100 per cent reading rates, then most participants would think twice about adopting it and discount the aforementioned benefits (Tu, 2018). Therefore, there is a need for the IoT service provider to ensure that the service fits well with users' value, which then reduces the perceived risk of adoption (Hsu & Lin, 2016). As the compatibility between devices and systems is significant for the firms' long-term strategy, the standardisation for the communication between devices and systems needs to be set up to smooth the pathway for adoption (Bao et al., 2014). Therefore, it can be hypothesized that trust affects compatibility for IoT adoption. In summary, perceived trust is ready to undergo further studies with regard to IoT within the manufacturing SMEs in Thailand.

4.2 Summary of Theoretical Framework

Based on the review of the general IT adoption models and literature of IT adoption models in relevant context, 26 factors from DoI, TOE, TAM, UTAUT theories and related literature were found relevant for assessing the adoption of IoT within manufacturing SMEs. **Table 6** below provides a summary of the 26 relevant factors and their literature references:

Table 6: 26 Relevant Factors and Their Literature References

Relevant factors	**Literature references**
1. Relative advantage	Alshamaila et al. (2013); Sin Tan., Choy Chong, Lin, & Cyril Eze (2009); Chiu, Chen, & Chen (2017); Premkumar, Ramamurthy, &Nilakanta (1994); Rogers (2003)
2. Compatibility	Daylami et al. (2005); Premkumar (2003); Rogers (2003); Shin (2015); Sinha & Mukherjee (2016); Rogers (2003); Sophonthummapharn (2009); Zhu et al.(2006);
3. Complexity	Brumec (2006); Chen (2013); Frambach, Barkema, Nooteboom, & Wedel (1998); Lean, Zailani, Ramayah, & Fernando (2009); Rogers (2003)

4. Trialability	Lee, Hsieh, & Hsu (2011); Odumeru (2012); Pashaeypoor, Ashktorab, Rassouli, & Alavi-Majd (2016); Rogers (2003)
5. Observability	Al-Jabri & Sohail (2012); Ju, Kim, & Ahn(2016); Rogers (2003); Vishwanath & Goldhaber (2003); Wang & Wang (2016)
6. Cost	Chong & Chan (2012); Chao & Lin (2017); Ong, Poong & Ng (2008); Park et al. (2017); Pearson & Grandon (2005); Riemenschneider& McKinney (2002)
7. Security and privacy risk	Coughlan et al. (2012); Evans (2015); Kshetri(2014); Saedi & Iahad (2013); Sivathanu (2019)
8. Image	Gounaris & Koritos (2008); Hsu, Lu, & Hsu(2007); Moore & Benbasat (1991)
9. Top management support	Chan & Chong (2013); Daylami et al. (2005);Jeyaraj et al. (2006); Seyal et al. (2007)
10. Organisational readiness	Depietro, Wiarda & Fleischeer (1990); Hsu &Yeh (2016); Jedermann & Lang (2008);
11. Organisational structure	Burns & Stalker's (1961); Ericsson (2015); Rogers (1983); Vukicevic (2018)
12. Organisational size	DePietro et al. (1990); Rogers (1983)
13. Competitive pressure	Chan & Chong (2013); Leminen et al. (2012);Oliveira and Martins (2010); Raymond & Uwizeyemungu (2007); Wang et al. (2010)
14. Technology support from vendors	Al-Qirim (2007); Bassi & Horn (2008); Chen,Zhang, & Zhang (2010); Ghobakhloo, Arias-Aranda & Benitez-Amado (2011); Mirchandani & Motwani (2001)
15. Business partner influence	DePietro et al. (1990); Premkumar et al.(1997);

16. Perceived usefulness	Acquity Group (2014); Al-Momani, Mahmoud, & Ahmad (2016); Gao & Bai(2014); Shin & Jin Park (2017)
17. Perceived ease of use	Davis et al. (1989); Gao & Bai (2014); Lee etal. (2012)
18. Experience	Dong et al. (2017); Speier & Venkatesh(2002)
19. Social influence	Davis et al. (1989); Gao & Bai (2014);Nikbin& Abushakra (2019)
20. Performance expectancy	Nikbin & Abushakra (2019); Peņicina &Kirikova (2013)
21. Facilitating condition	Dutton (2014); Nikbin & Abushakra (2019);Venkatesh et al. (2013)
22. Perceived behavioural control	Gao & Bai (2014); Lu et al. ()2009;Mathieson (1991).
23. Perceived intelligence	Dong et al. (2017); Wang, & Yan (2017)
24. Perceived convenience	Liao & Cheung (2002); Yoon & Kim (2007)
25. Perceived connectivity	Davis (1989); Lee & Lee (2015); Park, et al.(2017); Teo et al. (2003)
26. Perceived trust	Al-Momani et al. (2018); Flavián, Guinalíu, & Gurrea (2006); Gao & Bai (2014); Gefen etal. (2003); Siegrist, Cvetkovich, & Roth (2000); Wharton & Brunetto (2007)

However, after reviewing all the relevant factors, some factors can be considered either similar or the same, with some differences in wording. Some of the factors are already covered by other factors. For the purpose of this study, the 13 comprehensive factors, which are used at firm level, will be selected and supported by the other 13 relevant factors. **Table 7** below provides the selected factors which will be considered in this study and their supported factors:

Table 7: The Selected Factors and Their Supported Factors

Selected factors	**Other factors**
1. Relative advantage	Perceived usefulness, Image, Performance expectancy, Perceived intelligence, Perceivedconvenience,

	Perceived connectivity
2. Compatibility	Organisation readiness (Human resource), Facilitating condition, Experience, Perceived behavioural control
3. Complexity	Perceived ease of use
4. Trialability	
5. Observability	Trust (trust of the technology)
6. Cost	Organisation readiness (financial resources)
7. Security and privacy risk	
8. Top management support	
9. Organisational structure	
10. Size	
11. Competitive pressure	Social influence
12. Business partner influence	
13. Technology support from vendors	Trust (trust of service providers)

The selected factors from the relevant theories and literature after the integration are divided intothree contexts: technology, organisation and environment. This study considers the technologicalfactors: relative advantage, complexity, trialability, observability, security and privacy risk and cost. This study also considers the organisational factors: top management support, organisational structure and organisational size. Furthermore, the compatibility is included in both organisational and technological context as it explains the fit between technology requirements and organisational readiness, such as the technological infrastructure, skilled employees and financial resource. In addition, this research has considered environmental factors, such as competitive pressure, business partner influence and technology support from vendors. **Figure 18,** below**,** presents the conceptual framework/theoretical framework that highlight the factors that affect the adoption of IoT within manufacturing SMEs. The next section considers the research questions of this thesis.

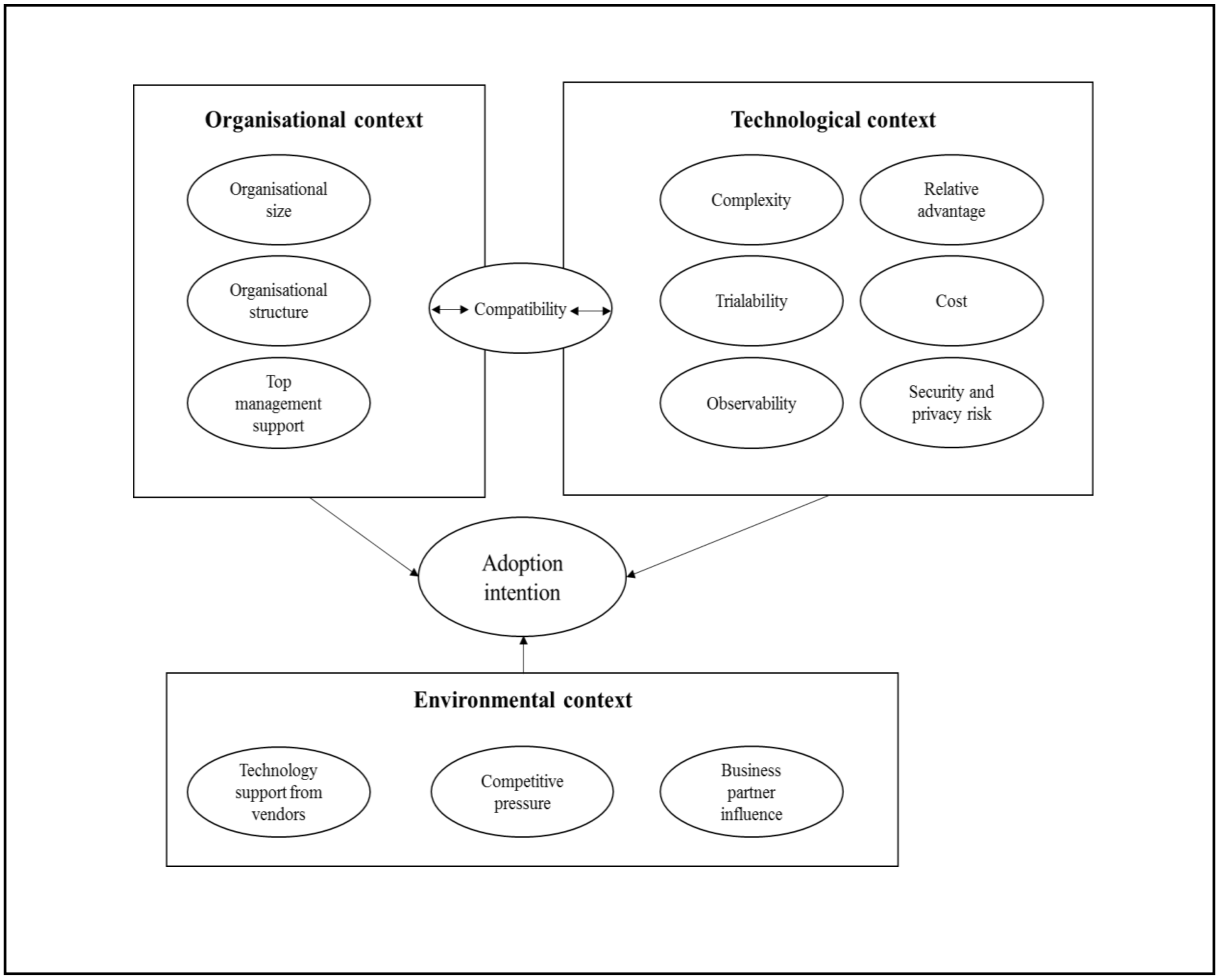

Figure 18: Conceptual Framework Presenting the Factors Affecting Adoption of IoT in Manufacturing SMEs

Source: Author's own

4.3 Research Questions

From the literature review in chapter 2, 3 and 4, and the original objective stated within section 1.2 , it was apparent that there exists only limited literature examining IoT within manufacturing SMEs. The majority of studies undertaken relates to the IoT adoption in manufacturing in general or large manufacturing organisations. The majority of the studies do not specify the countries/areas where the data was collected. This can be an issue, as consumer behavior and organisational behaviour in each country can be different. Furthermore, there is a lack of studies covering all the relevant factors. For example, there are few studies on the challenges that the firms should be identifying, but there is no robust study on the drivers or the motivation. Therefore, this study objective is to validate the influences of the factors, identified from the literature, in a developing country such as Thailand. Meaningful insights into those factors could be provided to fill the gaps. The research questions are as follows:

1. What are the factors affecting the adoption intention of IoT in manufacturing SMEs in Thailand?
2. How do those factors affect the adoption intention of IoT in manufacturing SMEs in Thailand?
3. What guidelines can be developed to guide practitioners in assessing the suitability of manufacturing SMEs in adopting IoT technologies?

Chapter 5: Research Methodology

5.0 Research Methodology Chapter

This chapter provides the overview of the research methodology that will guide the field exploration of factors that influence potential IoT adoption by manufacturing SMEs in Thailand. Important issues, including the research philosophy, research method and research strategy will be presented. The methodology adopted in this thesis is interpretivist, qualitative research and applies a multiple case study strategy. Interpretivism is chosen based on the research question **(Section 4.3)**, the complex and subjective nature of IoT adoption from the analysis literature (**Chapter 1, 2 and 3**) and the exploratory nature of the research proposition (**Section 4.2**). The interpretivist position influences the selection of the qualitative research method. Furthermore, the qualitative research and interpretivist exploratory study leads to a case study strategy (Yin, 2003). In particular, the multiple-case study will be adopted, as it enables the development of theory byidentifying the factors affecting IoT adoption in manufacturing SMEs. A snowball sampling technique will be used for identifying participating firms and interviews will be the primary data source (the conceptual framework developed in **Section 4.2** will be used to develop the initial interview questions), supported by the documentary sources. Thereafter, analysis of within-case and cross- case analysis will be undertaken through five stages:

1) Initial set-up
2) Interpretation
3) Categorisation
4) Analytical generalisation
5) Factor definition

This will lead to the identification of common themes and categories, thus creating a potential to craft the conceptual framework of factors that affect the adoption of IoT adoption in manufacturing SMEs. The following section considers the detail of the research philosophy.

5.1 Research Philosophy

This section considers the research philosophy that was adopted for this study. Any research should be based on a philosophical position, as it is critical to recognise the philosophical view that underlies the study when exploring and describing the research phenomenon (Bell, Bryman, & Harley, 2018). The research philosophical position will determine the research design, strategy and methods chosen as part of the strategy and the research findings (Bell et al., 2018). With regard to IS studies, various researchers typically support three positions:

1) Positivist/Empiricist position.
2) Interpretive/Constructivist position.
3) Critical Realist position (Orlikowski and Baroudi 1991;Stake 1995; Myers, 1997; Klein & Myers, 1999; Oates, 2006).

Typically, the research question, research aim and its objectives are the key justifications for the choice of the research philosophical position (Bell et al., 2018). In this thesis, exploratory research questions seek to identify the factors that influence the adoption of IoT within manufacturing by SMEs. Furthermore, the explanatory research question seeks to understand *why* these factors influence the adoption of the IoT by manufacturing SMEs. Therefore, the nature of the research questions leads to an interpretivist research epistemology which focuses on the understanding of the social world through an examination of the interpretation of that world by its participants (Bell et al., 2018).

The interpretivist position allows us to consider both complexity and subjectivity (Bell et al., 2018; Cepeda & Martin 2005; Fitzgerald & Howcroft 1998; Mingers 2003; Mingers & Brocklesby 1997; Sandelowski, 2000) regarding the adoption of IoT by manufacturing SMEs. As this thesis will rely on the views of the decision-makers within the SMEs to firstly uncover influential factors and then to understand these influences, the ontological position is 'constructionist', which implies that the individuals within the firms are not separate from events within the firms, and perceptions of the SMEs' key decision-makers are different. In addition, the interpretive view has emerged within the IS field as a significant research philosophical position (Walsham, 1995); and has been widely accepted by several authors (Orlikowski, 1993; Trauth & Jessup, 2000). In contrast to the interpretive position, the positivist position is not suitable for interpreting people's perceptions and behaviours. The critical realist position, which seeks to comment on the status quo of social systems to achieve some desired result or change (Cassell & Symon, 2004), is not suitable for this thesis, as the objective of this study is to discover the natural position of the business and requires rich insights into the behaviour of the individuals concerned. Therefore, this thesis adopts the interpretive position over positivist and critical realist positions. The next section will explain the ontological and epistemological positions of this thesis in detail.

5.1.1 Ontological Position

Ontology is defined as the type of reality assumed in order to exist and the nature or view of that reality, which can be objectivist with a singular or objective view of reality, or constructionism with a multiple, individually or culturally constructed view of reality (Bell et al., 2018; Cepeda & Martin 2005; Fitzgerald & Howcroft 1998; Mingers 2003; Mingers & Brocklesby 1997; Sandelowski, 2000). For this thesis, constructionism is a more suitable choice, due to the subjective and complex nature of the contexts and implications of factors that influence IoT adoption with regard to the heterogeneous views of SMEs; this includes the owner/managers, employees, customers and suppliers. These influences on the adoption of IoT may change over time and they depend on other social factors such as culture, organisational structure and strategy (Orlikowski & Baroudi, 1991); there are multiple realities. Thus, this constructionism perspective sees various factors that influence IoT adoption within manufacturing SMEs as being dependent on the key decision-makers' perception and interpretation of those factors. Ontologically, the subjective meaning will be derived from the key stakeholders in the SMEs.

5.1.2 Epistemological Position

Epistemology is defined as a form of representation of reality, related information sources and how to obtain them, and possibilities of and limitations upon knowledge of that reality (Hirschheim 1985; Mingers 2003; Mingers & Brocklesby 1997; Myers 1997; Sandelowski 2000). First, the form of representation of the reality; in order to be consistent with constructionism ontology earlier, an interpretivist epistemology is chosen as it takes into account the complexity and subjectivity (Fitzgerald & Howcroft 1998; Myers 1997; Sale, Lohfeld, & Brazil, 2002). Second, the sources of knowledge on factors influencing IoT adoption and how to obtain it. Based on the subjective and complex knowledge about the factors, it will be appropriate to explore those factors from their multiple, natural settings (Myers 1997; Sale et al. 2002) and from the subjective participants' complex experiences. This knowledge can be informed by multiple sources such as education, family influences, employment and self-employment experience, and culture (Jones et al., 2014).These are consistent with the interpretivist approach, as it accepts that humans have different interpretations of reality. Finally, the exploratory and explanatory nature of this thesis is suitable with interpretivistism, which accepts that knowledge can be obtained through possibilities and limitations of new concepts (Bell et al., 2018). For this thesis, the source of knowledge is obtained from the multiple actors and their interactions within research phenomenon.

To summarise, the epistemological position of this thesis is interpretivist. It provides a deep understanding of a research problem (Bell et al., 2018) that is the main focus of this current study. More specifically, it will help the researcher to understand human thoughts and actions within social and organisational contexts and it has the potential to generate deep insights into the various factors that affect IoT adoption within manufacturing SMEs. This approach, according to Easterby-Smith, Lyles and Tsang (2008), is an effective way by which data can be collected in order that different views of the phenomenon within the firms can be established, which is the aim of this research. In addition, the day-to-day social practices and language used to explain these factors will help them to be understood.

5.2 Research Method

This section considers the justification for selecting a qualitative method. Qualitative methods focus upon word data, rather than numeric data (Cassell & Symon, 2004). It studies the participants' meaning within their particular natural environment and describes human and social matters (Creswell, 2009). The choice of qualitative study is aligned with the objectives of this research, which is to explore, explain and comprehend a complex phenomenon by considering the context of its setting (Fitzgerald & Howcroft 1998; Malterud, 2001; Myers, 1997). Particularly within this thesis, this method provides an opportunity to gain in-depth understanding of the organisational factors that influence the adoption of IoT within manufacturing SMEs (Pickernell et al., 2013). The key reasons for the choice of a qualitative research method are the research questions, the researcher's epistemological position and the existing knowledge of the phenomenon (Slevitch, 2011).

The first reason for choosing a qualitative method is the research questions. These focus upon which factors have influence upon the adoption of IoT by manufacturing SMEs, and help us to fully understand why those factors influence the adoption decision. The qualitative method allows researchers to explore and explain the complexity and subjectivity within the national setting of the research phenomenon (Fitzgerald & Howcroft 1998; Miles & Huberman, 1994; Myers, 1997) as it relies on in-depth interviews or observations (Cassell & Symon, 2004). Therefore, the qualitative method is suitable for the “how” and “why” types of questions raised within this thesis.

The second reason for choosing a qualitative method is the chosen epistemology, which is interpretivism. The relevance of researcher epistemology in the choice of research method has been found in several studies regarding the research methods selection used in IS research (Fitzgerald & Howcroft, 1998; Myers, 1997; Trauth, 2001) and therefore offers a precedent for this approach. The interpretivist stance is consistent with a qualitative method, as it explains and understands the complex and subjective contexts of research phenomenon’s - such as IoT adoption - through their natural setting (Hoepfl, 1997; Ivankova, Creswell, & Stick, 2006; Myers, 1997; O’Donoghue, 2018; Rouse & Dick, 1994; Saleet al., 2002). The factors affecting the decision to adopt IoT within the firms are dependent on how IoT is understood and constructed by people. Therefore, it is critical to understand the thoughts of the key decision-makers within the SMEs, and to understand these thoughts regarding IoT that are in their own words.

The third reason to choose a qualitative method is the degree of uncertainty that surrounds the factors affecting IoT adoption, as such studies are still evolving and various features are not properly understood. Therefore, the common understandings and practices are still required for further in-depth study. This argument is consistent with Strauss and Corbin (1990), who suggest that qualitative research can be used for in-depth understanding of any phenomenon that is little known. The contribution of this thesis may lead to the formation of concepts and generalisable propositions, especially with regard to emerging economies (Glaser, 1965).

Several qualitative research strategies have been used in previous IS studies; action research, which allows the researcher to observe and make objective changes to the phenomena under investigation (Avison, Lau, Myers, & Nielsen, 1999; Baskerville, 1999); ethnography, which allows researchers to emerse themselves deeply into the study that is focused upon people and culture (Myers, 1999); grounded theory, which focuses on the theory that emerges from the empirical observations and interpretations (Corbin & Strauss, 1990; Rouse & Dick, 1994); and case study, which aims to investigate and understand a contemporary phenomenon, within its natural context, with a view to understanding the issue from the perspective of participants, especially when the boundaries between the phenomenon and its context are not evident (Brender & Markov, 2013; Hashem et al., 2015; Jamshidi, Ahmad, & Pahl, 2013; Jones et al., 2014). The next section considers case study strategy, which will be used in this thesis.

5.3 Research Strategy

This section considers the case study method, which will be utilised within this thesis. Collis and Hussey (2009) define case study as a methodology that is used to explore a phenomena in a natural setting by using various methods to gain in-depth knowledge. Yin (2003) emphasized that case study is especially useful when there is a need to investigate the research issue within a real-life specific context, where the deep understanding of phenomena is required, and multiple sources of evidence are used. The case study protocol will be used as a guideline for this study, as it keeps the fieldwork focused on the case study (Rashid, Rashid, Warraich, Sabir, & Waseem, 2019; Yin, 2003) and it also helps with the planning of the data management and report. According to Yin (2010), the case study protocol raises the reliability of case study research and is required for multiple case studies. Furthermore, Yin (2003) stated that the case study protocol should consider four elements. The first element is the design of this thesis, including objectives and conceptual framework (Yin, 2003), which was discussed in **Section 4.2.** In addition, the justification of the qualitative approach and case study strategy, the choice of multiple cases study strategy, unit of analysis and unit of observation, and sampling strategies (Rashid et al., 2019; Yin, 2003) will be discussed in this chapter. The second element is the data collection procedure, which provides a guideline for conducting fieldwork and handling potential issues that may occur whilst the data is being collected (Rashid et al., 2019; Yin, 2003). The third element is the field questions required for the data collection (Rashid et al., 2019; Yin, 2003). The fourth element is a guide for the case study report (outline, format for the data, conclusion drawing and presentation of other documentation) (Yin, 2003).

5.4 Research Design

5.4.1 Rationale for Using Case Study Strategy

This section considers the justification for using the case study strategy. This thesis will use case study as a research strategy. Case studies are widely used in organisation studies (Robson, 2002; Cassell & Symon, 2004) and in the IS field (Cassell & Symon, 2004; Jones et al., 2014; Robson, 2002). As for a qualitative research method and an interpretivist position, a case study strategy was argued to be suitable for this thesis (Yin, 2003). Chetty (1996) states that using case study research within the context of SMEs typically leads to observation of new insights. Wedawatta et al. (2011) supports this statement by determining that case study strategy, where an in-depth knowledge is an outcome, is suitable for the study of a heterogeneous sector like SMEs. Furthermore, by using case study strategy, reality can be observed in order to gain rich detail within a reasonable amount of time, more than with any other qualitative strategies (Chetty, 1996). Yin (2003) suggests case study strategy should be considered in the following situations:

1) When the focus of the study is to answer “how” and “why” questions’
2) When the focus is on contemporary phenomena within a real-life context, especially when boundaries between phenomenon and context are not apparent
3) When the investigator cannot influence behaviours of those involved in the study
4) In-depth understanding of the phenomenon is required and multiple sources of evidence are used.

The first reason to select a case study method is that the thesis research questions and objectives seek to explore the factors affecting IoT adoption within manufacturing SMEs, which are aligned with typical case study objectives (Eisenhardt, 1989; Miles & Huberman, 1994; Rashid et al., 2019; Yin, 2003). The second reason is that the focus of this thesis is about the contemporary nature of IoT adoption as a modern alternative to IS, and there are only limited previous studies that have considered the adoption and the usage of the IoT. The characteristics of the IoTs fit with the case study strategy when the boundaries between the phenomena and its context are not evident and require further explanation (Eisenhardt, 1989; Miles & Huberman, 1994; Myers, 1997; Rashid et al., 2019; Yin,1993). The third reason is the degree of control over the phenomenon. As the focus of this thesis is on understanding the complexity and subjectivity of IoT adoption within its natural context and settings with no interference from the researcher, the researcher will have no control over the behaviour of the SMEs and factors that may support or hinder the IoT computing adoption. Therefore, it is appropriate to use the case study strategy that requires no control of researchers over the phenomena (Rashid et al., 2019; Yin, 1994). The final reason to choose the case study is the generalization of findings. Prior developed theories are used as templates to compare with the results of the case study. Thereafter, common finding or regularities will be examined (Creswellet al., 2007; Tellis, 1997; Eisenhardt, 1989; Yin, 1994). However, as this study only focuses upon SMEs within manufacturing in Thailand, it may be difficult to generalize the findings to other contexts. In addition, the objective of this thesis is to gain in-depth knowledge and develop the conceptual framework in order to apply it in other relevant contexts, or extend existing theory to new contexts (Rashid et al., 2019; Yin, 1994). Therefore, case studies in this thesis will be analytically, not statistically generalized (Yin, 1994).

5.4.2 Unit of Analysis and Unit of Observation

This section considers the selection of unit of analysis and unit of observation. When planning a thesis, unit of analysis and unit of observation must be considered (Johnston, Leach, & Liu, 1999). A unit of analysis is the entity that will be analyzed as the central focus of this study (Yin,2003). The appropriate unit of analysis should be decided within the case study so that the research phenomena can be successfully analyzed (Baxter & Jack, 2008). Furthermore, it should be aligned with research questions (Yin, 2003), The unit of analysis can be an individual, group, or organisation (Benbasat, Goldstein, & Mead, 1987). To achieve the research objective and answer the research questions, the unit of analysis for this thesis will be the organisation, more specifically, the manufacturing SMEs in Thailand that have between 10 and 250 employees based on the EC definition. Those SMEs should have an annual turnover of between 400 and 2000 million Baht, or a balance sheet total of between 400 and 1720 million Baht (EC, 2016). In addition, those targeted organisations are required to have adopted, or have had the intention to adopt, the IoTs within their manufacturing sites. **Table 8,** below, provides the case study protocol for this thesis (Yin, 2003). The focus on the organisation as the unit of analysis will be a criterion for comparing findings across the cases in Thailand. The rationale to select organisations as the unit of analysis is that the conceptual framework developed from literature in this thesis is at an organisation level. The literature review identifies a lack of research that evaluates IoT adoption within an emerging economy context (see **section 1.4**). A unit of observation is the element that is actually observed, measured, or collected to learn something about the chosen unit of analysis (Yin, 2003).

Table 8: Case Study Protocol

Criteria	Measurement
Location	Thailand
SME	Headcount between 10 and 250 (EC, 2016)
	Annual turnover between 400 and 2000 million Baht (EC, 2016) or Balance sheet total between 400 and 1720 million Baht (EC, 2016)
Sector	Manufacturing
IoT adoption	The company must be (or have an intention to be) engaging in some form of IoT adoption
Participants	key decision makers: chief executive officer, operation/plant manager, product manager, project manager, IT manager, strategic manager and supply chain manager

The unit of observation is determined by the method of data collection used to answer that research question (Johnston et al., 1999). In this thesis, they are the key stakeholders, such as SME owners, directors, or IT managers that are responsible for IT adoption within manufacturing firms in Thailand. **Table 9,** below, provides the Role of the Key Stakeholders who were interviewed as part of the data collection process, and their description:

Table 9: Role of Key Stakeholders and their Description

Role of key stakeholders	Description
CEO/ Owner/Managing director/Manager	-Set overall strategic directions and plans forthe firm, as well as the responsibility for guiding actions that will realise those plans (Calori, Johnson, and Sarnin, 1994). -Set up a vision and direction on innovation(Tushman & Nadler, 1986).
Strategic Manager	-Top management with power to create innovation strategy, make important IS/IT decisions and allocate resources for the adoption of new technology (Vahtera, 2008). -Consider the integration of service, and re-engineering of process in the firms (Hsu & Yeh, 2016; Wang & Wang, 2016).

IT/IS manager	-Manage IT, IS and electronic data operations (Anantatmula, 2008). -Consider compatibility of IT/IS with operations department by designing, developing and implementing coordinate systems, policies and procedures as it affects the functional requirements (Kamin, 2017). -Ensure security of data, network access andbackup systems (Kamin, 2017).
Functional manager (Operations/Plant/Manufacturing /Production /Supply chain/Engineering manager)	-Drive continuous improvement and optimisation of all processes (Martin, 1989).
	-Develop processes that will maximize safety,quality and productivity (Fan et al., 2015; Reaidy et al., 2015). -Plan for available material, work in process,and arrival time of new material (Fan et al., 2015; Reaidy et al., 2015). -Monitors the process in the plant and transmitsdata on the condition and status of assets to ITsystem (Sharma, 2016). -Utilise data from the IT department to optimise the operation performance (Sharma, 2016).

5.4.3 Single Case Study Vs Multiple-Case Studies

This section considers the choice of case study strategy, those being single case study or multiple case studies. After deciding on the unit of analysis and unit of observation, this section considers whether to adopt a single case or a multiple case study design. Yin (2003) suggests that a single case study is suitable for an extreme or unique case. In contrast, multiple cases will be used in this thesis, as the findings can be replicated (Yin, 2003) and multiple case studies explore a range of behaviour within an emerging economy context. Based on the DoI theory, the manufacturing SMEs selected for multiple case studies should cover adopter categories from laggard to innovators (Rogers, 2003).The complexity and subjectivity of the factors that affect IoT adoption, from various perspectives of IoT adoption by manufacturing SMEs, requires multiple natural settings (Yin, 1994) in order to obtain in-depth understanding. Therefore, a multiple case study will be utilised in this thesis. Multiple case studies allow researchers to gather data from various firms to enable comprehensive description and explanation of the phenomena (Yin, 2003). In addition, multiple case studies use replication logic that allows researchers to choose specific cases that will predict similar results across the cases (literal replication) which can enhance the validity of the research outcomes (Yin, 2003). This strategy allows researchers to analyse the cases within the same country and also between two countries, so that differences and similarities alike can be extracted from the cases to generate regularities. More importantly, the result from the multiple cases study is more convincing and stronger than a single case study approach (Yin, 2003). It provides a means to effectively explain the how and why questions, which are the type of research questions in this thesis (Yin, 2003). Therefore, this thesis will employ a multiple case approach to investigate the factors affecting the adoption of IoT in manufacturing SMEs in Thailand. Another issue to consider regarding multiple case studies is the time horizon (Saunders, Lewis, & Thornhill, 2009) of which there are two types: cross sectional, which studies a particular phenomenon within a specific time frame (Saunders et al., 2009), and longitudinal, which studies a particular phenomenon over a long period of time in order to examine the change or trend (Saunders et al., 2009). This thesis will adopt the cross-sectional study, as it focuses on studying technology adoption on multiple cases within aspecific time frame (Jones et al., 2014).

5.4.4 Sampling Strategy

A sampling technique must be identified and applied to any studies so as to ensure a credible response (Eisenhardt, 1989, Sharma, 2017). Case sampling will be applied to the cases that are relevant to understanding IoT adoption by manufacturing SMEs in order to clarify the domain of the examination. The logical replication will be applied when selecting Thai SMEs within the manufacturing industries (Coyne, 1997;Eisenhardt, 1989; Miles & Huberman, 1994; Sharma, 2017). The selection of the SMEs follows three sampling techniques, including purposeful, snowball and maximum variation sampling (Eisenhardt, 1989; Meredith, 1998; Miles & Huberman, 1994; Patton, 1990; Sandelowski, 1995; Smulowitz, 2017). These three sampling techniques allow researchers to capture appropriate respondents for the case study (Eisenhardt, 1989; Meredith, 1998; Miles & Huberman, 1994; Patton, 1990; Sandelowski, 1995), as explained below. First, the study will use a non-probability sampling technique, or purposive sampling technique, to obtain the answers from legitimate and reliable respondents (Campbell et al., 2020; Eisenhardt, 1989). It is a flexible sampling technique (Campbell et al., 2020; Coyne, 1997; Miles & Huberman, 1994; Patton, 1990) that is suitable for this exploratory study initially so as to identify the SME that is willing to participate as a case subject. A selected case for a pilot study will be a business that is associated with Swansea University. In addition, a business in Thailand will be selected from the researcher's network. Thereafter, this thesis will apply a snowball technique; the researcher will begin the study with one of the businesses, and then, based on the information gleaned regarding the interrelationships from that particular business, the researcher will be able to select others before repeating the process (Parker, Scott, & Geddes; 2019; Kreuger &Neuman, 2006). In other words, the snowball sampling technique will identify participants using existing contacts and build further contacts from the first one. The benefits of using this approach is that the response rate can be high, it is less expensive and it is easy to create trust among potential participants, since they have been introduced by existing contacts (Heller, Kallevig, Mashak, 2014;Parker et al., 2019; Van, 1990). This strategy has proved to be crucial when trying to overcome access issues (Van, 1990).

The third sampling technique applied in this thesis is maximum variation sampling (Patton, 1990; Flyvbjerg, 2001; Schreier, 2018). This helps to identify the specific companies that are different in one dimension, which, in this thesis, is the degree of the adoption of IoT (Flyvbjerg, 2001; Schreier, 2018). This technique will cover the variation of issues in this study, such as barriers and motivation that hinder the adoption of IoT (Flyvbjerg, 2001; Schreier, 2018). According to Yin (2003), conducting 6-10 case studies would provide compelling support for the research focus of the study. Therefore, this thesis will target 10 manufacturing SMEs in Thailand that have various degrees of IoT adoption, then the sampling will continue - using the snowball sampling technique - until data saturation is achieved (Naderifar, Goli, & Ghaljaie, 2017). The next section outlines the data collection strategy used within this thesis.

5.5 Data Collection

The selection of data gathering tools is determined by the types of information that are essential in order to explore, explain and comprehend the research phenomena (Lincoln, 2002). The complexity and subjectivity of the factors that affect IoT adoption within manufacturing SMEs suggests a qualitative data source, or evidence (Lincoln, 2002). There are various sources, including documents, archival records, interviews, direct observation, participant observation and physical artefacts (Eisenhardt, 1989; Miles & Huberman, 1994; Yin, 2003). To find reliable and legitimate answers to the research questions, a combination of interview and alternative data sources will be utilised. Furthermore, the interview data will be analyzed using a theory building approach comprising within-case and cross-case stages of analysis.

5.5.1 Pilot Study

It should be noted that the pilot study should be undertaken in order to ensure that all the interview questions are effectively understood and not misinterpreted by the interviewees (Yin, 2003). This decreases errors, increases the credibility of the research and improves the accuracy of the data gathered (Bell et al., 2018). Saunders et al., (2009) stated that a pilot study would remove the text errors and refine and improve the research instrument. McGivern (2006) stated that designing poor questions could influence the quality of the data. In addition, the piloting process is helpful in estimating the time required for a single interview (McGivern, 2006). Furthermore, it helps to prepare the researcher to ensure that smooth flowing conversation takes place (Rowley, 2012). Because the IoT adoption within manufacturing SMEs in the UK is more advanced than in Thailand, three key decision-makers in manufacturing SMEs in the UK have been chosen to undertake the pilot study so as to ensure that all aspects of the research instrument will be evaluated. **Appendix 8** provides the overview of UK economy and its main sectors. The pilot interviews were with an operations manager of water technology, a CEO of bio-pesticides technology developing company and an operations manager of a disruptive photonic devices manufacturer.

Following the interviews, the research instrument was used for Thai case study interviews. The key decision-makers within the SME in the UK were identified and provided with the purpose of the communication. The meeting was then arranged and a letter sent to the interviewees confirming the interview details. The result of the interviews was evaluated and the set of research questions was adjusted according to the comments from the participants and the analysis of the result. Furthermore, discussions from the pilot study were focused upon determining whether or not the main study was feasible (In, 2017). In addition, possible biases or experimental problems that may occur in the main study are noted (In, 2017).

5.5.2 The Process of Identifying and Contacting Firms

This section considers how the organisations studied were identified and approached. Using a snowball sampling technique, one manufacturing SME in Thailand was selected from the researcher network. The next step after identifying the cases was to prepare a cover letter **(Appendix 1)**, a participant information sheet **(Appendix 2)** and a consent form **(Appendix 3).** The cover letter states the purpose of the research and invites key decision-makers within the business to participate in this study. The participant information sheet explains the aim of the study, the rationale to select the SMEs, the nature of the interview, the time frame, how the interview will be undertaken, how the data will be used and how confidentiality will be maintained throughout the study. A statement of research ethics approval from the Swansea University research ethics committee **(Appendix 4)** was obtained. All these documents were provided to the participants in preparation for the interviews. The identified organisations were then contacted by telephone or email before sending out the interview questions, participant information sheet and consent via email. The author of this thesis had returned to Thailand to undertake the data collection, although the Covid pandemic significantly impacted this process. After contacting the first company in Thailand, the potential organisations with their names, contact address, telephone numbers, location, email address and webpage address, were provided by the existing subjects and were contacted for collecting data. This process was repeated until the sample size was sufficient to analyse and draw conclusive results. **Table 12** provides the summary of the cases for this thesis. The next section considers the data collection method used.

5.5.3 Interview Method

This section considers the primary source of data in this thesis, namely the interviews. The face-to-face interviews were the most important sources of information for this case study (Yin, 2003; Zhang, Kuchinke, Woud, Velten, & Margraf, 2017). Interviews can be structured, unstructured and semi-structured (Roulston & Choi, 2018; Saunders et al., 2009). Structured interviews strictly follow the methods of standardised questions and typically use survey strategy to collect data (Roulston &Choi, 2018; Saunders et al., 2009). However, using this method may leave the researcher unable to glean insights from the respondents (Robson, 2002). The unstructured interview does not have a specific list of questions, thus these are difficult to compare results among the respondents (Easterby-Smith et al., 2008; Ghauri & Gronhaug, 2010; Robson, 2002; Roulston & Choi, 2018). Therefore, this thesis will not utilise structured and unstructured interviews but will use a semi-structured interview approach.

The nature of semi-structured interviews provides various interpretations of the same problem among the stakeholders and how they experience and perceive them (Evans & Lewis, 2018; Van, 1990). In addition, semi-structured interviews allow the interviewee to provide further insight regarding their answers and it is appropriate for the exploratory nature of this thesis (Evans & Lewis, 2018; Yin, 2003). The semi-structured interview has a set of interview questions, but there is room for the interviewee to express their opinion (Denzin & Lincoln, 2003; Eriksson & Kovalainen, 2008; Evans & Lewis, 2018). Furthermore, semi-structured interviews are suitable for both open-ended and complex research questions, which are used in this thesis. Although the semi-structured interviews are open-ended, they will follow the set of questions from the case study protocol. This means that the study will focus upon the research topic while allowing exploration of the research topic to take place. Leedy and Ormrod (2005) stated that semi-structured interviews will provide an explanation of all the factors and the stakeholders' views within the IT adoption process.

Table 10 below provides the summary of expected value of data collected from key stakeholders. This thesis will also use the conceptual framework developed in **section 4.2** to guide the interview questions. Thenext section considers telephone interviews utilised in this thesis.

Table 10: Summary of Expected Value of Data Collected from Key Stakeholders

Role of Key Stakeholders	Value of Data Collection
CEO/ Owner/Managing director/Manager	Comprehensive strategic perspective regarding thegoals and overall direction of the firms and key decision made in the firms (Lin, 2013). The development and execution of long-term strategicperspective (Geletkanycz, Boyd, & Finkelstein, 2001).
Strategic manager	Strategic perspective based on consideration of resources and an assessment of the internal and external environments in which the organisation operates (Nag, Hambrick, & Chen, 2007) Formulation and implementation of the major goalsand initiatives (Nag, Hambrick, & Chen, 2007).

IT/IS manager	Technical perspective regarding the IT/IS, such as theinfrastructure requirements, the compatibility with the existing system and the application of the IT/IS (Biliyaminu et al., 2018; Leuth, 2015).
Functional manager (Operations/Plant/Manufacturing/Production /Supply chain/Engineering manager)	Day-to-day operation perspective and the information regarding the implementation of operational policies and procedures (Matlay, 1999).

5.5.4 Telephone Interviews

Telephone interviews offer certain benefits in comparison with face-to-face interviews. Some of them are less costly and more convenient in term of access, speed and expenditure that is not associated with face-to-face interviewing (Cooper and Schindler, 2003; Saunders et al, 2009). Sturges & Hanrahan (2004) carried out telephone interviews in addition to face-to-face interviews and there was no significant difference in their results. Telephone interviews can be recorded on a mobile voice recording facility with the permission of the respondents (Zhang et al., 2017) and it can be useful when the interviewees are hard to reach or when safety is a concern (Bell et al., 2018). Furthermore, telephone interviews may be more comfortable for interviewees if the interview questions are of a sensitive nature, as it may make the interviewees feel less distressed about answering such questions if the interviewer is not physically present (Bell & Bryman, 2018). However, some issues regarding the use of a telephone interview technique could be the limitation of access to telephones or to the internet (if using video conferencing) (Bell et al., 2018). Telephone interviews are typically not as effective as conducting the interviews face-to-face, and the interviews may be very long (Bell et al., 2018). Lastly, a technical issue may occur, such as an unstable line connection, or difficulties with recording a telephone interview (Bell et al., 2018). As this thesis has been constructed during the Covid-19 pandemic, telephone or video conferencing interviews are used in all case studies to ensure the safety of all participants taking part in the study. Undertaking virtual interviews was also a requirement of Swansea University for all research students during the Covid-19 pandemic.

5.5.5 Interview Process

This section considers the interview processes used within each case study. Following the snowball approach, the responsible key decision-makers of a selected organisation (managers, owner, directors) were contacted to explain the nature of the interview. A summary of the interview questions was sent beforehand in order that the interviewees could prepare their answers. All participants also needed to sign a consent form granting permission to record the interviews.

In carrying out the interviews, the researcher aimed to discover what, why and how the interviewees perceived various IoT adoption factors. At the beginning of the interview, the researcher guaranteed the respondents anonymity and stressed that confidentiality would be paramount. It was important to keep the flow of the interview so that participants were not distracted during the process (Leedy & Ormrod, 2005; Moser & Korstjens, 2018). The interview for each participant was completed when all the questions had been answered (Patton, 2001). When each interview was completed, it was transcribed into Microsoft Word (Gale et al., 2019; Walsham, 1995). The audio recording and transcripts developed essential elements for the case study database, which helped to create data credibility and reliability of this multiple case research (Gale et al., 2019; Yin, 2003; Eisenhardt, 1989). Thereafter, all information was analyzed using NVivo in order to identify emergent themes and issues, then conclusions and verification was drawn from that data (Jackson & Bazeley, 2019; Miles and Huberman, 1994). For the case study strategy, data collection and data analysis processes may be overlapped (Eisenhardt, 1989; Moser & Korstjens, 2018). This overlap is beneficial for two reasons; first, it makes the data collection process flexible and adjustable (Eisenhardt. 1989; Moser & Korstjens, 2018), and second, it can speed up the data analysis process as the researcher can start analysing the data once the first group of data becomes available (Eisenhardt. 1989; Moser & Korstjens, 2018).

5.5.6 Design of the Case Study Research Instrument

This section considers the structure and justification for the case study questions. The case study questions guided the conversation and the researcher during the interview process (Myers and Newman, 2007) and it also ensured consistency and reliability during all interviews, as all interviewees were asked similar questions (Zohrabi, 2013). The research instrument was designed to avoid leading questions (Stringer & Genat, 2004) and it also ensured that further explanation could flow (Myers & Newman, 2007). The objective of this thesis is to validate the influences of the factors on IoT adoption that has been identified from literature in Thailand, and to provide meaningful insights (**section 4.3**). Therefore, the exploration and understanding of such factors by utilising case study questioning enabled the development of a conceptual framework that assisted manufacturing SMEs to maximize their deployment of the IoT. In addition, the questions had a potential to analyse the manufacturing readiness for IoT adoption. The case study questions were developed keeping in mind the variables of the conceptual framework developed in **Figure 18** from relevant literature and theories.

The structure of the case questions consists of five sections evaluating the firm demographic, the level of IS adoption and use in the firm, the adoption of IoT, questions regarding the factors affecting adoption of IoT with three subsections and round up questions. The first section of the case study questions considers business background, and demographic description, for example, development, establishment, type of business, industry and product and service. This section is useful to gain a concise understanding of the business and to contextualize the use of IoT within that business (Levy & Chard, 2001). The second section of the case study questions considers IS adoption within the business and their existing IS. The questions in this section are asked so as to understand the strategy and goals regarding the adoption of past and existing IS within the businesses in order that this may assist with understanding the IoT adoption process (Imhanwa, 2017). The information regarding the type of decision-making and the person who makes IS adoption decision will provide the researcher with an idea of who should be asked the questions, regarding the IoT adoption intention, in section four of the case study questions. In addition, the questions regarding the pros, cons and barriers that the business faces when adopting IS innovations in general provide the answers that can be comparable to IoT adoption. The third section of the case study questions considers the IoT adoption within the business. This section aims to investigate the firm's deployment, development and understanding of the IoT. The questions are related to issues that may affect the firm's intention to adopt IoT, such as the perception regarding the expected benefit to the firm, partners, suppliers and customers as a result of IoT adoption.

The fourth section of the case study questions considers the factors that affect the IoT adoption intention within the businesses. As this thesis selects the TOE as a primary framework (**section 4.1)** it is appropriate to separate the case study questions regarding the factors influencing IoT adoption into three sections: technology, organisation and environment (Tornatzky & Klein, 1982). For the technological-themed questions, interviewees were asked to explore the influence of six factors upon the IoT adoption intention, including relative advantage, compatibility, complexity, observability, cost and security and privacy risk that is identified from the developed conceptual framework (in sections 4.3) (Rogers, 2003; Tornatzky & Klein, 1982). The organisational-themed questions aim to understand the influence of three factors upon the IoT adoption intention, including top management support, organisational size and organisational structure identified from the developed conceptual framework **(sections 4.2)** (Tornatzky & Klein, 1982). Lastly, the environmental-themed questions focus on the influence of the three factors identified from the developed conceptual framework **(sections 4.2**). These are technological support from vendors, business partner influence and competitive pressures (Tornatzky & Klein, 1982). The last section of the case study questions is a summary section (Myers and Newman, 2007).The interviewees were invited to add, or ask, anything that they felt was required.

Furthermore, the interviewees were asked if they would prefer to remain anonymous or if they, and their businesses, would agree to be mentioned in the study (Imhanwa, 2017).
Lastly, they were asked if they would like to receive the end result of the study (Imhanwa, 2017). **Figure 19** below provides the flowchart for the case study questions:

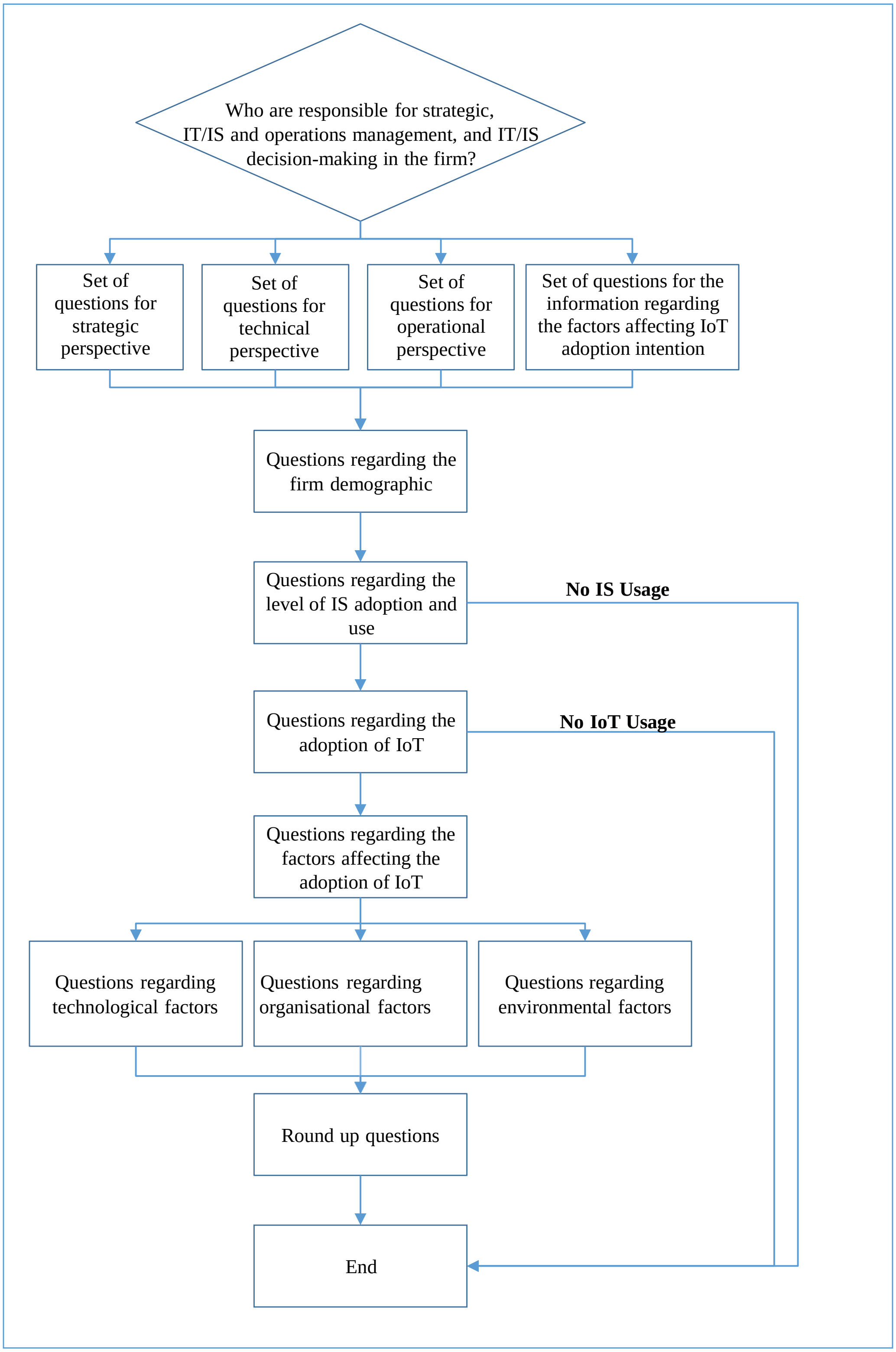

Figure 19: Flowchart for Case Study Questions

Source: Author's own

5.5.7 Amendments to Research Instruments

As a consequence of the UK pilot study, several changes were incorporated into the research instrument with regard to the full study. The interview result identified the requirement for several developments in the form of additions, or deletion or amendments to individual questions. The significant improvement was to remove the questions that were too long, too structured and inflexible, especially the questions regarding the effect of factors on IoT adoption. These questions were reduced in length and refined in order to improve readability. Furthermore, some "why" questions were replaced with "how" questions and vice versa, depending on the interviewee's response regarding previous questions. It was necessary to delete the irrelevant questions for the purpose of this thesis, such as a question asking 'what percentage of turnover does the business spend on IT/IS development annually?' The respondent was not prepared to answer this question due to its sensitivity. The respondent also suggested that the layout of the questionnaire should be rearranged to make it shorter and more appealing, especially the questions in the IT/IS adoption section, which provided a similar answer to questions asked in the IoT adoption section; for example, the respondent suggested going to the question regarding barriers when developing IoT directly. There was no need to go to the questions regarding IS in general first. Some questions that were seen as identical were combined or deleted; for example, the questions regarding the areas in which the business utilise IoT and the questions regarding IoT applications used in the manufacturing site could be combined. A question regarding the compatibility of the IoT systems with the organisation's previous or existing infrastructure was combined with questions regarding the ease by which IoT was integrated with existing IS. An example transcription of the interview with a water technology company is identified within **Appendix 6**.

After the pilot study with three UK firms, the interview was conducted via Skype with a stone mining and manufacturing business in Thailand. The interview was with the project manager. The interview result identified the requirement for minor developments in the form of additions, deletion or amendments to individual questions. The significant improvement was to change the questions in order to offer more focus on the effect of each factor regarding IoT adoption. Furthermore, some questions could be combined; for example, the questions regarding the areas/application where the business used IoT and the questions regarding the benefits from those applications. The irrelevant questions to the purpose of this thesis, such as a question asking the role of each department in within the relevant organisation, were deleted. Certain words in some of the questions were replaced with more specific terminology, such as "concern" instead of "important". After the questions had been adjusted, the follow-up interviews were conducted to obtain further necessary information. The case study research instrument after the amendment is located in **Appendix 5.**

5.5.8 Alternative Data Sources

This section considers alternative sources of data that were used within the analysis of the case studies. Yin (2003) stated that documentary information is valuable for case study strategy. The document needs to be carefully used, as it may introduce bias (Yin, 2003). For the case studies, the use of documents to corroborate with the interview in this thesis helps verify the correct spellings, titles,names of organisations and employees (Yin, 2003). Furthermore, it may support evidence for the result of the interview. McGivern (2006) stated that documentary sources as secondary data provide information within both the area of academia and commercialism. It can also answer the question of why manufacturing SMEs decided to implement, or consider implementing, IoT (McGivern, 2006). It helps researchers understand the strategic focus of each SME on the value of IoT and how they tend to include IoT in their core business strategy (Yin, 2003). It should be noted that some documents might provide contradictory results to the interviews (McGivern, 2006). The documents can be obtained both online and in-person throughout the collection of data stage (McGivern, 2006). Further analysis and interpretation of the data was required. Several documents can be obtained from the following:

- Annual reports (Stake, 1995)
- Business plan (Bell et al., 2018)
- Mission statement (McGivern, 2006)
- Publications (McGivern, 2006)
- Policy documents (Bell et al., 2018)
- Internal memoranda (Bell et al., 2018)
- Virtual outputs, such as internet sources (Bell et al., 2018).

For this thesis, alternative sources of data are utilised as in **Table 11**

Table 11: Alternative Data Sources

Case Study	Alternative Sources
A	Annual report, company website, facebook page
B	Company website, video presentation
C	Business plan, company website, supplier comment
D	Competitor comment, company website, partner website
E	Company website, customer review
F	Company website, customer website
G	Company website, social media
H	Company website
I	Company website, social media
J	Company website, supplier website

5.5.9 Case Study Report

The case study report provides a guide to the final content and layout of each case study (Yin, 2003). Case study reports are often missing from the majority of case study plans (Yin, 2003). Most studies consider the outline, format and audience for the case study report after the data collection process (Yin, 2003). Case study reports do not have a concrete outline and the basic outline of the case study report should be part of the research protocol (Yin, 2003). This will assist collection of the relevant data in the appropriate format as well as decreasing the possibility of having to instigate more interviews (Yin, 2003). However, it should be noted that the case study plans could change after the initial data collection (Yin, 2003). The following headings are the key points of the case study reports: the firm's background and demographic, IS strategy and decision-making within the firm, the past and existing IS adoption and usage within the firm, the adoption of IoT, the factors affecting the potential adoption of IoT with three contexts (technology, organisation and environment) and the conclusion regarding IoT utilization.

5.6 Data Analysis Techniques

This section considers the data analysis technique that has been utilised in this thesis.
The data analysis stage within this thesis processed the collected data from the interview and then documented and put out the findings (Yin, 2003). The analysis used a conceptual framework, along with the data collected, in order to develop a generalisable definition of factors, which formed an emergent theory of IoT adoption by manufacturing SMEs. The emergent theory provided a framework for drawing conclusions regarding the factors that were identified and their influence on the adoption of IoT within this study. Coding and thematic analysis were applied to analyse the data collected in this study. Using this approach, themes were identified, analysed and reported within the data using a word processor to run the analysis. This analysis technique was justified because the nature of the research objective under investigation suited this approach for analysing data; for example, to thematically categorize and interpret the technological, organisational and environmental factors as perceived by key decision-makers and how the adoption of IoT within their organisation is affected. Sheffield (2012) stated that thematic analysis could be used to interpret what influences a participant's behaviour on technology adoption. In addition, Miles and Huberman (1994) stated that a qualitative study aims to describe and explain a pattern of relationships, which could be carried out using a set of specified analytical categories or themes. Furthermore, Saldaña (2015) argued that coding and thematic approaches are one of the most suitable methods for qualitative analysis. The data analysis strategy used in this thesis comprises three simultaneous flows of data analysis processes for the analytical generalization purpose (Yin, 2003). They are data reduction, data display and conclusion drawing, and verification (Miles & Huberman, 1994; Yin, 2003).

Data reduction explores meaning and understanding of the interviews and document data by examining, sharpening, rearranging, focusing, categorizing and selecting (Baskerville, 1999;

Hyde 2000; Myers, 1999; Roberts & Wilson, 2002; Tellis, 1997; Yin, 2003). This data analysis activity can be divided into five stages: initial set-up, data interpretation, data categorization, analytical generalisation and factor definition (Baskerville, 1999; Hyde 2000; Myers, 1999; Roberts & Wilson, 2002; Tellis, 1997; Yin, 2003). The first three stages were utilised within each individual case. The fourth stage was utilised between the cases, and the fifth stage was used todefine emerged factors (Baskerville, 1999; Hyde 2000; Myers, 1999; Roberts & Wilson, 2002; Tellis, 1997; Yin, 2003).

The first stage was the initial set-up, and this specified the case objective and unit of analysis (Yin, 2003). It also provided a guide for interpreting units of analysis by following the conceptual framework developed in **Section 4.2** (Bell et al., 2018). The second stage was data interpretation which aimed to identify evidence within the data by reading the transcript from theinterview, focusing on the relevant text and finding themes by identifying units of analysis (Eisenhardt, 1989). At this stage, the credibility check was required for ensuring research quality and rigour (Eisenhardt, 1989). This check ensures the robust credibility of the themes identified and utilised when creating codes and categories (Eisenhardt, 1989). It may be achieved by cross checking the meaning of text with meanings in similar themes or definitions of theoretical categories in the database.

The third stage is categorization, which used codes and categories for dividing data into segments (Eisenhardt, 1989). This stage helped to organize the themes identified from prior stages (Eisenhardt, 1989). The organisation of segments of text linked to themes, codes and categories enabled a quick search through a within-case analysis data set (Eisenhardt, 1989). A theme was coded by linking a unique code to its related segment of data (Yin, 2003). Each code was a unique identifier for a segment of data that represents a unit of analysis (Yin, 2003). In order to develop a code for a theme, the meaning in a segment of data was compared (Yin, 2003) and if there was a match between data or a pattern was identified, a code for a theme was developed (Yin, 2003). However, if there was no matching or pattern, a new category might be found (Yin, 2003). In this case, the new segment of data was coded (Yin, 2003). In addition, codes were firstly created during the initial set up stage for conceptual framework (Eisenhardt, 1989).

The fourth stage of data reduction was analytical generalization, which analyzed the replication of the codes from the third stage (Eisenhardt, 1989). The frequency of the codes and categories across multiple cases noted that these are high and they were selected since it showed analytical generalizability of the theme that was represented by the codes (Eisenhardt, 1989). The selected codes provided strong evidence that led to a definition of factors in the next stage of data reduction activity (Eisenhardt, 1989). The fifth stage in data reduction activity was definition of factors, which both developed and confirmed the conceptual framework (Eisenhardt, 1989). The process began by creating a theoretical description of the theme represented by the codes, using the explanation of the theory related to the codes (Yin, 2003). Therefore, the theoretical categories associated with the factors affecting IoT adoption provided a strong generalisable description within the definition of each factor (Yin, 2003). The emergence of the definition of factors resulted in the data reduction process (Yin, 2003). The next data analysis activity was data display, which organises and compresses the evidence, then draws the conclusions (Miles and Huberman 1994). It provided a collective view of the data. Eisenhardt (1989); Miles and Huberman (1994); Yin (1994) suggested the use of tables, extended text, matrices, graphs, charts and networks in the case study data display. The last data analysis activity was conclusion drawing (Yin, 2003). This thesis used the conceptual framework developed in **section 4.2** to provide a structure for the reporting of the research finding and conclusion drawing (Yin, 2003).

The conclusions presented the factors identified from cross case analysis, using the conceptual framework to explain those factors and their influence on IoT adoption in manufacturing SMEs (Yin, 2003). Lastly, this study provided a conceptual framework as a representation of IoT adoption by manufacturing SMEs. In addition to interview data analysis, the document analysis was used to support the argument and to complement the data collected through the interviews (Tashakkori & Teddlie, 2003). These documents also helped with understanding the phenomena underpinning the study, and provided background and information regarding business activities such as digitalisation in organisations (Tashakkori & Teddlie, 2003).

5.6.1 Qualitative Computer Software Programs for Data Analysis

Qualitative analysis software programs have emerged in in recent years as a recognised method of analysing qualitative data, e.g. Nvivo. Manual coding is often used in addition to qualitative software programs as an additional quality assurance (Creswell, 2009). This kind of software is often called computer-assisted qualitative data analysis software (CAQDAS) (Creswell, 2009). A sample of the popular qualitative data analysis software programs is Atlasti.ti, QSR NVIvo, etc. (Creswell, 2009). These software types can remove the tasks associated with the manual coding and retrieving data (Bell et al., 2018). However, there is no industry leader for this type of software program (Bell et al., 2018).

Qualitative software programs can assist researchers to organize, sort, and search for information in text or image databases (Bell et al., 2018). Several software programs have similar features: the ability to incorporate text and image data, the feature of storing and organising data, the search ability of locating all text associated codes and themes, interrelated codes for making queries of the relationship among codes and the import and export of qualitative data to quantitative programs such as spreadsheets or data analysis programmes (Bell et al., 2018). Even though the researcher is required to go through each line of text (as in hand coding by going through transcriptions) and to assign codes, using the software programs may be faster and more efficient than hand coding (Creswell, 2009). In addition, the researcher can quickly locate passages or text segments that are coded identically and identify whether participants respond to a code idea similarly or differently (Creswell, 2009).

When all the qualitative data has been gathered, it is kept securely within a file on a computer software package (Quinlan et al, 2019); the image process of analysis will be highly organized and contain less errors within the structure of the data analysis package as opposed to when analysing large amounts of data by hand; it is very easy to incur errors when observing masses of data, and easy to miss relevant issues within the data (Quinlan et al., 2019). Several components of these software's concentrate upon the analysis of textual qualitative data as follows (Oates, 2005):

- Text search: to look for a word of phrase in the text
- Coding: to apply code or categories to units of text
- Data organisation: to organize and file data
- Writing tools: to write notes and self-memos
- Visual displays: to show the relationship between data segments
- Exporting: to incorporate the analysis in another software programs.

In addition, some software provides tools for analysing image, audio and video tapes such as (Oates, 2005):

- Transcript creation: to turn an audio file into text
- Coding: to attach code or categories to video or audio
- Data organisation: to organize and file digitized audio and video
- Hyperlink creation: to create links between different media types.

NVivo is the chosen software for data analysis in this thesis; it allows the researcher to manage data and ideas, and also to query the data (Bazeley, 2007). This software is one of the CAQDAS that has been developed by QSR International, the world's largest qualitative software developer (Wong, 2008). NVivo is one of the most widely used CAQDAS programs (Leech & Onwuegbuzie, 2011). It effectively handles large amounts of qualitative data (Richard, 2002) and it can assist with within-and cross-case analysis, thus it is suitable for comparative study in this thesis (Bassett, 2009). Furthermore, NVivo is a qualitative data analysis tool that is significantly used to manage and code field data (Bhattacharyya & Bhattacharyya, 2004; Caldeira & Ward, 2003). Therefore, it is appropriate to use this with regard to the interview data gathered during the research for this thesis. In particular, NVivo is designed to ease the construction of relational networks that identify the content and structure of participants' opinions (Fraser, 1999; Richards, 1999). It has a variety of search and retrieval tools, which assist with posed questions, or emerging themes from the interview data (Bassett, 2009).

5.7 Validation and Reliability of the Case Study Research

Eisenhardt (1989) and Yin (1994) emphasized the importance of the validity and reliability of the case study. To ensure the validity and reliability, several techniques were utilised (Guion 2002; Lincoln & Guba 1990; Tellis 1997). Yin (2003) suggested that there was a requirement for construct validity, internal and external validity and reliability, in order to increase the quality of the case study evidence. Construct validity was ensured by using multiple sources of evidence contained within this thesis (Yin, 2003). The interview transcripts and documents, such as the firm's mission and strategic plan from each case study, provided a chain of evidence regarding the effectiveness of the data collection phase (Yin, 2003). This study also applied multiple sources of knowledge from various literature and theories pertaining to IoT adoption and diffusion so as to guide the analysis of data from different settings (Imhanwa, 2017). Furthermore, participant corroboration of interview results was to ensure that the information provided during the interview was represented by real opinions (Shenton, 2004). This was undertaken by allowing participants to review the interview transcripts (Shenton, 2004) and the construct validity was ensured by reviewing the case study report in the write up stage (Riege, 2003).

External validity was ensured by applying literal replication logic in each case study and by providing definitions regarding the scope in the research design stage (Eisenhardt, 1989). The case study result was then compared with the conceptual framework developed from the literature in the conclusion **(section 4.2),** therefore, identifying contributions to knowledge (Yin, 2003). Within the context of analytical generalization, the conceptual framework played an important role as an analytical tool for generalizing findings from the different cases (Rowlands 2003).

Internal validity was ensured by utilising multiple procedures in the data analysis phase (Miles andHuberman, 1994); within-case analysis and cross-case analysis. For the case study analysis, pattern-matching logic was utilised in order to compare the pattern of the result of the case study with the conceptual framework; if a pattern was identified, the results could assist a case study to strengthen its internal validity (Yin, 2003). Reliability was concerned with consistency between the case study (Gasson, 2004) and was ensured by the development of the case study database, case study protocol and pilot study (Yin, 2003). The repeated process for deriving the findings could ensure the consistency (Yin, 2003). The reliability was achieved by recording the study activities, analysing the data, and from the coding process of emerging themes (Hoepfl, 1997; Yin, 2003).

5.8 Confidentiality and Ethics

This section considers the issues regarding the ethics and confidentiality. It is critical to address the ethical issues that could have occurred as a result of conducting interviews during the construction of this thesis (Ghauri and Gronhaug, 2010). The main concerns with regards to ethical issues within the qualitative study were: informed consent (McGiven, 2009); confidentiality and anonymity (Bell et al., 2018). Aluwihare-Samaranayake (2012) and Bell et al. (2018) also identified ethical concerns, such as causing participant stress, or asking questions that damage self-interest, and also involving interviewees in research without their informed consent. In order to prevent this, the confidentiality and ethics procedures were required to be robust throughout the study (Quinlan, Babin, Carr, & Griffin, 2019; Saunders et al, 2009). Furthermore, in order to ensure that the research fully considered the participants' privacy and confidentiality, an ethical approval form was submitted to Swansea University ethical committee and this was approved on 22/11/2019. Full ethical approval of application was subject to the process of a risk assessment system, and then a meeting of a full ethics committee was convened to consider all applications that are deemed as high risk (Research ethics, n.d.). After receiving the approval from the Swansea University, a cover letter was prepared. The cover letter clarified the aim of the research project and invited key decision-makers within the organisations to participate in this study. Regarding confidentiality and anonymity, the participant information sheet confirming participant anonymity and confidentiality were sent. Participants' details (individuals' names and organisation names) were anonymized for this study and the names of their companies replaced with pseudonyms to protect the participant's

right to privacy and anonymity (Allen & Wiles, 2016). Furthermore, the permission to use audio recordings was discussed. When informed consent had been obtained from the case study participants, explanation was given to them explaining the overall purpose of the research and how the resulting data would be used (Bell et al., 2018; Maylor and Blaclanon, 2005).
The informed consent allowed the participants to partake, decline or withdraw from the study at any given time (Bell et al., 2018). Once the participants had read the form and agreed to participate in the interview, they were required to sign the consent form (Bell et al., 2018). After the interview, a transcript was used for data analysis and a copy was sent to the participants (Levy & Powell, 2003). All data collected from the interview was kept securely stored within a password protected database and was not disclosed to any third party of any form (Walsham 2006). The research strategy was undertaken in a responsible and professional manner, utilising the appropriate data collection method and interpretation of results for this thesis (Shenton, 2004). The researcher had carefully assessed the possibility of harm to himself and the participants, and made sure to minimise both physical and emotional harm to all parties (Bell et al., 2018). The safety of the areas that were used to undertake data collection was ensured (Bell et al., 2018). The organisations that were used for the studies and the data collection, both in Thailand and the UK, were deemed low risk, and they were all in locations with low crime rates (Changraksa, Yogyorn, Boonyayothin, & Sujirarat, 2018; Tafere, Beyera, & Wami, 2019). A research plan was created to ensure data collection occurred in a systematic and logical manner with no risk to any participant. In addition, the interviews were conducted within a safe office environment with prior approval, and the interviewees were invited by email with all the details confirmed. The copy of the ethical approval from the Swansea University is in **Appendix 4.**

Chapter 6: Findings

6.0 Findings

This chapter provides an overview of the case studies. Thereafter, the research findings and analysis will be presented.

6.1 Overview of Case Studies

This section considers the descriptions of each of the case studies in preparation for analysis of data collection results. The background information for each case was obtained from the in-depth interviews, bureau of internal revenue, organisation websites, brochures provided by the participants, annual reports, mission and vision statements, employee comments, and digital resources, such as company presentations. For this thesis, the use of multiple sources, such as documents to corroborate the interview, aids the verification of correct spelling, titles, names of organisations and participants; it is a contributing element of supporting evidence for the result of the interview. The names of the firms have been replaced with pseudonyms to protect the participant's right to confidentiality and anonymity, as discussed within **section 5.8**. The example of a transcript of a completed interview is with an industrial gas producing firm (Case B) is in **Appendix 7**.

The case-study organisations used within this thesis are the manufacturing SMEs in Thailand. **Table 12** provides a summary of these 10 organisations, which were varied, ranging from stone manufacturing to corn processing, thus ensuring that IoT usage from various manufacturing activities was explored; this enabled the researcher to analyse a diversity of practices and experiences whilst researching for this thesis. The location of the businesses extended from the North to the South of Thailand. The number of employees, annual turnover and balance sheet total of all the businesses combined were within the SME criteria, as in **Table 2**. The number of employees ranged from 30 to 230. The annual turnover ranged from 92 to 2000 million Baht. The total balance sheet value ranged from 56 to 1680 million Baht and the staff positions of the interviewees within the organisations were varied, from Production Manager to Chief Executive Officer.

Table 12: Summary of case-study firms

Case Study	Year of incorporation	Enterprise Location (City in Thailand)	Enterprise Description	Number of Employees	Annual Turnover (millions Baht)	Balance Sheet Total (millions Baht)	Interviewee's Position
A	1983	Saraburi	Stone mining & manufacturing	103	< 2000	372	Project manager
B	1992	Bangopopkok	Industrial gas producing	230	< 2000	1020	Production manager
C	1994	Nakhon Ratchasima	Corn processing	150	< 2000	668	Operations manager
D	2005	Pathum Thani	Precast concrete manufacturing	220	< 2000	1668	Supply chain manager
E	2004	Bangkok	Machinery manufacturing	30	92	< 1720	Chief operating officer
F	1996	Lampang	Coal mining andprocessing	140	444	< 1720	Plant manager
G	1975	Chon Buri	Non-woven fabric& hygiene product manufacturing	130	1144	< 1720	Strategic manager
H	1964	Bangkok	Filter producer	220	< 2000	< 1720	IT manager
I	1988	Nakhon Si Thammarat	Rice producer	30	224	< 1720	Chief executive officer
J	1962	Samut Prakan	Automotive manufacturer	200	Between 1600-2000	< 1720	Chief engineer

This section considers the profile of each case study. The background and IoT usage in their industry and within the businesses will be presented.

6.1.1 Case study A

This section considers the overview of the Case Study firm A: a stone mining & manufacturing firm. This firm was established in 1983 and located in Saraburi. Currently, there are 103 employees with a balance sheet total of 372 million Baht. The main products are more than 16 types of stone for construction; dust stone, and Sam Thap rock, to give examples, with a wide range of size options. Those stones are used for various types of construction, for example, road, bridges and chemical products. The firm produces approximately 2.7 million tons of stone per annum. Firm A's primary customer is a large business that produces concrete and contributes a large amount of revenue to Firm A.. The main suppliers to Firm A are oil firms, as oil is used for every manufacturing process. The firms' mission statement is that they have the highest quality aggregate, the latest production technologies and the highest standards of environmental safety ("CPAC," 2021). This firm has three separate functional departments, namely strategy, IT, and operations. The strategic department initiates plan for IT/IS implementation and then the operation and IT department will produce feasibility plans. Thereafter, all the departments will discuss the possibility of implementing IT/IS, involving strategy, IT and the operation managers in the IT/IS adoption discussions; however, the most influential individual is the strategy manager. The key interviewee was a project manager who worked closely with the IT and operations department and who managed the IoT adoption project.

This section considers the existing IoT usage of Case Study A. Before utilising the IoT, the firm extracted data from machines manually and the data was managed on Microsoft Excel and Word software, with no connections to the internet. With regards to the current IoT adoption in the production line, the firm utilizes IoT sensors and sets up the limitation warning systems with the power gauge, oil level gauge, speed of machine meter and the vibration gauge. The sensors will warn the operators when limitations are reached. Furthermore, the firm utilizes 40 trucks, each of which generally run two kilometers each day between the pickup and drop off areas. IoT sensors are placed on these trucks in order to measure the weight of the stone and count the number of the trucks waiting at pick up areas and at the crushers (to drop out the stones). The software then optimizes the utilization rate of each truck's capacity to carry stone, resulting in a lower total distance that the trucks run each day. Previously one truck was assigned to one pick up station, but with the IoT system each truck can pick up stones from every pick-up station. As a result, the trucks are running constantly by finding the shortest waiting line at pick up spots and at the crushers, reducing the total waiting time, thus improving efficiency and end results. Radio is the only way to communicate between the drivers, but, at present, a monitor is also used to visualize which station to pick up from, and when. To summarise, the firm uses the IoT mainly for accurate operating conditions and logistics, facility management, optimisation, and increasing logistic efficiency.

6.1.2 Case Study B

This section considers the overview of Case Study firm B: a firm that produces industrial gas. The firm was established in 1992 and is located in Bangkok. Currently, there are 230 employees with abalance sheet total of 1020 million Baht. The main products are industrial gases, such as Argon, Helium and Nitrogen, which are delivered through cylinders, bulk, pipeline or on-site supplies. Firm B delivers both pure gases and advanced mixtures. There are small factories and one head office. The firm is at the top of the supply chain, providing the gases to two types of customers:

1) Automotive; electronic, refinery and rubber manufacturing firms
2) Industrial merchandises; hospitals, laboratories and other firms that do not significantly use gas

   This second type of customer orders a small batch at one time. The firm claims to be customer centric and operates 24 hours a day as some of the customers, such as the refinery, require 24 hours gas through the pipeline system.
   The firm includes three departments:

1) Strategic
2) IT
3) Operations.

For the IT department, there are two teams, IT operations and IT support. The IT support team handles administrative jobs, such as document management, accounting and after-sale services. The IT operation team manages the software and program management, such as SCADA. The firm has a protocol for every procedure or potential problem that may occur during the operations; for example, when the firm has an issue with a payment system, it should be reported on E-expense, which is linked to all departments involved. The top management within this firm is Thai by nationality and the key interviewee was a production manager who manages tools and production processes within the firm.

This section considers the IoT usage of Case Study B. Previously, all production processes were manually controlled. They have a distributed control system (DCS) to control and monitor all systems, without a connection via the internet. Once the firm had gathered a significant amount of data, SCADA was brought from another large industrial gas firm, which ensured that the data gathered from operations was available to monitor and extract in real-time. Engineers were not required to go to the factories. Thereafter, executives within the firm adopted the IoT to enable remote operations and data control within the factories. Operators managed this plant through a remote system, similar to the DCS in the control room, from anywhere in the world.
There is an alert system that warns the operators when machines breakdown, or inventory reaches a minimum level. This warning will be sent to the operators’ email through SCADA.

Having the IoT system reduced the cost of hiring operators and optimized the processes. Furthermore, because issues usually occurred similarly in each plant, the firm hired data analysts to analyse data collected from IoT equipment and to set up preventive maintenance. In the future, all data will be kept on a database, thus creating big data. The firm uses at present a paper-based system called logbook, but they are endeavoring to use tablet technology to fill up the data and report any information through platforms. Therefore, the firm could predict the demand for each product from various customers, thus reducing inventory levels. To summarise, the firm uses several applications of the IoT; first, facility management to enable predictive maintenance and alert engineers when machines breakdown. Second, digital/connected factories by way of sharing real-time and graphics-intensive information globally and managing the factory unit remotely. Third, inventory optimisation by reducing safety stock levels, as the IoT can precisely estimate available material, work in process and the arrival time of new materials.

6.1.3 Case Study C

This section considers the overview of Case Study C: a corn processing firm. The firm was established in 1994. It is located in Nakhon Ratchasima. Currently, there are 150 employees within firm C with a balance sheet total of 668 million Baht. A significant portion of revenue comes from baked corn, for which the main customer is a large food producer. The firm's revenue has been increasing over the past 5 years, as their customer was expanding its business, and that requires a large amount of food material, including baked corn. Initially, firm C was only a food material purchasing business, trading material on paper, thus not having significant fixed assets. However, the firm currently has manufacturing activities, one of which is processing corn (baking). The firm rents warehouses and factories to store and process the corn it receives from farmers. The goal of the firm is to provide sufficient processed corn for the customer. Nevertheless, the corn baking factory currently use only 50 per cent capacity; as firm C expects an increase in demand from the customer, more warehouses will be required, and a centralised system will be deemed necessary.

Because the firm is renting warehouses and factories, they prefer to invest in movable and less costly equipment. Thus, the IoT was introduced. In addition, their customer has exported products to Europe, hence, the food safety standard in terms of material sources is a concern, especially the food for humans such as Tuna and canned food. To be able to control the quality throughout the manufacturing process, everything needs to be traceable, and that is another reason for firms to adopt IoT. The firm's mission statement is to be a leader of the agriculture and food industry by expanding a variety of processed agri-food products (BPM, 2021).
The firm has three departments: strategic, IT and Operations. The key interviewee was an operations manager within the firm.

This section considers the IoT usage of Case Study C. The firm used a programmable logic controller system (PLC) in the control room, which could not monitor the baking process in real-time. Their PLC system was not effective, because complex logic cannot be input. Furthermore, the response to feedback for each parameter which affects the product quality, such as the humidity percentage, is slow and inaccurate, since the data was collected and analyzed manually; furthermore, the data regarding the condition of the corn required an update every 30 minutes. The operations manager received the summary of this data on paper, and at the end of the day, which is already outdated. Humidity is crucial for corn baking processes, normally, the corn should be at 14 per cent humidity so that when it is dried, it will not deteriorate rapidly. Conversely, if it is overdried, the corn will be lighter. This is why it needs to be kept at 14 per cent humidity exactly.

To summarise, the firm intend to adopt the IoT to undertake remote monitoring and control. This would be convenient for operations managers, as the head office is in the capital city and eight warehouses are in the countryside. As previously stated, conditions such as humidity during the manufacturing processes are crucial. The IoT would enable real-time and accurate operating conditions within manufacturing environments. Furthermore, traceability is required to track the whole supply chain from the farm, trucks, factory, warehouse to customer, in order that problems may be identified quickly.

6.1.4 Case Study D

This section considers the overview of Case Study D: a manufacturing firm that makes precast concrete. The firm was established in 2005 and is located in Pathum Thani. Currently, there are 220 employees with a balance sheet total of 1668 million Baht. The firm's main product is precast concrete used for housing construction. Most of the firm's revenue comes from a large real estate firm. The firm was established at a point when the housing demand in Thailand increased significantly, and construction firms started to collect land and move into the real estate business. As the demand continued to increase, the firm had to change from building houses individually, so as it could become more systematic. Firm D has seven small factories that produce each part of a house, including concrete walls, floors and poles, and components such as a pillar, dome and fences, and ready- made toilets. Typically, each part of the house is manufactured separately, prior to assembly. Firm D is the first precast manufacturing firm in Thailand. The firm has national (internal) and international (external) customers. Internal customers typically are the business development teams of real estate companies that initiate housing projects and create business plans, including where to develop real estate, the design and market segment focus. Firm D will provide the designs to produce such properties. After the house building process is completed, real estate companies will sell them to customers.

Typically, firm D produces precast for houses and relatively few for condominiums. In addition, their suppliers are firms that produce both concrete and steel. The firm currently uses real estate manufacturing systems (REM) as the main system. The factory brought in an autonomous system technology from Germany, which is controlled by a computer at every stage of the process. Shuttering robots are utilised in the factory to both reduce the number of workers and increase the quality of the products. In addition, a concrete recycling system is used to separate sand and concrete from waste and to recycle them. The factory is a green factory as it utilizes a closed-loop system, resulting in zero dust pollution outside of the facility.

The key interviewee was a supply chain manager who is responsible for material resources planning (MRP). This individual works closely with the business and operations department, to integrate the supply chain or resources management and business. This section considers the IoT usage of Case Study D. The main reason why the firm implemented the IoT is that the supply chain was unmanageable, as every system used in the firm was not integrated. Those systems are MRP, procurement system and sales systems, to give examples. When the firm makes a decision, it typically involves 5 to 10 systems, and the interaction between systems has the potential to cause error. Therefore, the main purpose of using the IoT is to put every system on a single platform, thus creating a system backbone, and connecting all the systems to the internet. The firm has a new system development procedure as follows: realise the entire current processes in the factory; identify the problems of the current processes; redesign the current processes; convert the redesigned processes into IT/system requirements; develop the systems; test the systems; and go live. Currently, the firm is at the stage of redesigning the processes, which are approximately 20 per cent of the completed IoT projects.

In summary, the firm uses two applications of IoT. First, supply chain visibility and optimisation from vertical integration between the all parties' systems and the elimination of data asymmetry issues. Second, the digital factory, by enabling IoT-based factory automation.

6.1.5 Case Study E

This section considers the overview of Case Study firm E: a machinery manufacturing firm established in 2004 and located in Bangkok with 30 employees. The annual firm revenue is 92 million Baht. Firm E is a family business, controlled by family members. Their main product is machinery used within the rubber, plastic, and food industry. This firm is regarded as a sophisticated firm due to the fact that they implemented and utilised PLC and touchscreen technology within their factory before their competitors did. In 2019, Tesco Lotus, a supermarket in Thailand, hired the firm with regard to adopting the IoT system for their warehouses, and this was the point that firm E decided to establish a new software business and began to work on the IoT project. Their main software product is an application for automating machinery.

Within the machinery manufacturing business, the key difference between the firm and its competitors is the technology that has been utilised in each of the machines; the firm seeks to adopt new technology every year. Because it manufactures a software product, the systems in the machinery manufacturing factory are developed in-house. The factory is accredited to the ISO9001 standard. Not only does the firm adopt the developed software within their own factory themselves, they also develop the software for the customers who bought the machines from them. For example, a rubber factory that has low skilled technicians and engineers could not solve the software problem within their factories, so firm E provides the service of changing from the PLC system to a Relay system, which requires more physical wiring, but is more easily understood. Hence, if there is anything broken, the engineers of the rubber factory could replace it with a new one at less cost. The key interviewee was a chief operating officer, managing the software business, the sales and the operations of the manufacturing business.

This section considers the IoT usage of Case Study E. The firm uses IoT mainly for factory automation, but they also implement the IoT system for their customers' factories, In particular, for customers having several factories with requirements for remote monitoring and controlling. For example, Tesco Lotus needs all its warehouse systems to be integrated and they need to be able to monitor and adjust key parameters online from the headquarters. With the adoption of IoT,the firm can collect the data from machines which have been sold to customers. Thus, the firm can analyse the occurrence of errors from the machines as IoT devices are attached to them, enabling predictive maintenance.

6.1.6 Case Study F

This section considers the overview of Case Study F: a coal mining and processing firm. This firm was established in 1996 in Lampang and employs local people. Currently, there are 140 employees, with an annual revenue of 444 million Baht. Typically, there are three types of coals which can be sold in Thailand: 'shell' (low grade), 'lignite' (medium grade) for use in electricity-producing and concrete manufacturing, and 'subdominant' which is used within forms that manufacture steel. However, Firm F does not produce the last type of coal. The main product of Firm F is lignite, which is sold solely to a large concrete firm in Thailand. Another product is industrial sand, which is sold to customers from a range of industries, but mainly to toilet manufacturers. The factory is a semi-open cut type whereby the manufacturing and mining site is inside a mountain, and it keeps the noise and air pollution inside. The firm also has a policy of planting trees in an area once the mining there has concluded. Furthermore, the firm utilises an environmental protection technology, which can eliminate dust in the manufacturing site with an 99 per cent elimination rate. The firm sets up an emission limitation of coal dust at 50 milligrams per NM^3. The firm has not been growing significantly, as the government has strict environmental legislation regarding coal production. The senior manager expects this emphasis to continue. The key interviewee was a plant manager, controlling the processes in the plant to meet the firm's requirements.

This section considers the IoT usage of Case Study F. The firm has limited machines, thus there are no information and communication systems used in the mining processes. However, there is a SCADA to control electricity and manage information during the crushing processes for coal manufacturing. The firm intends to adopt the IoT by connecting SCADA to the internet in order to be able to monitor the power consumption of each machine. In addition, the environmental standard, such as the quality of water, air and sound, would be monitored in real-time. Furthermore, the long-term plan would be to use robots instead of humans in the manufacturing site, as the coal mining and manufacturing site is unsafe, thus using robots would reduce potential accidents. In summary, with the IoT adoption, the firm would enable real-time and accurate operating conditions within manufacturing environments.

6.1.7 Case Study G

This section considers the overview of Case Study G: a non-woven fabric and hygiene product manufacturing firm located in Chon Buri. Firm G was established in 1975 to manufacture conventional textiles for underwear. Currently, there are 130 employees with an annual revenue of 1144 million Baht. The largest underwear firm in Thailand was Firm G's main customer and consequently the firm was able to expand by introducing a product line of conventional textiles for bedding. In 2015, the demand for conventional textiles was in decline, hence the firm sold-out of the bedding textile business. Thereafter, the firm began a new product line: industrial textiles, a non-woven fabric for use in the automotive manufacturing and air conditioning industry. In 2020, firm G established a new business: hygiene products such as masks and gloves. Currently, the main products of the firm are non-woven fabric and hygiene products. In total, 80 per cent of their total revenue is because of their produce of non-woven fabric, and 20 per cent to hygiene products. The firm has doubled its revenue in the past two years as they have expanded to include e-commerce channels. However, the firm's senior managers expect that the demand for car parts from the automotive manufacturers will be declining, as the labour cost in Thailand is increasing. The vision of the firm is to be a leader of the textile manufacturing industry in Thailand.

The key interviewee was a strategic manager with experience in retail marketing. This section considers the IoT usage of Case Study G. All businesses incorporated by the firm are using SAP for the IS system. However, only the non-woven fabric business unit currently uses IoT within the factory. The machines and systems are ready for IoT implementation, however, they are not as yet fully utilised, as the managers do not see it as advantageous. Currently, Firm G uses IoT for inventory level monitoring and forecasting through the dashboard. As a result, the material order is manageable in a more efficient way. In the future, the firm is expecting to utilise the IoT for remote controlling and automation. In summary, the firm uses the IoT for inventory visibility and optimisation by providing precise estimates of available materials, work in process and arrival time of new materials.

6.1.8 Case Study H

This section considers the overview of Case Study H: a filter producer with head quarters located in Bangkok, Thailand. The firm was established in 1964 during the rise of an automotive era in Thailand. Currently, the firm has 220 employees with an annual revenue of less than 2000 million Baht. The main products are:

1) Air filters
2) Oil filters
3) Fuel-water separator filters
4) Industrial (air) filters
5) Ecology-type filters
6) Hydraulic filters
7) Cabin air filters.

The firm's suppliers distribute materials that are used to produce filters such as steel sheet, glue, plastic pellets and paper. The firm supplies filter products to OEM firms such as IZUZU and Hino, OES, and after-market customers worldwide (mostly Japan and US). The main customers are in the following industries:

1) Automotive
2) Power sports
3) Marine
4) Medium and large trucks; forklifts; construction equipment
5) Agricultural equipment
6) Industrial equipment with over 6,000 different product lines.

The exhaust filter product can be used for almost anything that has an eternal combustion engine, as the combustion process will produce waste such as oil and dust. Therefore, it requires filters to reduce contamination. The interviewee is an IT manager, responsible for the firm's IT/IS, manufacturing processes and machines improvement within the factory. The interviewee is the third generation of this family business, and the key interviewee was the initiator of the firm's IoT adoption project. The manager initiated the PLC and other IS systems to the firm, such as a marketing software to improve sales and emphasise the importance of continuous process improvement.

This section considers the IoT usage of Case Study H. Previously, the firm have used Relay, Netware and Disk Operating System (DOS) for the operating systems, as Windows is not considered by all as a stable enterprise system for industrial processes. Thus, the firm decided to replace the Relay system with the IoT. Regarding the IoT system within the factory, the firm uses Genesis, Genesis64 and Open Platform Communications (OPC) server (a driver to gather all PLCs and to communicate between the machines) for the IoT software. RS485 protocol is utilised to communicate IoT devices, such as sensors. The IoT costs roughly 10,000 Baht per machine. With the OPC server, the internet and LAN wiring, for example, it would be 200,000 Bahtfor 10 machines, compared to 500,000 if the firm decided to hire vendors. Therefore, the firm developed the IoT system in-house. The firm utilizes IoT with HMI (human-machine interface) in the factory. Currently, the IT (server and database) such as Window server, Structured Query Language (SQL), Cloud-based system and IoT are utilised in the manufacturing site. As the firm does not have a specific department to adopt the technology, most work has been initiated and managed by the operations manager.

Currently, the firm is working on a IoT pilot project, embedding IoT with 10 machines. The machines are able to capture key data, such as the number of pieces of filters being processed to control the production quality. In addition, the IoT can identify problems that may occur with the machines by utilising the data generated from the machines, as it is transferred through the internet to the operation manager's computer. The factory has previously used control panels and hand switches to input or manage data. At present, IoT with the HMI from Taiwan and China is adopted and utilised.With the HMI, the firm would save costs on equipment such as wiring. In addition, it would be convenient for the workers, as they only need to monitor one screen at each machine. Furthermore, the IoT could collect the pertinent data from the machines with regards to the jobs of the workers in order to monitor these jobs. In summary, with IoT adoption, the firm is able to enable real-time monitoring for both the processes and workers to improve production quality. In addition, the IoT minimizes machine failure by warning the operations manager when the problem at each machine occurs. Nevertheless, the factory does notsee it advantageous to utilise IoT to control the machines as yet.

6.1.9 Case Study I

This section considers the overview of Case Study I: a rice producer. The main product is uncooked milled rice. The firm is located in the south of Thailand and was established in 1988 asthe first rice producer in the region. There are 30 employees with an annual revenue of 224 million Baht, and the initial business was as a wholesale producer of rice, sugar and drinks, to name a few examples. They then proceeded to focus on selling rice, as it was deemed to be more profitable than the other products. On the 15th August 1988, the business became registered as a rice trading firm, 'Kao Chat Thai Rung Rung limited'. Historically, rice was sold in sacks of 100 Kilograms only and the customers needed to come to the stores to buy it; however, it was too heavy for customers to carry. The firm recognised this as being a difficulty for its customers and decided to offer a delivery service. As a result, they could gain market shares from the other rice retailers and wholesalers. The business continued growing, from one rice storage unit to 15, located in commercial buildings around southern Thailand. The business then expanded to become a large factory and warehouse. The firm transitioned from a trading firm, to manufacturing (process and package) and distribution. In 30 years, the firm has evolved and developed the products and processes in many ways; first, they created a greater variety of sizes of sacks of rice, from having just100 kilograms per sack to 5, 10,15 and 48 kilograms per sack. Secondly, they brought in the information system to check the customers' history and orders (first mover in the South. (KCR, n.d.) and third, they created house brands; prior to this, there were only the very well known rice brands for exporting but none for domestic purposes. Currently, the firm has three main house brands: Sawadee, Kanokthai and Thengthong. In terms of quality control, rice producers typically filter the rice quality by hand. However, this firm has adopted machinery for quality control.

At present, the main manufactured product is processed rice, varying in quality, price and types. The firm buys the rice from rice mills outside the South of Thailand, which the factory will then process and pack into sacks. Thereafter it will be sold to retailers and wholesalers in the south of Thailand. The firm has three small factories and one head office. Its total production capacity is 100,000 tons of rice a day. The main machines in the factory are stone-waste sorting machines that purify the rice from dirt, polishing machines to whiten the rice, multi-colour sorting machines to separate each type of rice and digital scales controller feeders to measure the weight of the rice (This one is currently embedded with IoT) in decimal scale from 0.5 kilograms to 50 kilograms per sack. In addition to rice products, the firm has a service business that they may provide consultation to the customers who are endeavouring to open a rice shop. The firm also sells equipment to rice wholesalers, such as sacks of (5-15 kgs), sack-sewing machinery, sack sewing needle, a pallet to store rice and a digital scale controller. Furthermore, the firm is an OEM, producing rice for other rice brands when the machines are available to do so. The key interviewee was the CEO, responsible for managing the entire firm.

This section considers the IoT usage of Case Study I. The firm uses manual processes to scale the proportion of mixed rice. Each rice production line produces different types of rice before proceeding to the mixing process. The size of the hole after drilling is estimated by the workers based on flow rate they need. Thereafter, the executives of the company decided to adopt the IoT in 2015 and the firm hired software engineers to develop IoT software. The concept and system architecture was the owner's idea; he adapted the concept from the drug manufacturing industry, which requires a deliberate process. The objective of implementing IoT was to gain more accuracy in the rice mixing process. With the IoT, the mixing and processing machines would be able to communicate in order to adjust the right flow rate and mixing proportion. For example, typical rice producers are able to mix rice in an estimated proportion such as 70:30 of rice A to rice B. By contrast, with the IoT embedded within the machinery, the firm could mix it in fine-scale such as 72:68. The managers thought that this would bring an advantage over competitors, as accuracy brings about both cost-saving and customer satisfaction. The firm would be able to provide any price and weight of rice based on individual customer requirement. In addition, the CEO emphasises that the key point of the IoT system are the sensors that control the flow rate of each type of rice. The sensors can stop or alert the workers if the required proportion is reached automatically. At the end of the day, the data would be summarized to plan for the inventory and accounting. This fim not only used the IoT within the factory setting, they also adopted it within their marketing department. ERM is utilised to store and keep the customer's data, which is updated in real-time and can be monitored by management. In summary, the firm uses IoT mainly for smart processes, creating a more customer-centric product and promoting more efficient use of resources. As a result, the firm can differentiate themselves from competitors and increase their revenue.

6.1.10 Case Study J

This section considers the overview of Case Study J: an automotive manufacturer. The firm was established in 1962 and is located in Samut Prakan, Thailand. Currently, there are approximately 200 employees with an annual revenue of between 1600 to 2000 million Baht. The firm's main customer is a large Japanese automobile manufacturing firm, and Firm J mainly assembles trucks for the company. The finished trucks will be sent to the automotive manufacturers, and they will distribute to their dealer later. The firm also manufactures auto parts for export.
With regard to the manufacturing process, the production consists of five main processes, each of which is equipped with equipment so as to reduce the amount of waste, including environmentally harmful substances such as air pollutants and waste-water, as well as noise pollution. Firm J has recently developed a process for the disposal of both liquid and solid waste. The first part of the manufacturing process is to create a mould for the different parts of the body of the car. It consists of sub-processes: trimming of parts, preparing of holes and binding of the finished parts. An automatic, computer-controlled system for maximum efficiency and accuracy is employed to achieve a result. The second process is welding. which begins with the welding of body parts by employees; robots are used to weld the main body parts whrn this first step has been completed. The third process is the painting, which begins with washing the oil and dirt form the vehicle, and when clean, the body is coated with rust-

resistant primer before the body is placed on the assembly line where seams are sealed and the body is primed and painted. The fourth process is pre-assembly which involves separation of parts into groups for easier inspection and more convenient access during assembly. The final process is the assembly of the engine compartment, suspension and passenger compartment. After painting,the body is put on an assembly line, where the suspension, engine and passenger compartment components will be assembled.

Regarding the materials used for manufacturing, some of them are bought from other companies, such as the gears and the engines. However, some parts are manufactured in house, such as steel sheets that are transformed into car parts by way of stamping machines. The firm strategy emphasises continuous improvement and process optimisation in order to remain competitive, with its focus upon innovative products and process development. The firm has been granted ISO 14001:1996 and certification for environmental protection in 1997 and 1998 respectively. The key interviewee was a chief engineer, overseeing the operations department and has been with the firm since 2002. This section considers the IoT usage of Case Study J. They use PLCs and SCADA systems on the factory floor to control the machines and conveyor lines that are directly making the car parts. The general information systems used within the firm are Oracle so as to keep, monitor and control the cost of production. However, the firm is planning to use SAP instead. Examples of the gathered data are direct and indirect material cost, and budget. Regarding the IoT, the IoT system and equipment are embedded with conveyors to monitor the stop time and count the number of cars that have been manufactured. Furthermore, the conveyor with IoT can collect, in real time. the data on flowrate and track-time of each process undertaken on the production line. The data from the conveyors is sent to the server via the internet and is securely protected. The engineers use the real-time information for production control and efficiency improvement. The firm aim to have above 95 per cent efficiency for each process and they plan to manufacture 105 per cent of the order, as they expect that some of the vehicles will have defects. Most of the issues will still require engineers to be on the site and solve issues such as the unstable flowrate at the conveyor belts. The real-time monitoring of the production process is critical, as the conveyor belts never cease to run. If any processes were to be stopped, the entire factory is required to cease also because the processes are housed next to each other. Furthermore, IoT is used to monitor the energy in kilowatts per hour (KWhr) and to monitor the Carbon dioxide (CO_2) emission in real-time. The chief engineer may view all the data held on the computer at any time. In the future, the firm plans to bring in AI and integrate as many processes as possible to reduce the number of the human workforce. The firm uses IoT to reduce the time of communicating through a paper-based system - as well as on the production line - as the IoT will integrate data and ensure that information systems are more centralised. In summary, the firm uses two applications of IoT. First, facility management to ensure accurate operating conditions within manufacturing environments. Second, the production processes will monitor in real-time to increase operational efficiency. The next section will consider the finding as evident within the case studies.

6.2 Thematic Analysis

This section provides the findings from the semi-structured interviews that have been undertaken with ten manufacturing SMEs in Thailand, organisation websites, brochures provided by the participants, mission and vision statement, employee comments and company presentations. The majority of cases (80 per cent) were interviewed twice to ensure that all aspects of the intention to adopt the IoT were examined. The remaining 20 per cent provided significant clarity on the data collection and further interviews were not required. The findings used a thematic analysis technique **(section 5.6)** to identify themes relating to IoT adoption intention within each of the firms. Thirteen factors emerged that were shown to have an affect upon IoT adoption within manufacturing SMEs in Thailand; these were classified into three main themes namely technology, organisation and environment. The influence of those factors is discussed in this section. Direct quotes from interviewees are included to provide a richer interpretation of the findings. In this analysis, the names of the firms have been replaced with pseudonyms to protect the participant's right to privacy and anonymity. **Table 13** provides a summary of the result of the findings as evidence within the case studies. The next section considers the details for each factor that affects IoT adoption in Thailand manufacturing SMEs, as well as their influences.

Table 13: Summary of Result of the Finding as Evident within the Case Studies

Factors	Thai Case A	Thai Case B	Thai Case C	Thai Case D	Thai Case E	Thai Case F	Thai Case G	Thai Case H	Thai Case I	Thai Case J
Technological factors										
Relative advantage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Compatibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Complexity	No	No	No	No	No	No	No	No	No	No
Trialability	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Observability	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes
Cost	Yes	Yes	No	Yes	Yes	Yes	No	No	No	Yes
Security and Privacy	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes
Organisational factors										
Top management support	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Organisational size	Yes	No idea	No	No	Yes	Yes	No	Yes	No	No
Organisational structure	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Environmental factors										
Technology support from vendor	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No
Business partner influence	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Competitive pressure	No	Yes	No	No	No	Yes	No	No	Yes	No

6.2.1 Relative Advantage

This section examines the relative advantage factor promoting the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.4** and **4.1.6**. All of the cases perceive the IoT as a technology offering greater advantages than their current information technology. They believe that the benefits of the IoT positively affects the adoption intention. The relative advantage of the IoTs that is shown within the case studies are the convenience of use, enhanced image, efficiency, and economic value. The majority of the cases (A, B, C, E, F, H, I) reveal that more convenience of use is one of the main reasons for IoT adoption. Specifically, the IoT would decrease the workload of managers, engineers and workers in the long term. The following quote offers further insight:

> *"It is easier to expand the type of service as IoT makes the employee more efficient in controlling and monitoring the machines, thus can have more workload." (E)*

In addition, the IoT could improve data collection processes and reduce the complexity of the processes:

> *"Imagine that the controller of a baking process still uses paper to keep the information, but I need to analyse it on excel, therefore, they need to hand in the papers to someone in the office every evening (48 rows of information, 10 data for each row) who need to put everything into excel. But if the data flow into the database automatically, we could reduce the tasks." (C)*

However, it should be understood that such a strategy requires training, adaptation and change in existing systems, which impacts upon employees. Therefore, there is a need to convince people regarding the value of these changes:

> "*We need to make it easier for them to use. But there is no way to make it successful at first, we need feedback and programmers could not consider and cover every aspect in one time. We need to try it first so we can know the problems. We need to do continuous improvement and gradually adjust everything until internal customers satisfied (employees)*." (B)

The IoT would enhance the ease of use within the factory from data visualization. Case H stated that it has utilised HMI with IoT systems for each machine. This is convenient for the workers and engineers alike, as they will know how many pieces have been produced and that is easier for them:

> "*Furthermore, we do not need to use hand to adjust the machines, we could just click on the screen when we would like to order the machine to do something. Besides, I would save more time by using IoT. In the past, it had a lot of problems as the worker could not monitor the machine all the time, and they may miss some problem as well. After adopting the IoT, we can monitor the machine in real-time on the screen which is quite easy to read every parameter at the same time*." (E)

Other than increasing the convenience of use, the IoT is regarded as a tool that will serve to strengthen the image, or the status, of the firms (A, B, E, F, G, H). The IoT systems support traceability and visibility, and they increase organisation efficiency and effectiveness. Such improvement will only boost the credibility and reputation of the firm, and this will potentially increase customer satisfaction:

> "*In the past customers phone in to order. Currently, since we have an application for them, they could simply look into the data on the application. Or some data they could just look at the date online. This makes them feel like they can trust us. They could rely on our product. In addition, when they order something, we can plan for them, so they do not require inventory and waste much product. They will feel the stability of our firm.*" (B)

Firm G emphasises the positive boost to the image of the firm, rather than the economic value:

> "*Actually, my father decides to have those advanced machines. However, I do not think the main purpose is the economic value but to increase the image with less cost*." (G)

By contrast, Firms A, D and C note that cost saving is more important than the enhanced image oftheir firm:

> "*because to look more innovative, do we need to invest in the IoT? So more or less, not really. There are many ways to increase innovative image.*" (D)

In addition, Firm J does not see the image as a determinant to the IoT adoption, as it was not technologically able to enhance the image of the firm:

> "*Ummm not the priority as our customers do not see the factory inside and they do not want to know. They only want to have good cars. That's it. Also, we could lift our image by doing CSR instead." (*J)

Furthermore, it is apparent that every case expects the implementation of the IoTs to improve the efficiency of their business in various ways. The IoT may reduce the time and number of workers in the factory; for example, Firm A utilizes the IoT in order to reduce the running time of the trucks. By contrast, Firm F replaces the worker with machines and assigns them to more significant jobs:

> *"Each truck will pick up the stone, carry it over, and then drop them to the grounding machine. Thereafter, they go to the scale to get the stones again. With the IoT attached to the scale, we could count the number of the trucks waiting to pick up stones. In addition, the spots at the grounding machine have sensors to count the number of trucks waiting to drop the stone. So, with these sensors, they can tell which crusher the truck should drop out the stones. This makes the trucks running all the time by finding the shortest waiting line at pick up spots and the crushers."* (A)

Firms B and C intend to utilise the IoT to enable remote monitoring, thus eliminating travelling time:

> *"The first objective of using IoT would be remoted monitoring. As I am in the capital city, but I need to monitor 8 warehouses. We want to make it systematic. As I mentioned, we will expand the number of factories, so the experience of people is not enough when comparing with a good control system. We would like to delete the uncertainty." (C)*

Firms C, F, I and J utilizes the IoT for real-time monitoring, improving the efficiency/effectiveness/quality of the operations and products:

> *"IoT systems embed in conveyors to monitor the stop time. So, it can measure the time of each process. So we would know stop time of each process. We use this for the production control to improve the efficiency in production lines. Furthermore, I can look a the final screen to see how many cars have been manufactured or are manufacturing. We would know the flowrate or track time of each process. There are 5 main processes in our factory: welding, painting, assemble,…and there are KPI for each process that we have to monitor. We aim to make above 95 per cent efficiency of each process. The IoT will count the number of cars come out of each process. This will let us know which process has a problem." (J)*

Another example of efficiency improvement capability of the IoT is power consumption and environmental monitoring, such as quality of water, air and noise pollution (F). Furthermore, the IoT enables traceability in the food supply chain, as traceability requires accuracy and real-time monitoring (C) so as to control food quality:

> *"At present, it is difficult to control the baking process in real-time, because we now use paper-based systems. Can you imagine that you have a lot of must-controlled parameters to monitor, quality, etc. and we updated the data of our corn every 30. The issue is that the information would be outdated as I receive it at the end of the day only." (C)*

Case Study I states that increased accuracy in production processes enables greater variety of products:

> *"The main reason is that my father wants more accuracy. For example, some other firm might be able to mix 70:30 of rice A and B but we could do something like 70.33:29.67. In addition, I was the one who improves the accuracy of the machine to be automative. More specifically, at the motor to control the flow rate of the rice." (I)*

Another application of the IoT implementation within the case studies is the system and data integration to increase efficiency throughout the supply chain, both eliminating the paper-based systems (reduce communication time) (J) and reducing the miscommunication between parties. Several of the case studies were able to provide tangible examples of how IoT usage had enhanced their organisational efficiency. This use of IoT technologies represented a significant investment in information technology as part of a wider strategy that effectively embraced the technology within the firm. An example would be in Firm G, where everyone could utilise the system data on the same platform (G):

> *"There is currently an integrated system of various sub-systems. To make a decision,it involves 5 to 10 systems. So, every interaction between the systems could cause some error. The first goal of the IoT is system integration. It does not mean to integrate all the systems like 500 systems. I mean to reduce and integrate them such as selling system, manufacturing system, procurement system, MRP, etc. What we want is a platform to manage the supply chain and business together. The second priority is data integration. In the past one set of data might be in different systems, and all of them sometimes are different. The integrated data system would result in more efficient planning, business management, supply chain, and continuous production." (D)*

Some firms utilise the IoT to reduce the machine downtime during production processes by issuing an alert when the machines require regular maintenance (E, G):

> "*Also if they have any issue with the machines, we could report to the machinery manufacturers in real-time, then they could check up online and fix the problems remotely*." (G)

The majority of the cases intend to adopt the IoT because of the economic value it offers. The majority of cases are saving costs, thus leading to increased efficiency, effectiveness and quality. Further advantages include the increased potential to predict demand, and reduce machine breakdown and human error. The IoT may reduce operating expenses, such as fuel cost, which equates to 60 percent of the total expenses for firm A, and the number of operators for firm J. Case H mentions that current IoT hardware is not as expensive as previously. The cost-saving benefit was expressed in several ways:

> "*For the central system, it will reduce the cost of hiring operators, also optimise the processes. We optimise and simulate the data for scenario and situation that we used to use the experience to make decisions. Usually, we want 3 years payback period. So this investment is definitely worth it. Furthermore, we can predict the demand of each product from each customer. Hence we know who dislike or like what? This will reduce inventory level*." (B)

> *"It is not accurate since it is noted by a human. We need to bake the corn until the humidity is at 14 per cent. When it is dried, it will not be rotten easily. If it is overdried you could get less money as they would be lighter 10 per cent reduction cost estimation. The problem is we can not control it well because of slow feedback, and inaccuracy of the information." (C)*

In some cases, increasing revenue was emphasized more so than cost-saving. Case D states that the IoT could expand their customer numbers:

> *"The economic benefit can be in form of expanding customer, etc. to increase the marginal profit. So, I mean IoT may not save cost, but it may increase profit and increase cost but less." (D)*

In summary, all of the cases argue that the IoT has a relative advantage over existing information technology, namely convenience of use, ability to enhance the image of the firms, efficiency, and economic value. Most of the functions of the IoT mentioned in the cases studies are real-time/remote control and monitoring in production, data and systems integration, and data visualization improvement.

6.2.2 Compatibility

This section examines the compatibility factor for IoT adoption in Thai manufacturing SMEs. This issue was considered in **Section 4.1.4, 4.1.5** and **4.1.6.** It should be noted that this factor is presented within the table as a technological factor, as the discussion was focused on the technological perspective. All of the cases argue that the consistency between the IoT system with current infrastructure and systems, existing values, IT department expertise and knowledge/experience of the employees, requires consideration. They believe that compatibility negatively affects the IoT adoption intention. Half of the cases (A, B, C, D, F) reveal that the existing technological infrastructure and its ability to easily integrate with IoT systems are concerns. The firm might want to install new hardware (such as transmitter (C), or software, causing further depletion of the investment budget. Firm C stated that, as their factories are different, various types of IoT hardware are a concern. In addition, they state that the return on investments are required to be evaluated:

> *"But we need to validate to see how much do we need to get rid of old systems and is it worth it? We need to estimate if we could get a significant return or not. If it can increase profit we would get rid of the old system. If not, we would try to synchronize with it first or try to find other IoT service provider." (B)*

Regarding the infrastructure requirement, it was highlighted that the stability of the internet connection on the manufacturing site is the main issue (A, B, F), especially for factories considered to be in harsh environments, such as the mining industry (A and F):

> *"The speed of the internet. This is not happening to only my firm. It also happens to other firms that want to implement IoT as the internet in Thailand is not stable." (A)*

For Case D, it has the standard of procedure regarding technology adoption. The integration and synchronization are considered in the design phase, before the IoT adoption takes place:

> *"I have to tell you first that when we do system development, we need to realise how the entire current process that we would adopted the new system works, so that we could know the true requirement of our system that we want to develop. To invest in IoT, we will not put this new system on the process if it does not fit. we will check the integration and synchronization with the entire precast supply chain before we decide to adopt it." (D)*

By contrast, Case I states that the integration with existing infrastructure is not a significant determinant of whether or not adoption of the IoT takes place, as it hire vendors to adopt the

IoT for them. Case F argues that the IoT device within the market is easily integrated with the existing machines.

The existing IT infrastructure of many organisations is rather out-dated. Therefore, when adopting the IoT, these organisations could replace this infrastructure easily (A, H):

> *"We just need to do what can be integrated? For example, we have old machines, so when we want to adopt IoT device such as GPS, it should be stand-alone. At the present we have a lot of this technology in the market, hence we do not need to adjust or change the machines. We just place this GPS, the new thing beside the machines, not integrate them." (F)*

Two cases (E and G) believe that their infrastructure is ready for IoT adoption.Hence, there is no concern regarding the compatibility with existing systems:

> *"I think they would be complementing each other. Now the machine can communicate with computers in our factory through wiring (Lan). So we will have the integrated wiring. They could use the same data storage and the touch screens attached to each machine and on the computers. All the machines can be integrated using the same database." (E)*

In addition to infrastructure compatibility, the existing value of the firms has been discussed (B, C, D, G), especially regarding the people, culture, strategy and policy of the firms, as the IoT project is a large investment. Case D emphasises the concerns regarding people, rather than the technological concern:

> *"However, for senior managers, they are quite old and we need to push them a lot. They would see the benefit only when they found the problem and they need IoT to solve it." (G)*

> *"The main problem is not technical things, but it is people. I mean when we want to make a change, the key to success is not the technology itself, but it is about the management of change. so the key factors to decide whether to invest is that does it fit the strategy of the organisation?" (D)*

By contrast, few cases argue that the alignment with existing value is not significant before the adoption of the IoT takes place, but they will consider it later. Case A stated that the policy regarding the internet and cloud is required to be adjusted after adoption. Furthermore, both Case C and E believe that the workers in the factories may feel that it is not easy to use the new technology, and that it will take time to acquire familiarity:

> *"I think it depends mainly on the policy of the firm. Some employees do not accept new technology, but they will accept it gradually by the time as IoT will eventually help them work easier. In the first place, they may need training. But to not use it no, if the firm wants to do smart mining and processing. It is the main policy, so employees need to follow that." (C)*

The IT departments' expertise is mentioned during the interviews. Three cases argue that the IT people are significant to the IoT adoption (C, D, E). The IT department was involved in a new process development throughout the factory so as to ensure that the technology adoption was feasible (D). For example, Case C stated that high quality of the IT department brings about the effectiveness of the operation:

> *"My role is to get the data, find the pain points or requirement then report to IT department. So the quality of IT department affect the adoption for sure as in the past I used to work with IT on chatting application. The operators could record the data through a chatting application. IT plays a big part in this, they spend only two weeks to create this function. It is finished before the corn purchasing season of the year. If IT team was not skillful, we would have more lead time. Also, the information will not be accurate. Corn can be collected only three to four months a year. If we miss it, we have to wait until a year later." (C)*

One firm emphasises that the difficulty within the IT department is with the software team, not the hardware team:

> *"This can be divided into two parts, software team and technician. The technician I do not think it affects the intention at all as they just follow the drawing and wiring diagram. But the software team who would develop and deploy the IoT affects the intention. They might need some training. We are still in the developing process." (E)*

There has been an issue regarding the lack of IT personnel as they have their main tasks in hand:

> *"In our software team, we do have some other project to focus as well such as creating mobile applications which are not related to the IoT. I mean they have their priority already, so when the top management asks them to do R&D on the IoT, they said they do not have time for the new project." (E)*

However, several cases (A, F, G, H) use outsourcing; the IT department is disregarded in these cases. Some reasons given for this is that the IoT is beyond their IT department skill (H):

> *"I can see that we are not software firms, we should use the outsource. If you ask me if our IT team could work on the IoT themselves, I think they might be able to do it. However, I do not think it is worth the time and money. Using outsource would save us money and time." (G)*

Regarding the knowledge and experience with regards to adopting the IoT, Case B states that they want to gain more knowledge before adopting the IoT. Case D believes that it is important to find talented people towork on the IoT project, as it will affect the long term performance of the firm:

"For the IoT project, we need top people from the organisation. However, do you think they are available? Good people are always busy. This kind of problem is usually solved by bringing available person instead of a talented person to drive change. So turns out, we bring those people to the new project which will impact the long term of the firm as talented people are busy with the short term operation. Therefore, for the critical processes in IoT adoption, if we could not get the best people, we would adopt the IoT at all." (D)

The majority of the cases think of knowledge and experience from the users' perspective. Case H believes that the IoT is easy to use. Other firms (A, I, G) believe that the IoT could be adopted, either by external training or by self-teaching, hence it is not the main concern. Some firms design the system to be as simple as possible. Therefore, knowledge and experience does not affect the decision to adopt the IoT.

"Feedback from our employees is positive. For HMI, everyone knows how to use the smartphone. It is the same thing. I think at this time even the worker knows how to use Facebook and other applications. And I think it is easier than in the past if you want to program, like if you manufacture which can produce 32 types, 010101. If you have the interface you will just type 32. it is easier than in the past." (H)

"This depends on which generation you are talking about. So in the factory, the engineers are the young generation and they had training by machinery manufacturer already. Moreover, they learn it pretty quickly." (G)

In summary, all of the cases argue that the concerns regarding compatibility of the IoTs with their existing infrastructure, systems, existing values, IT department expertise and knowledge/experience of the employees, negatively influences their IoT adoption intention. The majority of the cases mentioned the compatibility of the IoT with existing technology infrastructure as it may be difficult to integrate the IoT with their existing system, or may even require that additional hardware and software is installed

6.2.3 Complexity

This section examines the complexity factor with regards to the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.4** and **4.1.6.** All of the cases argue that the complexity of the IoT is not a concern for them with regard to IoT adoption. Their answers are related to the discussion on prior knowledge and experience before the IoT is adopted, as the complexity depends on an organisation's level of knowledge and expertise. The majority of cases state that the complications of the IoT should be considered separately, and from two different perspectives, namely software developers and users. Overall, IoT adoption might be difficult for software developers, but less so for users due to differences in the interfaces:

"IoT is a new thing, we experience this by adopting ERP, applications, etc. So the difficulty is on the developer. But for the users it should be easy to use for sure." (C)

Firm B emphasises that as there are a large number of people involved in the organisation, the equipment and platforms should be easy to use, and training is necessary:

"The main problem occurs when we communicate with more people, human resource is important. The equipment and platforms need to be easy to use, otherwise it would negatively impact the entire organisation. If it is difficult to use, operators do not feel like using it. Because we do not have good programmers, we need to fill out the information on the program that the interface looks complicated. We used tablets to fill out the information and the tablets are too small, so operators did not want to use it. But anyway I do not think it is too difficult, if we train our employees well." (B)

However, all of the cases believe that it does not affect the IoT adoption intention. Firm C states that it is just inconvenient and that there are more problems than the complexity of the IoT (C). Firm D believes that the IoT will be easier to use gradually in the future. It is the same for the ERP, SAP,etc. that has been difficult to use previously. Firm A focuses more on the result after adoption rather than the difficulty of the adoption process:

"End-users no, but for the guys who design and adopt it such as engineers are difficult to understand the technical things. But we care more about the result. So I do not think IoT is so complicated that it impacts the adoption intention." (A)

Firm J believe that it will not only be complicated for the engineers, but also the accounting department, as the data regarding the manufacturing process is related to cost accounting:

"I think for the users it is easier to use, but for the engineer or accounting who works at the back office, it may be more complicated for them as they need to change their accounting system as well. so it depends." (J)

One firm even thinks that the IoT is easier to understand and use than their previous systems (H). Firm I stated that they did not consider that the IoT system in their factory would be difficult to use, as the nature of their manufacturing sector (rice-producing) is not complicated:

"HMI with the IoT will save cost for you as you do not require to have a control equipment, wiring. It is so complicated. With the HMI, you need only one screen with each machine. Furthermore, the factory used to use control panels and hand switch to input or manage data. But now everything is quite automatic. Machines are able to read significant indicators such as a number of pieces of filters being processed to control the production quality automatically. The data generated from the machines are transferred through the internet to the operations manager's computer automatically." (H)

Firm F believes in the ability of their people to use the IoT, thus the complexity of the technology does not hinder adoption:

> *"My firm is confident in the ability of the people. I believe that everybody can improve all the time. So, it is not a barrier to adopt the IoT. My firm creates a mindset that everyone has a good capability." (F)*

In summary, all of the cases argue that the complexity of the IoT does not affect the IoT adoption intention. It would bring more work for software developers, which is a mere inconvenience.

6.2.4 Observability

This section examines the observability factor regarding the IoT adoption in Thai manufacturing SMEs.This issue was previously considered in **Section 4.1.4** and **4.1.6.** Six out of ten cases (B, D, F, H,I, J) acknowledge that seeing successful cases of the IoT adoption process enhances their adoption intention. The firm's top management would like proof of success, thus ensuring that their decision has been correct, as the IoT project would require an investment of a million Baht (D). Firm H visited different types of factories and applied some selected functions of the IoT from those factories:

> *"We visit some factories. I would say the factory doing mass production is easier than us as they have fewer processes, fewer type of machines. That is worth the investment for sure. But yeah I saw some benefit from it from those companies such as to monitor in real-time which is our main goal as there are various crucial indicators to monitor such as a number of pieces of filters being processed to control the production quality." (H)*

Asking the technology provider to demonstrate the success of the IoT adoption, as well as observing the successful cases of implementation by visiting the firms, is another option for firms. In some cases, those vendors will even approach the firms in the first instance (D):

> *"If we could prove the result before, it would be great as some technology we do not have to study it by ourselves. Normally, technology providers could show us the successful cases first. So if we see that beneficial to our firm, we could use it." (F)*

Firm D states that observing successful cases helps increase their confidence with regard to the IoT adoption, which creates the thought within the firm that changing technologies is possible. . By contrast, Firm C states that this observation increases their confidence regarding the IoT adoption, but it does not affect the adoption intention:

"Who wants to make a change by adopting IoT do not have other choice of technology that is as effective as this one. When they see the successful case of other firms, it affects the confidence, creating the thinking of changing the process." (D)

"It affects in term of confidence. It just increases our confidence in IoT. But I have to say that even though we did not observe anything, we still intend to adopt it. Because our aim of adopting is clear. We know what our problem is in the control room, which could not control the baking process in real-time and we know that IoT can solve it. However, if we could find any use case, it will increase our confidence." (C)

For Case B, they have seen the successful adoption of the IoT in their alliances firms, and that strengthens the adoption intention:

"We have a model pilot plant in our geographic-specific alliance who agreed to co-brand some products in Singapore in the past. We agreed to have a testing of IoT over there. If it works we could apply it to a factory in Thailand." (B)

Case J argues that they could utilise a factory of their customer, a large Japanese automobile manufacturer, as a role model for technology adoption:

"I am not sure but based on my opinion I think it is because of the global trend. We use Japanese firms as role models. So we compare our systems with them, our largest customer within the automobile industry specifically." (J)

However, some cases argue that observation does not affect the adoption intention of the IoT. For example, Case E did not observe any successful cases before deciding to adopt the IoT. The other cases offer the following views:

"Actually, we did not decide to adopt IoT, we had a small budget, and look for something that benefits us in the long run, and I think IoT is a necessary thing to have in the future." (G)

"I did not see the result from other company adopting IoT first before adopting it. I do not think it affects the adoption intention. But some managers might go to some seminar but still, it is nothing serious. It is like visiting other plants regularly to get ideas of improvement." (A)

In summary, the majority of the cases argue that observing successful IoT adoption in other firms increases their confidence in the technology and also positively affects the adoption intention.

6.2.5 Cost

This section examines the cost factor with regards to the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.4** and **4.1.5.** The majority of cases (A, B, D, E, F,J) argue that the costs of investment, such as cost of buying, using and repairing the IoT system or service has a negative affect on their IoT adoption intention. Case A states that they are worried about the infrastructure expense, such as the internet network and sensors.

> *"If they want to adopt IoT, they need to invest in the good internet infrastructure and it is costly. IoT has cloud expense which is quite costly and the sim cards and sensors as well. One sensor for one truck is about 5000 baht. Maybe what we did does not save anything just promote the firm innovative image. When I talked to suppliers, I always ask how long this IoT equipment can still be used effectively. They all said 4-5 years. But I do not believe it. Hardware last 5 years usually and need to be replaced. Hardware is 50 per cent of the initial investment." (A)*

Both Case B and F believe that it requires significant investment costs, hence they invest with caution, using a gradual approach. Firm F mentioned the short-term and long-term plan of utilising the IoT:

> *"The second thing might be the real cost-saving benefit. We need to prove it first. Although we can invest it part by part, not the whole thing. IoT adoption cost compared with the normal operation cost is big. Currently we utilise the IoT to manage information in the crushing process. Next step would be to monitor the power consumption of each machine. In addition, the environmental standard such as the quality of water, air and sounds will be monitored in real-time. In the long run, we will use robots instead of human in the manufacturing site as the coal mining and manufacturing site is unsafe, thus using robot would reduce potential accidents on the site." (F)*

Three firms discussed the cost evaluation. They emphasized the breakeven point, and the return on investments in the long term:

> *"Yes, especially during the Covid-19 we have to be careful about what to invest in. Moreover, we have to save money from everywhere that is possible. If the breakeven is more than 2 years we do not invest in it. But before the Covid usually, if the project breakeven is three years, we will invest." (J)*

Firm E believes that the total expense of the IoT project would be gradually less in the long run, as the fixed cost which is the largest part remains constant:

> *"For us, we would like to adopt it in house as we already have our software team, and so we use our servers and also have our knowledge. For example, if we use*

Arduino, I would develop it myself. It will be large in the first place, because we need to invest. I mean we can think of it as an R&D expense. But once, we achieve it, the fixed cost which is a huge part will be the same. We can enjoy the benefits in the long run. The variable cost would be less than buying the completed product from outsource would be more expensive. So yes cost is needed to be evaluated first." (E)

Case D believes that this matter requires top management support to make the decision, as the IoT project would require a large financial investment:

"The third problems when adopting IoT is the cost of investment which is huge. Actually, if we can earn a lot of money, the cost is not a problem. However, the people who could tell how much to invest, and is it worth it in the long run? Usually, we need the top people in our firm." (D)

In Case H, respondents were not worried about the cost of the IoT system for various reasons; for example, a rice producer believes that the benefit is significantly higher than the cost, as, with the IoT, the firm would be able to produce a variety of prices and different weights of rice, increasing product mix and customer satisfaction. Firm C may also have some support from its minority shareholder regarding the required financial resource:

"For my firm, it is not much a concern, it does not affect the intention to adopt IoT. However, for the smaller firm, it might affect them. We think our minority shareholder of our company, the largest food holding company in Thailand may provide us some support for the financial resource." (C)

Case G places importance on the benefit of increasing the image of the firm, rather than the cost of the investment:

"For the IoT with machines, the cost was not a lot. My father decides to have those advanced machines. However, I do not think the main purpose is the economic value but to increase the image and credibility of the factory with less cost." (G)

In addition, Case H provides the information on the cost of investment in detail. The interviewee suggests that in their experience, developing the IoTs on site can be significantly cheaper than buying the software and hardware from vendors. The respondent noted the cost of investment will depend on how large the project requirements are for each firm and what functions the firm would like to have. For example, for the factory producing glass, the measurement of the temperature at each machine is critical, so they require the IoT, ergo they require real-time monitoring. Furthermore, this case would cost roughly three million Baht. The real-time monitoring function is also expensive:

"It depends on how many things you want from the IoT. If you want to count the number of pieces, it is one task. So usually they are sold in a set of tasks, like 50 tasks for 10,000 Baht/ machine. But I do not like this way of selling software from a

vendor, so I decided to do it myself. What I bought is only OPC server which is like a driver printer. And it costs me 40,000 Baht, all the other software, I write it myself. And the other investment is just to set up the internet, and LAN wiring, etc. So altogether, it costs like 200,000 Baht for 10 machines to do it all yourself. But if you buy software from a vendor, it would be 500,000 Baht for 10 machines." (H)

For the Firm H, the IoT is not significant for them, hence it was allocated a small budget:

"My IoT project is not seen as that significant in the firm, so there is no significant investment budget for it. 20 machines is a big project but we have fewer than this." (H)

In summary, the majority of the cases argue that cost of buying, using and repairing the IoT system negatively affects their intention to adopt the IoT. However, a few cases believe that they may have some support from their minority shareholder, or some believe that the benefit of the IoT warrants investment.

6.2.6 Security and Privacy

This section examines the security and privacy factor for the IoT adoption within Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.4**. As to the question of security, most of the respondents (A, B, C, D, F, J) were of the view that there is a security issue which negatively affects the IoT adoption intention. Firm A prefers to use local servers and wiring rather than cloud servers or the internet:

"The firm does not want to use the internet or cloud. They prefer ethernet and data server. The firm does not want the information to leak out." (A)

One case emphasises the information regarding trading, price and cost, which is secret data within the firm:

"Yes, it is a concern. Engineering wise, it is not our concern as the information about manufacturing are general, so the competitors could not do anything about it or they have it already. However, the information about the trading, price, cost, etc. as they are involved in some other parties such as middle man in the market. It is our main concern, especially for the firm like us that trading is a significant part. Price and cost are the key to success." (C)

Therefore, the protocol for security and privacy, when it comes to any new system development, is required in some firms:

"This is important. So every system needs to be done under security and privacy. For example, when we use the computer, we need to confirm the VPN in the application to proof that we are real employees. Another example is that we could not just install more applications without permission first. Everything needs ID and password and classification for authorization. All these are managed by the IT team. We call it security management system. We need to ensure that the information will not leak out. We also do testability, such as try to leak out the virus, especially for the company from Europe, UK, Germany that have brunch in Thailand because when they got fine from leaking information, the fine itself could not cover the profit from the brunch in Thailand." (B)

"The data about selling or the data about the certification. However, we have a department to take care of this matter. Every notebook has a password. We could not install any program without permission. Yes we have a concern regarding the data leak. We have many thing such as firewall, antivirus, and we have a policy that coversthis. We are scared of this but we still want to adopt it. This includes in the decision whether to adopt it or not." (F)

Firm J limits some data access to top managers only:

"We have the internet with the private server. I mean there is security protection. Every systems and machine connect to the internet but normally if we go outside the factory we can not connect to them just because of the data security of the firm. However, during the usual time like this, we are allowed to work at home. Therefore, it is just a protocol from the firm. But for some parameter, only top management can use the remote access." (J)

However, this data security risk is unavoidable, thus the possible risks, the damage of the risks, and the way to solve each risk when it occurs should be evaluated (D):

"So, this risk of the data leaking, security of the data is unavoidable. But we have to think if it is worth to take risk or not. So first thing first, the policy to fix it, if we have it, it is fine. So when we think about this matter, we need to evaluate the possibility of this risk, the outcome of the risk, and the way to solve each case when it occurs." (D)

In addition to the data leak, data loss is another concern for Case A, thus the backup file is required:

"If everything is on the internet already, we would be really concerned. We need to backup the file to keep the file for at least one day use. If the internet is bad. It is over." (A)

By contrast, some cases believe that security and privacy is not a determinant for IoT adoption. Firm H believe that storing data with the reliable cloud server provider is safe, even though storing it in a local server is safer:

> *"I do not think so. Because it all depends on your database like SQL. If you have OPC server or central server you could get the data from the IoT device. But it depends on if you keep your data on the cloud or your local datacenter. So in my firm's case, it is on the cloud, so it is hard for google cloud to break down I guess. But for some firms, they keep the data in Local storage, which is supposed to be safer." (H)*

Firm G believes that they will not be the victim of cyber crime purely because their firm is small. Firm E believes that they have a skillful software team, hence cyber crime is not a concern for them:

> *"In my opinion the data security like data leaking or the stability of the system is not a barrier. There might be a problem but I am not afraid of that. Because I am working side by side with my software team for 7 years already and I am in the big system. So I know that the system could breakdown and it requires the procedure for the security. So we understand this very well. So we are not afraid of that. I think we can design the protocol to handle these things." (E)*

In summary, most of the cases argue that any data security concerns will negatively affect the IoT adoption intention. The main issues are leakage or loss of private data, as the data are kept on the cloud which can be retrieved via the internet.

6.2.7 Trialability

This section examines the trialability factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.4**. In terms of the impact of the trialability, it was found to negatively affect the IoT adoption for every case except for Case G. The firms would like to test the IoT qualities, understand how the system works and assess its usefulness before deciding to adopt it. Testing is mandatory for almost all of the cases (A, C, D, E, F, H, I, J). The testing could be undertaken either by the firms themselves, or by vendors (I). Firm A tests the IoT sensor with one truck; it tries the system and becomes accustomed to how it works before implementing it throughout all the trucks. Firm F states that testing is required especially for emerging technology such as IoT:

> *"We will try to do research about it as much as possible first. So one guy who owns this project will see what would be feasible, which module, and in which function/areas? We will not implement it all at once, but little by little. If we have no choice but fully implement everything at once, we would still adopt it, but actually if it is an emerging technology, that nobody has tried it before, we will need to use the R&D team to proof before using it." (F)*

One firm states that the testing is critical, especially for the car manufacturing firm, as all five processes are linked to each other and if one point of the system should breakdown, the entire process throughout the factory would have to shut down:

> *"Yes, you have to do it. For example, when we change the Oracle to SAP, if we do not test it, it can bring down the whole things as we have orders every day!!! So it is quite sensitive." (J)*

Three of the cases (D, E, H) mention the proof of concept and the technology/system development procedure, of which testing is an integral part:

> *"Every technology, like when we want to create a new type of machine, we need to do POC or proof of concept, to be able to match the requirement from our customers. So if we could not pass the POC, we can not let it pass. We need to match every function required by our customers." (E)*

Case H conducts a pilot project before becoming fully finished with the proof of concept:

> *"However, I have not fully implemented it as we still need a proof of concept, we need visibility first. I am doing a pilot now. So now we can do only data visualisation function which is the first step of utilising the IoT to monitor operation of each machine ." (H)*

Case D provides some detail about the new process/system development procedure. When developing IoT, the firm starts with the process improvement, or process redesign, which can be separated into three stages. The first one is to summarise the problems, the second is to redesign a new process. The third process improvement is to change the new process into an IT requirement; find the new system to make the new process happen. When the firm has found the requirement, they will implement the system design, system development and system testing before they go live. The manager states that for the testing stage, the testers should include not only the software developers, but also the operations team that is responsible for the manufacturing process that will implement the IoT. In addition, he emphasises that as the firm utilise the agile working method, ongoing and constant testing is required:

> *"Testability is the key to developing new systems. It is common sense. If we did not test it, we would not adopt it. More than that, the people who test need to be the people who are process owner only. Then end-users and key users need to test it." (D)*

By contrast, only one case would fully adopt the IoT at once. Testability is not required, but the case would undertake research about the IoT first. This might be because the firm believed that the cost of IoT investment is not high:

"I would adopt it all at once, but we need to do a lot of research first. Even if I could not test the system, I would still adopt the IoT if I think I study the technology enough." (G)

In summary, almost every case argues that testing is required to prove the practice, quality and usefulness of the IoT. Therefore, trialability affects the adoption intention.

6.2.8 Organisational Structure

This section examines the organisational structure factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.5**. The majority of the cases (B, C, D, E, G, H, I, J) argue that their organisational structure has an impact upon the IoT adoption intention. However, there was a mixed opinion on whether it negatively or positively influences the adoption intention, depending on their structures. The participants response to the question regarding the organisational structure and the effect produced upon the IoT adoption intention occurs in four ways: openness, flexibility, adaptability and hierarchical structure. The opened structure aids the creation of new ideas and innovation (E):

"Actually my organisation is quite opened for new idea and innovation. So I think that positively affect the intention to adopt the new technology. For example, if they would like to work on something new like big data analytic or AI, I would let them try that. I might open the new business line for that as well. It is like building a new startup." (E)

Whereas the fear of using new technology hinders the adoption intention (I):

"I think it is more about the workers that are afraid of using new technology. I think it is normal like they are ready to adopt the technology only if they were pushed." (I)

With regard to the flexibility of the organisations, Firm B believes that inflexible structure creates systematic and clear direction to adopt the IoT:

"About the structure when approving something, it is not too difficult but it is fixed to be assigned for a specific person. The system will auto-link to that person directly to approve it. So, it is not flexible, but it is clear. There is clear direction part. It is very systematic. So it is not a barrier to adopt IoT as everyone has a mindset in the same direction." (B)

The decisions could be made faster than the flexible structure. One reason for this is flexible structure, which requires change often (J):

"But it is a policy from the firm. so do you ask them if they want the new technology? It depends. If the initiative is from the accounting and it got approved, we need to

comply with it. But if the new technology is from us, manufacturing site, and it got approved, the other department also needs to listen to us. We do not feel comfortable with flexibility as it brings more work and changing every time. It makes everything slow" (J)

However, one firm believes that this subject is not relevant to its IoT adoption (A):

"The structure from the lowest to the top are as follow: Subcontractor, Silasanon workers, engineers. It is a quite flexible structure. I do not think it is relevant." (A)

Moving on to the adaptability of the organisation, Case G states that the younger generation, who are adaptable, push for the IoT adoption:

"As this firm has been established for a long time, we have old generation and young generation I would say that old generation have zero speed movement! But for the young generation, they could adapt quickly. So the young generation would like to adopt IoT as to reduce the miscommunication and also to avoid communication with the older generation as well!" (G)

In contrast, Case F thinks that the adaptability of their firm does not affect the IoT adoption intention as their firm is in a mutual industry and does not require changes from technological advancement:

"We are quite flexible. We adapt the organisational structure quite often but not about the technology changes. I do not think it is relevant here as the construction business industry is mutual already." (F)

Furthermore, concerning the hierarchical structure of the firms, flat structure affects the IoT adoption intention positively, as flat structure has a larger staff of top managers who can initiate the innovative project, such as the IoT project (H). The line of approval for technology adoption decision is short (C):

"As my firm is quite flat, I can deal with IT directly. I do not need permission from many people. Therefore we could try the system and implement it quickly and smoothly. However, if we need to request a lot and the line of approval is long, it would affect the decision to adoption. So it is like if we need approval from many people, it would be more difficult to adopt IoT, some might not agree to adopt it. The time to think about whether to adopt it will be longer. More analysis will be required." (C)

In addition, the organisational structure affects the IoT adoption and vice versa. FirmsD and G believe that the IoT would help reduce the mis/delay in communication, especially for the firms that have a complex organisational structure:

> *"We intend to adopt the IoT to reduce the complex structure of our firm and to make it smooth. IoT is a way to do that to make the firm flexible as well by integrating data in different department, eliminating data asymmetry issues." (D)*

> *"Because the management is the person who analyses data and makes the decision about the textile orders and the worker will basically need to wait for the decision. So it used to require much time to wait for the decision from the management but since we had the application, we could reduce the time to communicate between the inside factory and management." (G)*

In summary, almost all the cases argue that their organisational structure influences the IoT adoption intention. The open, flat, adaptable and inflexible structure positively effects the IoT adoption intention.

6.2.9 Top Management Support

This section examines the top management support factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.**5. Regarding top management support on the IoT adoption intention, eight out of ten interviewees (B, C, E F, G, H, I, J) state that the top managers of their companies are keen on adopting the IoT, thus positively influencing the adoption intention. The views of different interviewees regarding the top management support on IoT adoption can be summarised in five main points:

1) Training
2) Communication
3) Budget
4) Innovative culture
5) Strategy & direction on innovation.

One firm sends out its employee to a workshop relating to the IoT:

> *"It is in order like a pyramid, from top to local leader who will be sent to train first. We need to plan when to use it and when to send people to train about systems. Champion leaders who achieve the training will teach other people thereafter." (B)*

Firms E, F, G and J communicate clearly to their employees about the need for IoT adoption:

> *"IoT now is just like the top management team thinking and they need to convince their employee to spare some time with the IoT project. We need to tell them that if we do not do R&D on IoT now, when the customers have a requirement of the IoT, we will not be able to give it to them." (E)*

Even though, in some cases, the workers do not agree with an IoT application, they still need to follow orders:

> *"For the machine with IoT, the worker needs to use them as we order. We pay them a better salary as well." (G)*

> *"The top management is trying to know every KPI in real-time such as the cost of production each day which I do not agree with that as I think a report on the accounting monthly is enough." (J)*

In terms of the allocated budget for the IoT project, Cases F and J state that they have a significant budget. Case J states that normally, the cost control department strictly approve the technology adoption. However, IoT adoption is exceptional:

> *"Now the problem is the budget. We have the idea but no money. Normally, there is a cost control department that allocates budget for each department and the plant manager do not have the authority over the cost control department. So, me or the plant manager have idea to improve the factory but sometimes we do not have much budget. Cost control normally tell us to do everything in house first, not buy it from vendors. But for the IoT, it is necessary so we put it as our first priority." (J)*

By contrast, Case A does not have a large amount of money for the IoT project and they believe that it does not affect the decision to invest in the IoT. Moving to the innovative culture within the firms, some cases (B and E) mention the innovation competitions among their employees, which create innovative culture and initiate IoT projects. Case E states that those competitions typically are typically held among the software teams, who create new innovation, and they are not for the technicians who operate the machines:

> *"We do have innovative competition that will reward the winner. In addition, we have workshops and competition to improve our efficiency in the factory. I think these things help to push people to be more innovative, so it affects the IoT adoption intention more or less." (B)*

However, Case D states that they do not have competitions and that this does not affect the adoption intention. Some cases argue that their organisations always have an innovative mindset, especially among the executives. Even though it is not in their policy, they keep track of the new technology. One firm hires specialists, such as vendors, or university professors, to train their employees in how to work and develop software and machinery. Their main goal is to enable the full automation within the factory (E):

> *"Yes, we want everything fast. We want it automatic. We want to know fast. As the plan can be changed all the time, we need to be very flexible. For me I need to learn new things." (J)*

Lastly, regarding the top management support effect on the IoT project, strategy and direction toward the technology development are evident within 6 firms. Firm B has clear management of change policy regarding technology adoption:

> *"I would emphasise on MOC again. I would look at a part in MOC which tells me the procedure to achieve this task of implementing new technology. Training engineer is one of the steps to achieve as well. For example, to adopt the new technology, the firm need to find people with some criteria. To train engineers, MD needs to allocate budget for that at X amount. With the MOC procedure, everyone has the same mindset that the firm needs to do digitalisation. We have a specific duty clearly. Now, it is clear in medium plan for three to five years." (B)*

Furthermore, Firm F believes that the top to bottom structure pushes the innovative project, such as the IoT project:

> *"We use the top to bottom management policy. Top management is very important. We also use the bottom to top management but not very often as when the employees want to propose something, if the top management does not see the vision of it, they will reject that." (F)*

Below are examples of IoT adoption that were greatly advocated for by top management:

> *"I think my father had a vision of this technology. So I think that is determined. It will make more profit. My father was the one who told the engineer what is the requirement for the software. In the past, the southern people of Thailand usually eat rice A, B,…based on their preference of pricing and taste. Then some people start looking for more option, mixing various rice. My father saw this trend coming. He bought the warehouse and factory and start manufacturing to mix the rice, and the feedback was great, selling it all in just half a day every day. So, my father is the one who push for the technology implementation. He has a vision about this and push for it" (I)*

This push by top management could be in the form of goal-setting, which is found to be fast and effective:

> *"I mean we have more orders and to keep up with that, we need to be more efficiency. The management saw this coming and thought IoT would help the factory with that. The real-time monitoring of the production processes is brought in as the conveyor never stop running. The conveyor with IoT will collect data on flowrate and track-time of each process in the production line. The top management even set the*

goal to have above 95 per cent efficiency for each process. You can see that when top management is pushing, it is quick and effective" (J)

In some cases, if top management does not see and support the vision regarding the IoT adoption, the IoT adoption would not happen, as they are the ones who make the final decision:

"It affects. In the case that, for example, if the top management does not agree with IoT. We used to propose to have sensors in our corn factories, but they did not buy the idea. They thought that your engineering job is not purchasing things. You did nothing like modifying cars. They did not think IoT would be helpful. However, my department still tries to push it by doing as much as we can. We use excel, other systems. And report to them until they saw the limitation of the old information system. So if they say no, you could not do anything, but we could try showing them the real situation. when they agree on that, it becomes smooth." (C)

In summary, most cases argue that support from top managers will positively influence the adoption intention. Their top management support team create the adoption intention in five ways:

1) Sending employees to workshop related to the IoT technology
2) Communicating clearly about the requirement for the IoT system
3) Providing more than sufficient budget for the IoT
4) Holding innovative competition
5) Having clear strategic & direction on the IoT project.

6.2.10 Organisational Size

This section examines the organisational size factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.5**. Four cases (A, E, F, H) argue thatthe organisation's size affects the IoT adoption intention. Overall, cases A, E, F, and H believe that larger firm has more advantage to adopt the IoT. The main reason is that they have more financial resources:

"In term of the size of the area (factory), my firm does not have the internet, we could not use the IoT. We need to set up the access point, the wifi range extenders. We have to calculate if it is worth an investment or not. This is not about changing new technology. But I think a larger firm can make more profit, having more financial resources, hence they can make a decision easily to invest in IoT." (F)

Case H believes that the business laws in Thailand do not show favour to small firms. The interviewee compares the benefits and costs and summarizes that larger firms should benefit more from the IoT:

> *"So the factory is not like start-up firms or technology firms. For the start-up, I think a small size is better. But for the small factory, I think in Thailand we do not have the advantage at all because of the laws about pollution, tax, etc does not support us. So the smaller sized factories in Thailand are decreasing over the years. As the IoT project requires a significant initial investment, the larger firms could gain more benefit as larger sized requires more IoT application to monitor the factory, so they could get the most out of the IoT." (H)*

One firm believes that it might not be feasible for a small stone mine to adopt the IoT:

> *"Because of the fixed cost of initial investment, 50 per cent from software. Honestly, I do not think it is feasible. I filtered the mine in Thailand, I do not think any of them would get benefit from adopting IoT. A large firm has more advantage." (A)*

However, case A states that larger firms might require a change of policies and protocol for new technology adoption, which can hinder the IoT adoption. Some firms suggests that SMEs would not take a risk by developing new technology if they were still not making enough profit:

> *"So if you make a lot of revenue or profit, you may have more budget for the R&D to develop the IoT system. But if you are losing money on your main business, you might need to survive first. I will talk about the SME. I mean if the IoT is the key to survive, they need to bet on developing that technology. But if they still have something else to focus on they will not take the risk for the new technology. And for the large organisation, it just depends on the planning of the organisations. How they will innovate their organisation." (E)*

On the contrary, four cases (C, D, G, I, J) argue that the size of a firm should not affect the IoT adoption intention, whereas one case has no comment on this matter (B). Two firms posit that larger firms have had more advantages in the past. However, currently, the cost of IT investment is cheaper:

> *"I think any sized firms should be able to implement it regardless of their size as the investment cost is now much cheaper than in the past. For example, we invested in a machine which costs us 7 million baht. Nobody at that time invested in it. There was only 4 type of machines. But now it is 1 million baht for the same type of machine." (I)*

Firm D suggests that small firms have various ways by which they can adopt IoT, ways that are less costly than in previous times. They could use on-premise systems, or any subscription model systems for IoT applications:

"larger organisations may have more advantage as they see this technology is a must, and they are more ready to adopt it. However, currently, small firms could be able to implement it as well with a lower investment than before. For example the on-premise systems, cloud, subscription model, and all the basic systems that in the past it was almost impossible for small firm. Therefore, I do not think the smaller size is a barrier to the IoT adoption anymore." (D)

Furthermore, one firm argues that both small and large size businesses could gain benefit from the IoT in different ways:

"I think they both have a different advantage. For smaller sized firm, the IoT would help the work in process to be more agile. But for the large firms, it would cut down the issues about the employees, like more people more problems. So I think the IoT will reduce miscommunication." (G)

Firm C provides some thought about the timing when adopting the IoT. They argue that the different sizes of various firms does not affect the IoT adoption intention, as any size of firms could benefit from adopting it at any given time. Small firms have more acceleration so they may adopt the Iot more swiftly. However, although larger firms may be slower to adopt the IoT, they may have more efficient and completed IoT systems:

"I think it depends on the timing. Like smaller firm has more acceleration. If a big and small firm starts at the same time, the small firm would finish the adoption first. But the point is after the adoption, even though the big firm is slower but they could get more benefit from the IoT: more efficiency. Actually big or small can adopt IoT. I think they both have benefit. It is just different in scale so it does not affect. It is about timing." (C)

In summary, half of the cases argue that the size of the firm does not affect the IoT adoption intention. As the cost of systems, such as on-premise systems, has been decreasing, even small firms could use the IoT based on their usage. Nevertheless, the other half of the cases argue that the larger firms have more advantage regarding financial resources. However, they would be required to implement a change of policies and protocols that are more complicated than small firms.

6.2.11 Technology Support from Vendor

This section examines the technology support from the vendor factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.5** and **4.1.6.** The majority of the firms (A, B, C, D, F, G, H) emphasise the importance of technology vendor efforts and support regarding the IoT adoption decision process. They agree that the technology vendor support factor negatively impacts the intention to adopt the IoT. This is because they require support from them after adoption. However, they could not find high-quality vendors. Firm G suggests that for the non-software business, using outsourcing is appropriate when it comes to new technology development, as it would save wasting time and money from using a ‘trial and error’ approach:

> *“I can see that we are not software firms, we should use the outsource. If you ask me if our IT team could work on the IoT themselves, I think they might be able to do it. However, I do not think it is worth the time and money. Using outsource would save us money and time.” (G)*

Case C would use outsource at the beginning. Once the firm creates knowledge and experience with the IoT implementation, they will use permanent employees to manage the system:

> *“Use 100 per cent outsources in the first place to be fast. But once we learn it all. We sent people to learn from them. Once we know everything, we would do most of the things by ourselves and stop hiring the outsources. But yes, we require a lot of support from them at the beginning. The second step after outsource to kick off quickly is to hire someone permanently to manage the system.” (C)*

Several firms (A, D, F, G) mention the difficulty of finding good vendors, which is a concern regarding the IoT adoption decision. Therefore, selecting appropriate vendors is critical. Case A states that IoT technology is new and most of the vendors in Thailand lack the required expertise:

> *“Most of them are not well-expertise. It is hard to find a good one. Most of them just had the IoT service recently. But they really want a job, so they just do not care about the quality of the service. For example, in the past, we adopt a face scanner for use in the dangerous zone in stone mine by hiring various vendors. Even though it is just a small thing, we still have a conflict with the them. So, that was a big mistake, so I said to myself that next time I would selectively pick only one outsource. Therefore, for the IoT , all outsource is from one firm only: Sensor, UI, the Internet, implementation, software.” (A)*

The vendor selection is critical especially for the firm using 100 percent outsourcing (D, F). The system development process at the design stage could be achieved by utilising internal people (D):

> *“We use 100 per cent outsources. We will use the vendors to set up everything for us, but the equipment and assets are ours. We just send the requirements to the IoT provider. So finding a good vendor affects the adoption intention a lot. We need a lot of services to improve and adjust the IoT systems.” (F)*

Cases A, B, C, G and H require significant support from the vendor to improve and adjust the IoT system following the adoption. Case C and G state that the first period after adoption is crucial, as there would be much adjustment and improvement to fit with current operations and IT infrastructure:

> *“Regarding the programming, of course PLC we buy it but the software we*

developed in house, and the machine we produce it ourselves. I think it is risky to hire someone to create machines for you, they will know some secret. The hardboard and screen, we buy them and assemble by ourselves so we buy those components. So yes we need them. In factories, devices and sensors have protocol RS485. It is like you use two cables which can communicate with each other. We need to be able to read their language, so these would require the manual from vendors and we need to adjust this in the future." (H)

Firm A states that the IoT system lacks reliability with regard to their coal manufacturing site:

> *"I would require support from the vendors a lot as IoT overall is easy to breakdown both software and hardware. This affects adoption intention of IoT because we use outsource 100 per cent." (A)*

In some cases, the vendor support is crucial, as they utilise the IoT for safety purposes:

> *"We require support a lot like 70 per cent from vendors as we use IoT for the safety purpose: predictive maintenance which is critical for the pipeline system. If any point of the pipe line is broken, it would cause accident. So the support from them is crucial for the IoT adoption intention." (B)*

By contrast, some firms (E, I, J) argue that technology support from vendors does not affect their decision to adopt the IoT. For example, Case I requires support from vendors once in every three to four years:

> *"We just told the engineers about the requirement and hire vendors to do it for us. It is just once in 3-4 years that require support from them. But mostly the problem is that some equipment is expired and we just need to change them, like some part of the machine and we need a mechanical engineer to come and change them. it is very common in factories." (I)*

Case study J states that the support of the IoT would be more related to the accounting function, and not manufacturing:

> *"Yes, but not a lot, such as data matching. It is about accounting, not manufacturing. So, actually about the data linkage between the supplier, customers, production. We just want to check the system. But It is not a big problem" (J)*

Case E, which adopted the IoT entirely on site, argues that they do not require support from the technology provider, as they have a software business and therefore sufficient expertise:

> *"If it is a small thing and not related to my main business, I would use the solution from China. However, the IoT relate to my software business. Therefore, for the IoT with machinery production, I would develop everything myself by using Arduino.*

Because we have software business to support and work on the IoT solution in the factory." (E)

In summary, the majority of the cases argue that the concern regarding technology support from vendors negatively impacts their intention to adopt the IoT, as vendors are required particularly in the first period of technology adoption. However, it is difficult to find good vendors, as there is a,lack of technology vendors in Thailand with the required IoT expertise. By contrast, few firms argue that they do not require support from vendors very often, or state that they have their own competent software team.

6.2.12 Business Partner Influence

This section examines the business partner influence factor for the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.5.** All of the cases agree that their business partner positively influences their decision to adopt the IoT. Based on the interviews, three parties are found to have an effect on the IoT adoption decision: suppliers, customers, and alliances. Their alliances influence Firms B and F to adopt the IoT, either by recommendation or policy deployment, such as for Case B:

"Our geographic-specific alliance who agrees to co-brand some products in Thailand told us that everything should be the same for their factories in each country, same platform. It is obvious that they are bigger than us, so even if we joint market in Thailand together, they have influence on us." (B)

In terms of supplier influence on the IoT adoption, the influence from them is found to be uncommon among most of the interviewees. Three cases (A, B, H) argue that they are at the top of the supply chain, so they do not require many suppliers:

"Never discussed the adoption of IoT with suppliers for material used in the factory, but if the firm was bigger maybe. Also, because we do not have many suppliers. We are like an upstream in the supply chain as we have a stone mining unit as well." (A)

"If you search in google about filter you will see that the filter composite of steel, glue, etc. So, we buy steel sheet then we process it to be in the shape we want and we paint them ourselves. For the plastic, we buy plastic pellets then we mould it ourselves. In addition, the paper we buy it in a big roll then we fold it in the shape we want. To sum up, we are like at the top of the supply chain. Basically, we buy just basic raw materials." (H)

However, only rice-producing firms (Case I) states that their suppliers, of which there are several rice mills, influence the IoT decision adoption:

"No, we actually bought it from various rice mills from outside the south of Thailand

> *are. So basically, the rice from rice mills will be sent to us in large sacks." (I)*

The customer's influence affects almost all of the cases with regard to the adoption of the IoT (A, B, C, D, E, G, H, I, J). Their largest customers influence them to adopt the IoT in several ways. Most of the cases state that the IoT could increase their customers' satisfaction by improving the efficiency within the factory, resulting in a quick response to the demand, an increased variety of products, and possibly a reduced price. Cases G and H argue that they would like the customer to understand the high-quality manufacturing facilities that the firm offers and the advantages over competitors:

> *"My firm is influenced by our biggest customers, CPF (Charoen Pokphand Foods Public Company Limited) (a big holding company producing food for human and for the animal). Most of the material will be served to CPF as our priority customers. We need to satisfy customers of CPF. CPF does not care if it is IoT or what system. However, there is a pressure from CPF, such as price reduction demand or traceability policy from the CPF. For example, to reduce 10 per cent of the price (CPF), our firm decide to use IoT to make the factory be more efficient to reduce cost." (C)*

Below are some other comments from the cases regarding the customers' indirect influence on IoT adoption:

> *"For the customer, to reduce the paperwork for customers, also more optimisation of the truck benefits the customer as well since they could get the products faster. But we have not talked to customers at all about the IoT." (A)*

> *"There is a requirement from customers indirectly. I mean we have more orders and to keep up with that, we need to be more efficiency. But if you ask me it is just we need to satisfy customers by respond to the demands quickly but they do not push us to adopt the IoT." (J)*

Furthermore, in some cases, they would adopt the IoT to increase sales, by increasing customer satisfaction:

> *"Most of them are retailers and wholesalers in the south of Thailand. So it is more like it increases customer satisfaction as they could just tell us the budget of each rice sack and we can mix the rice (expensive and cheap) at the appropriate proportion which is fair for both us and customer. We can sell more as we can do what every proportion they want with accuracy, and we can sell at any price the customers want. So, yes it affects. It is about the demand of the market if you think you could sell more after investing in the technology, you should invest in it." (I)*

This is significant, especially for Case B, which focuses on a customer-centric strategy:

“Because we know that we want more customer, we want more market share. Therefore, we did some analysis to find out what is the need of the customer, then we will serve their need. It is like if they say using the document is just fine, nobody would invest a lot in IoT. But the customer wants something more meaning that more speed, less period time and response time. They want less price. We definitely need tooptimise everything, manage cost. In return, we the customers will buy more of our products. All of this can be managed by your IoT.”(B)

In summary, all of the cases argues that their business partners positively influence their decision to adopt the IoT, typically by alliances through recommendation or policy deployment.Customers, especially their largest ones, significantly influence their IoT adoption intention.

6.2.13 Competitive Pressure

This section examines the competitive pressure factor with regard to the IoT adoption in Thai manufacturing SMEs. This issue was previously considered in **Section 4.1.5** and **4.1.6.** The majority of the participants (A, C, D, E, G, H, J) indicated that they do not consider competitive pressure as a significant factor regarding the IoT adoption intention. Case J noted the technology advancement in Japanese firms, it being a technology that they would like to implement themselves. Cases D and G stated that it is the long-term benefits of the IoT which influences the adoption intention, rather than the pressure from their competitors:

“It was not driven by the competitors, but we just need to be improving all the time in the way that. I mean we have our growth plan and IoT can be a part to make it happen” (D)

“So I think my firm would like to jump on the bandwagon. In addition, actually, we did not decide to adopt IoT, we had a small budget, and look for something that benefits us in the long run, and I think IoT is a necessary thing to have in the future.” (G)

Firm G states that other firms in the same industry would not allow them to visit their factories, thus showing that the firms’ competitors have no influence on the IoT adoption intention:

“The same type of factories would not allow us to visit them. But I think they are all trying to implement this. So there are only 2-3 big filter manufacturers in Thailand. All of them should be doing it as they are public companies, and they want to look good.” (H)

Firms A and E state that since they were the first organisations within the industry to adopt the IoT, there was no effect on them from competitive pressure:

"The competitors do not have an influence on IoT adoption. Not at all. But if there is a significant number of our peers that adopt IoT, it might affect us in the first place. But at that moment, there was no stone mine firm that has adopted IoT in Thailand. When we see that the IoT was coming to the industries in Thailand, we would like to adopt it as well" (A)

By contrast, only three cases out of the ten interviewed firms – B, F and I - believed that there was a direct threat from other competitors, or similar firms, within their industry; this is motivation for their firms to adopt the IoT:

"It affects the decision to implement the IoT. Most of the time we would be a first mover. Actually, some technology or function we do it first, some others do it first and we copy them if we see a good result from them. It is like the technology change in organisations in the same industry will be quite relatively in the same period. If others adopt something, we will do so. If we adopt something, others will do as well. And this time we are the follower." (B)

Firm I believe that the IoT implementation would positively differentiate them from their competitors:

"And so, the main reason we brought in this technology is the competitiveness to reduce cost from mixing rice at the wrong proportion. The problem is that rice manufacturers are all the same, having the same type of rice. So it will be very price competitive. Having these machines with the IoT, we can be very variable in the price like we can sell a 50 baht a sack, 75 a sack, and so on. We can select which price of a sack of rice has the highest demand and lowest supply. This will increase profit. This will not be easy to be imitated by the competitors as it is quite complicated." (I)

In summary, the majority of the firms posit that competitive pressure does not influence the IoT adoption intention. Only some firms, which are in a price-competitive industry, intend to adopt the IoT to reduce their production costs and increase their product variety.

6.3 Summary

This chapter presented and discussed the findings from the case studies. It was found that various factors affected the adoption of the IoT in Thai manufacturing SMEs. These factors are classified into three themes:

1) Technological
2) Organisational
3) Environmental.

Regarding the technological context, all of the cases support the view that the relative advantage of the IoT positively influences the decision to adopt it. The relative advantages of the IoT, as evidenced from the case studies, are the convenience of use, ability to enhance the image of the firms, efficiency, and economic value. The IoT enables real-time/remote control and monitoring in production, integrates the data and systems, and improves the firms' data visualization. All of the cases identify the lack of compatibility of the IoT with existing infrastructure, systems, values and IT department expertise; knowledge/experience of the employees negatively affects their IoT adoption intention. Half of the cases revealed that the existing technological infrastructure and its ability to easily integrate with the IoT system are concerns. The firm may need to install new hardware or software and this requires further financial investment. The return on investment is required to be evaluated. Furthermore, all of the cases have suggested that the complexity of the IoT does not affect the IoT adoption intention. It would be complicated for the software developers, but not for the users, but nevertheless, it is inconvenient for the users. Regarding the observability of the IoT, six cases state that seeing the successful adoption of the IoT in other firms increases their confidence in the adoption decision, thus positively affecting the adoption intention. Regarding the cost of investment, the majority of the cases expressed concerns about purchase expenditure, and also the using and repairing of the IoT system. Therefore, the cost negatively impacts their intention to adopt the IoT. Certain respondents decided to invest on an incremental basis, but not commit to full adoption. In some cases, they are not worried about the investment costs as they believe that they may have support from minority shareholders, or they consider that the benefits of the IoT will significantly outweigh the costs. As to the question of security, most of the cases believed that there is a security issue that negatively influences the IoT adoption intention. The key issues are data leakages and losses, as the data are stored in the cloud, which can be retrieved via the internet. Some firms have a protocol for security and privacy when it comes to any new system development; for almost every case except Case G, the interviewee states that the testing is required to prove the functionality, quality and usefulness of the IoT, thus affecting the adoption intention. By contrast, only Case G undertook research on the IoT usage before deciding to adopt it.

Regarding the organisational context, eight cases posit that their organisational structure affects the IoT adoption intention. This was expressed in four ways: adaptability, flexibility, hierarchical structure and openness. The adaptability of the firms was found to positively influence the IoT adoption for the firms that had a large number of young employees. In addition, an open structure helps create new ideas and innovations, initiating the IoT adoption intention. The inflexible structure and flat structure is positive for IoT adoption, as the line of approval for IoT adoption is short, hence the decision could be made more swiftly. Regarding the top management support and its effect on the IoT adoption, most cases state that the top managers do encourage the adoption of the IoT, hence positively impacting the adoption intention. Their top management support creates the adoption intention in five ways:

1) Sending employees to workshops related to the IoT technology
2) Communicating clearly about the need for the IoT system
3) Allocating significant budget for the IoT
4) Having innovation competition within organsations
5) Having clear strategic and direction on the IoT project.

Furthermore, half of the cases indicate that the size of the firm should not affect the IoT adoption intention, as larger firms might have greater advantages from economies of scale. However, the cost of IT investment has been decreasing, and small firms have an alternative way of using the IoT, such as on-premise systems that are less costly. Large and small firms alike could benefit from the IoT in different ways. By contrast, four cases argue that the firm's size affects the IoT adoption, as the larger firms have more advantages regarding the financial resource. However, they require a change of policies and protocols which are more complicated within small firms.

Regarding the environmental context, all of the cases agree that their business partner positively influences their decision of whether to adopt the IoT. Two firms out of ten state that their alliances encourage them to adopt the IoT either by recommendation or policy deployment. With regard to the supplier’s influence, only the rice producing firm states that their suppliers affect the IoT adoption decision. Furthermore, the influence of the customers was found to significantly affect the IoT adoption intention, especially from their largest customers. Several cases demonstrate that adopting the IoT would increase customer satisfaction by improving factory efficiency, thus resulting in improved response times, an increased variety of products and possibly reduced prices. In some cases, respondents believed that the IoT would increase the capability and sophistication of their factory as perceived by their customers. As to concerns regarding the technology support from the technology vendors, the majority of the firms state that this negatively affects their intention to adopt the IoT, especially for the firms using 100 percent outsourcing. Several firms mention the difficulty to find good vendors, as technology vendors in Thailand lack the required IoT expertise. Moreover,some firms state that the vendors are particularly important for the first period after adopting the IoT, as there would be a lot of adjustment and improvement of the IoT system. By contrast, few firms argue that they do not require regular vendor support, hence it does not affect their decision to adopt the Io;. in some cases, they even have their own software team. Regarding the competitive pressure on the IoT adoption, the majority of firms indicate that it does not affect their decision of whether to adopt or not. Some firms argue that the initiative to adopt the IoT is because of the benefit of the technology. Several respondents state that they were the first IoT adopters within their sectors. By contrast, three firms believed that there was a direct threat from other competitors within their industry, such as the pricing competition, and they believed that IoT would positively differentiate them from their competitors.Therefore, the competitive pressure positively affects the IoT adoption intention. The following chapter will present the discussion on the findings by analysing, comparing and contrasting against the extant literature.

Chapter 7: Discussion

7.0 Discussion Chapter

This chapter provides a detailed discussion regarding the findings from the case studies in relation to the literature review. Two research questions will be answered respectively:

1. What are the factors affecting the adoption intention of IoT in manufacturing SMEs in Thailand?

2. How do those factors affect the adoption intention of IoT in manufacturing SMEs in Thailand?

3. What guidelines can be developed to guide practitioners in assessing the suitability of manufacturing SMEs in adopting IoT technologies?

The findings presented in chapter 6 will be analyzed, compared and contrasted against the extant literature discussed within chapter two and three, and with theories and models reviewed in chapter four in order to provide answers to the research questions. Based on the analysis, among the initial thirteen factors taken from the conceptual framework that was developed in **Figure 18,** this study does not find sufficient evidence to support the theory that complexity, organisational size and competitive pressure are significant determinants of IoT adoption in Thai manufacturing SMEs. The complexity factor is found not to affect the adoption intention. As argued in the literature, one of the key barriers regarding the IoT adoption is complexity, which has been discussed in several studies (Gangwar, Date, & Ramaswamy 2015; Gutierrez et al., 2015; Oliveira & Martins, 2010; Tashkandi & Al-Jabri, 2015). Nonetheless, most of the cases in this study argue that the perceived complexity depends largely on an organisation's level of knowledge and expertise. Based on the findings of the case studies, the participants believed in the ability of their staff to use the IoT, ergo the firms perceived that their employees have a high level of knowledge and experience compared with the complexity of the IoT.

The results from the case study analysis regarding complexity are consistent with those of Jin Park (2017), who suggests that an organisation may consider the IoT either easy or difficult to use depending on the degree of knowledge it possesses about the prior use of technologies. Another explanation for the lack of significance of this factor is that the expectation of the IoT utilisation in most cases is low, they do not require complex systems in the first place and the knowledge and experience of the firm are not required. The participants believe that the IoT technology is easier to understand and to use than prior IS systems and they are of the opinion that the IoT, as a new innovation, would be designed to be user-friendly. In reality, the IoT can ease information communication in some manufacturing contexts. The respondents suggested that the difficulties are found later. Most of the participants believed that top management could provide the training and this study identified the relationship between factors. For example, the cost concern was found to strengthen the concerns surrounding the infrastructure compatibility, as the firms might be required to install new hardware or software, causing further investment expenditure. In addition, this cost factor emphasises the need to observe the successful adoption of the IoT in other firms. However, minority shareholders of some firms who took part in this study support the IoT project, hence reducing the concern regarding the financial resource.

In this chapter, the two research questions will be individually considered within the strict validity and reliability criteria. The structure of this chapter is such that each research question is presented and its result is discussed in detail. The first research question will be considered in the following section.

7.1 Research Question One: What are the Factors Affecting Adoption Intention of IoT in Manufacturing SMEs in Thailand?

This section considers research question one by discussing the factors that influenced the intention to adopt the IoT in Thai SMEs, as perceived by the case study's used within this research. These factors relate to the technological, organisational and environmental context that are from the conceptual framework adopted and shown in **Figure 18,** as discussed in chapter four. In addition, by exploring the findings, it has been found that categorizing factors into drivers and barriers is a suitable and convenient approach to use in order to gain improved understanding regarding the influence of these factors on the IoT adoption intention in Thai manufacturing SMEs, as presented next. For each factor, if it was found to affect IoT adoption intention by fewer than seven case studies, this thesis would consider it as a moderate factor. However, if it was found to affect IoT adoption intention by seven case studies or more, this thesis would consider it as a significant factor.

Table 14 below provides a summary of factors as evident within the case studies:

Table 14: Summary of Factors as Evident within the Case Studies

Factors	Perception
Technological factors	
Relative advantage	Significant driver
Compatibility	Significant barrier
Complexity	No effect
Observability	Moderate driver
Cost	Moderate barrier
Security and Privacy	Moderate barrier
Trialability	Significant barrier
Organisational factors	
Organisational structure	Significant driver/barrier
Top management support	Significant driver
Organisational size	No effect
Environmental factors	
Technology support from vendor	Significant barrier
Business partner influence	Significant driver
Competitive pressure	No effect

Based on the findings in **Section 6.2**, among the thirteen factors taken from the conceptual framework, ten factors were found to affect the IoT adoption intention within Thai manufacturing SMEs: relative advantage, compatibility, business partner influence, trialability, top management support, organisational structure, technology support from vendors, observability, cost and security, and privacy. Among these ten factors, relative advantage, business partner influence and top management support were identified as significant drivers

toward the IoT adoption intention. The relative advantage and business partner influence were found to be the most significant drivers, and compatibility, trialability and technology support from vendors were identified as significant barriers to the IoT adoption intention; from these three barriers, compatibility was found to be the most significant. In contrast to the literature, this study does not find evidence that complexity, competitive pressure and organisational size were the factors affecting IoT adoption in Thai manufacturing SMEs. In particular, the complexity factor was unanimously found to not affect the adoption intention.
The following section provides the argument pertaining to the technological, organisational and environmental factors that affect the IoT adoption intention in Thaimanufacturing SMEs.

7.1.1 Technological Factors

This section considers the technological factors. The case studies demonstrated that one of the most significant drivers of the IoT adoption in Thai manufacturing SMEs is the relative advantage. This result concurs with the literature. Rogers (2003) states that relative advantage is the strongest determinant influencing adoption of innovation. Therefore, relative advantage is frequently quoted as a significant variable in the innovative technology literature (Oliveira et al., 2014; Ramdani, Kawalek, & Lorenzo, 2009). Relative advantage is found to be an important factor for SMEs to consider when taking steps to adopt this technology (Alshamaila et al., 2013; Sin et al., 2009). In particular, for the majority of firms, gaining benefits from IoT implementation and usage is the most important factor that provides incentives to the firms to invest in the projects. The participants perceive IoT as a means to connect between objects with a speedy response. Teo et al.(2013) confirmed this argument and emphasized that more connectivity and responsiveness of the IoT make everything more effective and efficient, thus enhancing the firms' performance (Dong et al., 2017; Ferretti & Schiavone, 2016). This makes the IoT system more advanced than traditional IS (Dong et al., 2017). In addition, the leaders within the cases expect the IoT to have a significant impact on the growth and productivity of the companies. Ahsan et al. (2016) state that several organisations adopt IoT because the existing technology may not solve the problems. This correlation between relative advantage and IoT adoption corroborates the results of a great deal of the previous studies that have been undertaken within this field (Premkumar & Roberts, 1999; Nelson, 2003; Dedrick & West, 2014). Based on the findings, all of the cases perceive the IoTs as a technology that offers greater potential advantage than their current information technology provision. They believe that the benefits of IoT positively affect the adoption intention. The relative advantages of the IoTs, as evidenced in this study, are the convenience of use, ability to enhance the image of the firms, efficiency, and economic value. The economic value and increased efficiency are the most emphasized benefits, as stated by the interviewees.

The case studies demonstrate that one of the most significant barriers toward the IoT adoption in Thai manufacturing SMEs is compatibility. This finding is in line with the literature, which suggests that compatibility is an essential negative attribute of the information system innovation (Premkumar et al., 1997; Thong, 1999; Premkumar & Roberts, 1999), especially for SMEs that will be more likely to adopt them if they are compatible with existing work practices (Coughlan et al., 2012; Rosas et al., 2017; Tornatzky & Fleischer, 1990). Rogers (2003) maintains that a rapid adoption rate for technology usually occurs if organisations recognize the compatibility of the innovation with the needs and existing practice of said organisation. For that reason, decision-makers endeavor to ensure that new ICT services are compatible with individuals' job responsibility and value systems. The compatibility with the case studies is discussed in four areas: existing infrastructure and systems, existing values, IT department expertise, and knowledge/experience of the employees. The main concern is regarding the compatibility of the IoTs with the technological infrastructure and its ability to integrate. This has been highlighted in several studies, such as Kamin (2017), Rosas et al. (2017) and Venkatesh et al. (2013) as compatibility of IoT involves sensors, networks, and application from different suppliers, which are factors when considering IoT adoption (Haddud, DeSouza, Khare, & Lee, 2017). The compatibility between systems and applications are an important aspect of the IoT devices, as it is required in order to transition from previous technology to an IoT system (Islam et al., 2015).

In this study, complexity is not found to affect the IoT adoption within Thai manufacturing SMEs. This contradicts several studies that found that complexity does act as a barrier toward technology adoption (Gangwar et al., 2015; Gutierrez et al., 2015; Oliveira & Martins, 2010; Tashkandi & Al-Jabri, 2015). The IoTs potentially offer more comprehensive information to managers (Accenture, 2017). The development of IoT devices is high and the functionalities are varying (Bi, 2017). The variety of available IoT devices increases the complexity of selection choices during product selection and planning (Zhong et al., 2017) and the IoTs require a high learning curve (Kamin, 2017). The present findings are consistent with prior studies which did not find complexity was a significant factor with regard to the decision-making of the SME's when it came to the adoption of new innovation; for example, Kendall (2001); Ramdani and Kawalek (2008).

Observability, is found to be a moderate driver toward the IoT adoption in Thai manufacturing SMEs. This result concurs with the literature, which suggests that observability is positively correlated with technology adoption (Rogers, 2003; Wang & Wang, 2016). In the context of IoT, organisations need to observe the IoT to ensure that its benefit aligns with the objectives of the company (McMullen et al., 2015). The study participants would like to ensure that technology will provide benefits to their organisations. This argument is evident in Ju et al. (2016). Several studies are in support of the correlation of the observability factor and technology adoption intention, such as agricultural technology (Ajili et al., 2012) and mobile banking technology (Al-Jabri & Sohail, 2012). However, even though the majority of the cases agree that observability is a driver toward IoT adoption, some cases believe that it does not affect the firm's intention to adopt the IoT. Several studies support that observability does not significantly impact the technology adoption (Kamin, 2017) such as Kapoor et al. (2014a).

The present finding demonstrates that cost is a moderate barrier toward IoT adoption in Thai manufacturing SMEs. The majority of the cases express concern regarding the cost of buying, using and repairing the IoT system. Previous studies have found similar evidence which suggests that lack of financial resources is one of the primary reasons that SMEs hesitate to adopt AI or other Industry 4.0 related technologies (Paiola, Agostini, Grandinetti, & Nosella, 2022; Stentoft, Jensen, Philipsen, & Haug, 2019). For the IoT technology, several studies found that cost is a significant factor in determining whether the adoption of IoT is implemented within a business (Al-Momani et al., 2016; Chong & Chan, 2012; Chao & Lin, 2017; de Panizza et al., 2010). In particular, for SMEs to implement the IoT in the manufacturing industry, one of the most important challenges is resource scarcity (Nylander et al., 2017; Warrian & Southin, 2017). The 3G, which is one of the main components of IoT, was very slow to be adopted in the past because of the cost (Ong, et al., 2008). It should be noted the size of the production facility is one specific characteristic that could make the implementation of IoT more expensive (Tomic, 2017).

Cyert and March (1963) stated that SMEs typically have less available resources than large firms, and have therefore invested late into new technology. In this study, it was found that only a few firms believe that the cost is not a barrier for them to adopt the IoT as it would not require a large investment. A study by Nikbin & Abushakra (2012) on consumer acceptance found that price value does not significantly affect IoT adoption intention, as users feel that IoT services may not be costly.

Moving to the security and privacy factor, it is found to be a moderate barrier towards the adoption of IoT within Thai manufacturing SMEs. This is because the IoT still has many issues that need to be fixed, such as data security and privacy. These have been regarded as an uncertainty factor within the study. Hsu and Lin (2016) divide the data security concerns into four dimensions: collection, unauthorized secondary use, improper access, and errors. In the case of the IoT system, IoT security concerns stem from the embedded connected devices within the network heterogeneity (Sahraoui & Bilami, 2015; Xu et al., 2016). The weakness of the IoT system pertains to insecure web interfaces, software and firmware vulnerabilities and a lack of transport encryption (Airehrour et al.,2016). Kshetri (2014) state that security concerns are a key barrier with regard to the adoption of new big data, which is a significant part of IoT system. Implementing strong security software is a deterrent to technological innovation (Parida et al., 2010), especially with internet-related technologies (Zhu et al., 2006; Gupta et al., 2013; Lian, Yen, & Wang, 2014). The adopters need to feel safe when interacting with multiple systems in order to increase the adoption rate and the level of IS usage (Alghamdi & Beloff, 2014). In this study, security and privacy mean that the firms are worried about their data, due to the fact that they have little control over it. The main issues in this case studies are data leakage and loss. This is in line with other similar studies (Senyo, Effah, & Addae, 2016; Tashkandi & Al-Jabri, 2015). In addition, it is evident, from several studies, that the IoT used with cloud computing is a cyber security concern (Lin & Chen, 2012; Wang & He, 2014). Myriad studies regarding IS and IoT mention the concerns about data security, institution and system security (Chan & Chong, 2013; Chen et al., 2014; Medaglia & Serbanati, 2010; Oliveira & Martins, 2008; Tao et al., 2014; Weber, 2010). In this study, it was found that only a few firms believe that security and privacy is not a barrier against them adopting the IoT, as they believe the cloud service providers they choose are reliable.

When it comes to the last technological context factor, trialability, this was found to be a significant barrier toward the IoT adoption in Thai manufacturing SMEs, as the testing is required to prove the practice, quality and usefulness of the IoT for the majority of the case studies. The case studies would like to test the IoT qualities and understand how the system works, and to access its usefulness, before deciding to adopt it. Trialability was found to be positively correlated with technology adoption in several studies (Pashaeypoor et al., 2016; Rogers, 2003). The case studies in this research argue that they could test the technology before adopting it to see the benefits and risks in advance. The opportunity to test IoT security, reliability and privacy issues may decrease the risk for the organisation (Kamin, 2017) Fang et al. (2015) suggested that trialability enables firms to plan for the features and risks and with a view to understanding if it can provide benefit to their specific process. Several studies indicate that trialability decreases uncertainty about a technology's adoption (Wang, 2014). A discussion with one interviewee identifies the relationship between knowledge and experience that is needed to reduce the need for the test. This is in line with Lippert and Forman (2005) who state that familiarity with technologies, such as virtualisation, or computing, can have a direct influence upon user perceptions regarding cloud computing services, and trialability may not be important because they may have prior adequate experience of how things would work in similar technology. The next section considers the organisational factors.

7.1.2 Organisational Factors

This section considers the organisational factors. The case studies demonstrate that organisational structure significantly affects their IoT adoption intention. However, there are mixed opinions on whether this factor should be a driver or barrier; it depends on each case and which dimension of the organisational structure they discuss. Overall, the case studies view the organisational structure in four dimensions: openness, flexibility, adaptability and hierarchy. The correlation of these dimensions of the organisational structure and technology adoption is found in several studies (Burns & Stalker, 1961; Ericsson, 2015; Rogers, 1983). Ericsson (2015) and Vukicevic (2018) found that the organisational structure does affect the IoT adoption, as IoT is not a simple IT system, and it requires significant organisational change. Therefore, it will involve more collaboration and input from several departments (Bughin et al., 2015). For instance, some of the case studies require the operationsteam to work together with the IT department to ensure the good practice and feasibility of the IoT adoption. Thus, the organisational structure is required to be evaluated when it comes to IoT adoption.

Regarding the top management support, it is found to be a significant driver to the IoT adoption in Thai manufacturing SMEs. Tushman and Nadler (1986) identified six methods that top management can foster technologies, including innovation in core strategy; the clear communication regarding the importance of technology; the use of formal and informal rewards; the creation of innovative culture by emphasizing the competition; the provision of training and the setup of clear vision and direction innovation. The case studies in this study reveal that their top management has helped to create the adoption intention in five ways: sending employees to a workshop related to the IoT technology; communicating clearly about the need for the IoT system; allocating significant budget for the IoT; holding innovative competition; and having clear strategic & direction regarding the IoT project.

Based on Tushman and Nadler's (1986) research, to only provide a reward to an employee has not been evident in this study. Furthermore, the interviewees state that top management is a key decision-maker for investing in technology and instigating the adoption of technology, ergo their decision impacts the adoption intention significantly. This is in line with Daylami et al. (2005) and Jeyaraj et al. (2006). With regard to SMEs, Seyal et al. (2007) found that management support is a significant predictor that had an influence on IT adoption. The finding indicates that if top management does not appreciate the vision regarding the IoT adoption, the IoT adoption would not happen, because they are the people who will make the final decision. This is evident in a study by Vukicevic (2018), who found that top management support is crucial, as IoT will have a great impact on the organisation. Without top management support, the organisation may resist adopting IoT (Wang & Wang, 2016). The correlation between top management support and technology adoption is confirmed in several studies, such as Gutierrez et al. (2015), Gangwar et al. (2015) and Senyo et al (2016).

When it comes to the last organisational context factor, organisational size, the case studies demonstrate that organisational size does not affect the IoT adoption in Thai manufacturing SMEs. The participants discussed the size of the business in terms of financial resource and organisational structure. This finding contradicts the literature. DePietro et al. (1990) and Rogers (1983) state that the size of an organisation is one of the most crucial factors for adopting the technology. Several studies support the fact that size is considered to be an important factor of ICT adoption (Jeyaraj et al. 2006) and Lee and Xia, 2006)). Tomic (2017) noted that the size of the production facility is one specific characteristic that could make the implementation of IoT much more complex and expensive. Furthermore, some studies report a positive correlation between organisational size and technology adoption (Aguila-Obra & Padilla- Meléndez, 2006; Belso-Martinez, 2010; Kamal, 2006; Ramdani & Kawaiek, 2007), studies that report a negative correlation (Goode and Stevens, 2000; Utterback, 1974;) and only a few studies that report a non-significant correlation (Ahsan, Talib, Sarwar, Khan, & Sarwar, 1980; Varun & Goslar, 1993). In these case studies, most of the researchers argue that large and small firms could benefit from the IoT in different ways. Therefore, organisational size is not a predictor for IoT adoption. The finding on the size and IoT adoption is in line with Manyika and Roxburgh (2011). Some participants added that the different sizes of the firms does not affect the IoT adoption intention, as any size of firms may benefit from adopting it at different times. The following section considers the environmental factors.

7.1.3 Environmental Factors

The case studies have demonstrated that one of the most significant drivers toward the IoT adoption within Thai manufacturing SMEs is business partner influence and this result concurs with the literature. The power of partner influence was found to be an enabler of technology adoption intention (Low et al., 2011; Senyo et al., 2016). With the presence of a strong trading partner, organisations tend to adopt changes more aggressively. From a firm-level perspective, many industry leaders expect that the collaboration between partners will work on IoT in order to significantly impact the growth and productivity of the companies (Mourtzis etal., 2016; Turber et al., 2014). In this study, two parties have been identified that have an impact upon the IoT adoption intention: customers and alliances. Whereas the influence from suppliers is uncommon for most of the interviewees, as most of the case studies are in the manufacturing industry, they are at the top with regards to the supply chain. The examples of the effect of partners on the IoT adoption include leading retailers such as Wal-Mart (USA), Target (USA), Tesco (UK) and Metro (Germany), who have made it obligatory that their major suppliers use RFID in every case or pallet which is shipped to their yards (Chong, Ooi, Lin, & Raman, 2009).

The present findings demonstrate that technology support from the vendor is a significant barrier to IoT adoption in Thai manufacturing SMEs. The interviewees refer the technology support to the availability of support from the vendors in form of training, backup, and security. Prior studies have demonstrated that the implementation of new IS within SMEs typically demands expertise and support from vendors (Thong, 1999) and it is found that support from technology vendors positively influences IS's adoption within the SMEs (Al-Qirim, 2007; Ghobakhloo et al., 2011; Mirchandani & Motwani, 2001). This study found that the more a firm relies on vendors to adopt the IoT, the more concerns they have when it comes to the IoT adoption. Overall, most of the cases use outsourcing to adopt the IoT, rather than their own IT staff. Most of the respondent businesses have raised their concerns regarding the trust of their vendors in adoption of the IoT, which agrees with Al-Momani et al. (2018) who states that for the IoT, trust is the user’s confidence in the IoT system provided by IoT service provider. Furthermore, studies regarding the adoption of new technologies have demonstrated that trust is an important factor pertaining to the adoption of IT (Al-Momani et al., 2018; Gefen et al., 2003; Wharton & Brunetto, 2007; Siegrist et al.,2000). In addition, Gao and Bai (2014) state that the users’ trust in IoT technology and service providers is believed to significantly affect the IoT adoption intention. This may be because new technologies, such as IoT, typically comes with risks, which negatively impact the users’ intention and behaviour to adopt it. The IoT system's two important characteristics, which are intangibility and a high level of various IT involvement, may increase a level of perceived uncertainty and risk for the users (Gao & Bai, 2014). Lin (2011) stated that trust is one of the most effective tools for decreasing uncertainty and risks, and for generating a sense of safety. The lower the technological uncertainties, the more confident participants will become as they can anticipate the technology benefits (Tu, 2018). Therefore, there is a need for the IoT service provider to ensure that the service fits well with the values of the user, which then reduces the perceived risk of adoption (Hsu & Lin, 2016).

In this study, the last environmental factor - competitive pressure - is not found to affect the IoT adoption within Thai manufacturing SMEs. Only three cases believe that there is a direct threat from other competitors within their industry. Most of the cases do not think that they are falling behind their competitors, and his contrasts with several studies that found that competitive pressure affects the technology adoption intention in an organisation (Chan & Chong, 2013; Leminen et al., 2012; Raymond & Uwizeyemungu, 2007; Wang et al., 2010). Overall, the discussion regarding competitive pressure in this study is mostly related to the nature of IoT adoption within the manufacturing industry throughout Thailand as a whole. Most of the cases argue that the impact of other factors, the relative advantage in particular, is more pertinent than this factor. The next section considers the discussion to research question two.

7.2 Research Question Two: How Do Those Factors Affect the Adoption Intention of IoT in Manufacturing SMEs in Thailand?

This section considers the second research question by discussing the importance and influence of the thirteen factors as perceived by the case studies on IoT adoption in Thai manufacturing SMEs. The significance of each factor is analyzed, as well as the relationships between these factors.

7.2.1 Relative Advantage

From the findings in the previous chapter, the discussion regarding the relative advantages of the IoT is organized into the following categories: increased efficiency and economic value, convenience of use and enhanced image. The most expected advantage from the IoT, in most of the cases, is improved efficiency. The majority of the cases have adopted the IoT for real-time monitoring and control functions in order to improve the operations and products' efficiency/effectiveness/quality. The adoption of the IoT within the manufacturing sector leads to increased resources and operation efficiency, reduced defects and shorter time to market. An example of this, within this research, is the corn processing firm (Case Study C) which intends to adopt the IoTs. Their product is perishable and by utilising the IoT, they can trace the entire corn supply chain to control its quality throughout the processes, from its production to its delivery. This is because the IoT could potentially increase product quality, by utilising the capability of real-time monitoring and analysis (Moeuf et al., 2017). Another example within this thesis is that of power consumption and environmental monitoring, such as quality of water, air, and sound, and this results in increased efficiency of power consumption. Furthermore, several participants argue that the IoT could reduce the time and number of factory employees by increased automation in production processes. In such cases, the workers will be assigned with more significant roles, rather than routine ones. This is possible, because with the IoT, each unit in the autonomous system is independent and can be configurable by itself (Akimana et al., 2017). Automation can displace lower-skilled workers but will increase demand for higher- skilled labour, such as data scientists, mechatronics engineers and software engineers (Rüßmann et al., 2015). In the case of the firms that have overseas alliances, the IoT enables remote monitoring and controlling, thus eliminating travelling time. This method of remote monitoring is utilised within the mining cases, for examples, Case A and Case F, which operate in harsh environments. This is possible, as one of the relative advantages for the IoT is to track the individual users and target them based on the information that is supplied by the devices. Another application of the IoT within the case studies are system and data integration, both of which increase efficiency throughout the supply chain, thus eliminating paper-based systems (reduce communication time), and reducing miscommunication between parties, as everyone is able to view the data using the same platform.

Previously, Kagermann et al. (2013) demonstrated that the IoT enables horizontal integration of many manufacturing resources and capabilities that are used in various stages of manufacturing. It can allow vertical integration between all parties (Kagermann et al., 2013), reducing the need for intermediaries (Porter & Heppelmann, 2014). Furthermore, this study found that some firms utilise the IoTs to reduce machine downtime by providing an alert when the machines require maintenance, and this is supported in a previous study by Pye (2014).

The economic advantage of using the IoT is cost-saving, which comes from increased efficiency and quality, reduced machine breakdowns and diminished human errors. The improved information flow by adopting IoT reduces the costs and errors at several stages within the supply chain. An example is Case Study J, an automotive manufacturing firm which has reduced its operating expenses, such as the cost of gas, which is 60 per cent of their total expenses. In some cases, increasing revenue benefit is emphasized more so than cost-savings. This is possible through mass customization, as the IoT shifts supply chains from being centralized to decentralised so that manufacturers can focus more on localization and customization (Boger et al., 2016). An example of this is the rice-producing study (Case I), which utilizes the IoT for mass customization purposes, having increased their varieties of mixed rice. The use of the IoT creates more customized products for the customers, and this strengthens the SMEs competitiveness and provides a unique product or service to particular target groups.

For the convenience of use, one of the benefits of using the IoT is that the majority of the cases state that the workload of managers, engineers and workers will be reduced, as the IoT is systematic. Data visualization within the factory will improve significantly from the previous IS. The filter producing firm (Case H) in this study utilizes HMI with an IoT system in each machine and this provides workers with a knowledge of daily quotas. The last benefit of using the IoT is that it increases the image, or status of the firms, as the IoT enables traceability and visibility, thus increasing the credibility of the firm. The IoT has been identified as a trendy, emerging technology that can assist businesses in promoting their identity as a creative and innovative entity (Christensen & Huang, 2018). However, few cases argue that enhanced image is not as important as cost saving for the purpose of utilising the IoT. In summary, the findings of this thesis confirm the importance of relative advantage regarding the IoT adoption with the prior literature.

7.2.2 Compatibility

The discussion regarding the compatibility with the case studies is organised into the following categories:

1) Existing infrastructure and systems
2) Existing values
3) IT department expertise and employees knowledge/experience.

For the compatibility with the existing infrastructure and systems, the case studies were concerned that they may be required to install new hardware or software to implement the IoT, thus raising business costs. Therefore, the relationship exists between the infrastructure concerns and the cost of further investment; the compatibility with existing infrastructure concerns increases the cost concern. All these issues serve to raise significant questions for adopters as they are not able to estimate the return on investments because the IoT is a new and conceptual technology (Tomic, 2017). The manufacturer has to invest in both the IoT and its integration into current operating systems (Tomic, 2017). Moreover, it was highlighted that the stability of the internet connection on the manufacturing site is the main issue of concern, especially for the case studies in harsh environments, such as coal and stone mining. Furthermore, the corn processing firm (Case C), that has more than one factory, argues that each factory has different protocols for the IT systems, and it is difficult to integrate the new information systems throughout all the factories. This is even more complicated when it comes to IoT adoption, as the IoT consists of networks of unique objects based on a set of communication protocols (Shin & Park, 2017). Therefore, as there are various different standards to be considered, compatibility between communication standards can be difficult (Shin & Park, 2017). This is an issue for international firms, such as the gas producer (Case B). To create both vertical and horizontal integration in manufacturing, data integration is a major challenge (Sadiku et al., 2017), especially for manufacturers having international operations: centralised data management systems must be able to integrate various data types (PWC, 2015). Data needs to be cleansed, aggregated, aligned and transformed in order to be ready for when a business decision is made (PWC, 2015). By contrast, Case I argues that the integration with existing infrastructure is not a significant determinant of whether to adopt the IoT, or not, as it hires vendors for them. Hence, it should be noted that the technology support from the vendor factor within this study reduces the concerns regarding the compatibility with existing infrastructure to the IoT adoption. Some cases (A,F and H) state that the IoT is easily integrated with the existing systems and processes and that the existing IT infrastructure of some firms is obsolete. Therefore, when adopting the IoT, they could just replace entire systems and processes.

For compatibility with the existing values, the majority of the case studies mentioned people acceptance, culture and policy. In many cases, the policy regarding the internet connection and cloud will be required to be adjusted after adoption. This is supported by Conwey (2016) who states that to ensure the IoT devices can work together effectively in an existing infrastructure with existing devices, standardisation is required. In addition, the integration of various networks of the IoT would require new security, privacy and reliability standards (Jing et al., 2014). Concerning the people acceptance and culture, the workers in several case studies, for example, C and E, felt that it was not easy to use the new IoT technology, but that acceptance would be achieved overtime. Cultural resistance and social acceptance are evident in various prior studies,such as Dutton (2014) and Tomic (2017). Dutton (2014) explains that IoT adoption changes thedaily basis work practice of employees and management needs to convince their employees to adopt the IoT because the employees are wary of being replaced by automation (Tomic, 2017).

With regard to compatibility with IT department expertise, there has been an issue regarding the lack of IT employees, as they have their main tasks on hand. DePietro et al. (1990) noted that there are two types of 'resource deficiencies', namely limited finances knowledge, commitment and skills to handle system problems/difficulties; all of these can hinder IoT adoption (Ferretti & Schiavone, 2016). Furthermore, some cases – Case E, for example - state that the software team is more important than the hardware team. The software team is involved in the new design process within the factory in order to ensure that the technology adoption is feasible. It is important to find talented people to work on the IoT project, as it will affect the long-term performance of their firms. However, several cases use outsourcing and to this end the IT department competency is disregarded during this study. It should be noted that the technology support from the vendor factor in this study reduces the concerns regarding the compatibility with the IT department expertise. DePietro et al. (1990) suggested that human resources are required to adopt an innovation, but it can also be adopted if there is enough financial slack.

The majority of the cases believed that compatibility, together with knowledge and experience, was not a concern regarding the intent to adopt the IoT, as it is easy to use and could be adopted following appropriate training, or by self-learning. This view, however, is in contrast with the literature that explains that knowledge and experience are important for the potential use of data (Ericsson, 2015; Gao & Bai, 2014) in order that meaningful insight from the IoT could be achieved. Users with more experience know how to utilise the systems more effectively and reduce the risk in the future. (Dong et al., 2017). Yarrow (2005) emphasised that SMEs' managerial ICT skills, ICT knowledge, and ICT practices are important determinants of IT adoption intention. This contradiction may be because the potential benefits of the IoT, and the way to achieve these benefits, is not fully comprehended as yet. The users may not know how to capture IoT value, mainly due to the lack of knowledge itself (Ericsson, 2015; Wang et al., 2013). Currently, not many organisations have sufficient knowledge regarding the IoT and its use (Ericsson, 2015). In summary, the findings of this thesis confirm the importance of compatibility regarding the IoT adoption with the prior literature. Moreover, the relationship between the compatibility concern and the cost of further investment has been established within this thesis.

7.2.3 Complexity

The discussion regarding complexity is related to knowledge and experience. Most of the cases argue that the perceived complexity depends largely on the level of knowledge and expertise of an organisation, which is supported by Rogers (1962). The participants believe in the ability of their people to utilise the IoT impactfully. This implies that the firms perceive that their employees have a high level of knowledge and experience, compared with the complexity of the

IoT, thus the complexity of the IoT does not hinder the adoption intention. This result from the case study analysis regarding complexity is consistent with the results of Grover (1993) and Thong (1999), which suggest that businesses may be less likely to adopt an innovation or technology if it requires that the employees within the organisation should possess a high level of new skills. Therefore, the relationship exists between the knowledge and experience in the compatibility factor and the complexity factor. In this study, knowledge and experience reduce the complexity to be a concern of the IoT adoption. Another explanation for this insignificant factor is that the expectation of IoT utilization, in most cases, is low, hence the knowledge and experience of the firm is not highly required. Shin and Park (2017) state that an organisation may consider IoT easier or more difficult to use depending on the degree of knowledge it possesses regarding the use of technologies

Furthermore, the majority of the cases separate the complexity into two perspectives: software developers and users. Overall, IoT adoption might be difficult for software developers and engineers, but not for its users. Kamin (2017) state that the IoT may require a high learning curve for end-users and IT resources alike. The engineers may face difficulty integrating, maintaining, or upgrading due to the complexity of the IoT (Kamin, 2017). However, as mentioned above, the case studies believe in the knowledge and experience of their employees, thus reducing the worry for the software developers and engineers. This may be because they are already familiar with similar technology to the IoT, as familiarity is one of the reasons that complexity relates to the adoption (Frambach et al., 1998; Kamin, 2017). For the users, the IoT interface is typically developed with ease of use in mind, thus the complexity can be disregarded for the users.

A further reason that the case studies are of the opinion that the complexity does not present any issue is because the IoT technology is actually easy to understand and use than the previous IS. This is in contrast with a study by Kamin (2017) and Christensen and Huang (2018), who all state that more complex technology, such as IoT, will require more time in order that firms can adopt and adjust their existing business model, or product, and it may be difficult to integrate, maintain or upgrade due to the complexity of IoT. The Explanation could be that the expectation of IoT utilisation in most case is low, hence they do not require complex systems in the first place. They also believe that the IoT, as a new innovation, would be designed to be user-friendly. In fact, the IoT even eases information communication in some factories. The difficulty is found later, most of the participants believe that top management could provide the training. Some cases overlook the complexity and state that it will be easier to bring in gradually in the future. One case draws attention to the fact that the nature of their manufacturing (Case I) is not complicated; hence, the IoT's complexity should be limited. Previously, Goode and Stevens (2000) indicated that the business sector that a company operates within is one of the factors consistently found to influence technology adoption.

In summary, the findings of this thesis contradict the prior literature, which found that the complexity, regarding the IoT adoption, is important. The relationship between the knowledge and experience and the complexity was found to exist during the writing of this thesis.

7.2.4 Observability

The observability of these case studies is undertaken by visiting other firms in the same industry or viewing the successful adoption of IoT in a competitor’s or a customer’s factory. In some cases – Case D and F, for example, the technology provider demonstrates the success that they have achieved by implementing the IoT adoption. All of these cases serve to strengthen the adoption intention. Sanchez et al. (2014) suggested that firms may consider observing IoT adoption from other organisations that have already adopted the technology and see how it provides value to them. Furthermore, most cases note that observing the successful adoption within other companies helps to increase their confidence in the IoT, which then affects the adoption decision. It is crucial for IT managers to observe the successful result of IoT adoption so that they become confident about the security, privacy and reliability of said technology (Kamin, 2017). As new technologies typically come with risks, they will negatively affect the users' intention and behaviour to adopt them (Gao & Bai, 2014). Therefore, two important characteristics of the IoT system, which are intangibility and high levels of various IT involvement, may increase the potential users' levels of perceived uncertainty and risk (Gao & Bai, 2014). After all, Lin (2011) states that trust, which is created by observability, is one of the most effective tools for decreasing uncertainty and risks, and for generating a sense of safety. The lower the technology uncertainties, the more confident participants will become, as they can anticipate the technology benefits (Tu, 2018). For instance, many participants considered the scanners without a line of sight, and the bulk reads of tagged items, as significant benefits of IoT technology under the assumption that they would provide 100 percent reading rates. If IoT technology cannot guarantee 100 percent reading rates, then most participants would think twice about adopting it and discount its aforementioned benefits (Tu, 2018). All in all, this study found that observability increases confidence in the technology, which in turn positively affects the adoption intention.

Top management plays a significant role regarding observability. Kamin (2017) states that having a visible result provides positive evidence to stakeholders, especially the top management of the firms, in that the technology is beneficial. Therefore, observability helps to promote the technology to stakeholders while they are undertaking the decision-making process. Top management in this study appreciate seeing the proof of the success of the IoT adoption because it gives them confidence that their decision is the right one, as the IoT project requires a significant investment. This cost concern, which strengthens the need for observation, is evident in some case studies, shown by the way that they visit different types of factories and apply some critical functions of the IoT from those factories.

By contrast, few firms believe that the observability does not affect the adoption intention, as they look at the benefits and whether there is a necessity to implement the IoT within their own factories before they make the adoption decision. Another explanation may be the nature of the Thai manufacturing industries which were not yet open when it came to the critical innovation that the firms used. The filter producer (Case H) state that they could not find similar firms that would welcome them to visit their factories. The reason for the limitation regarding visiting other firms might be because the factories were in an early stage of the IoT adoption themselves, thus the firms preferred their IoT research and development to be private. Nysveen and Pedersen (2014) found that the successful implementation of IoT within organisations is more difficult to observe than the individual experimentation with IoT due to the limitations of revealing the data in this competitive environment.

In summary, the findings of this thesis confirms the importance of observability regarding the IoT adoption with the prior literature. Moreover, the relationship between the cost concern and the observability was found during the writing of this thesis. This study found that observability increases the confidence in the technology, which in turn positively impacts the adoption intention.

7.2.5 Cost

Most of the cases have concerns regarding the infrastructure expenses, in particular the Internetnet work and sensors; they believe that this will require a significant initial investment. Actually, SMEs realise the potential benefits of IoT but they dislike the costs that are incurred from acquiring new machinery, or adjusting the existing machinery as well as the integration of sensors and software (Müller, Buliga, & Voigt, 2018). The implementation of industrial IoT requires infrastructure, such as middleware and network cloud-based data centres (Sivathanu, 2019). The manufacturer has to invest in IoT and its integration into current operating systems (Tomic, 2017). The cost estimation is even more difficult for enterprises that want to integrate IoT with more advanced technologies, such as 3D printing or a System on a Chip (SOC) device. The indirect cost of training people to use industrial IoT and the cost of implementing the technology is necessary for the firms (Love & Irani, 2004). Nevertheless, in this study, only afew cases (F and J) mention the evaluation of a breakeven point and return on investment in the long term, which should make them more able to decide whether to invest in the IoT or not. This may imply that most of the cases are not able to estimate these measures, and this makes them worry about the cost of IoT investment. This is according to studies that found that most of the firms do trust the potential of the IoT, but they could not determine the true value of the IoT (Ericsson, 2015; Wang, et al., 2013). A study by Tomic (2017) confirms that adopters may not able to estimate the return on investment, as IoT is a new and conceptual technology.

The way to handle the cost concern is, as some cases decide to do, that is to invest gradually, and not fully adopt the IoT system. This is possible, as some of the investments can be on-premise systems. Hansen etal. (2017) suggested that cloud computing and Hadoop systems can be the solutions in terms of investment for SME manufacturers in order that they may handle the big data from IoT implementation. The entire IoT platform can be maintained in the cloud, which is much more favourable than building from zero in the firm's own data centres, as SMEs can meet their business goals much more swiftly than traditional data centers. This way, the software technical cost can be minimized or avoided (Illa & Padhi, 2018). There are several outsourced cloud platforms associated with big data (Illa & Padhi, 2018). However, the cloud-based system and other premise systems were only mentioned by the precast manufacturing case.

By contrast, few case studies (C, G and H) argue that cost is not a barrier when it comes to the IoT adoption decision. They argue that the total expense of the gradual implementation of the IoT project would be less in the long term than the fixed cost/initial investment. These case studies believe that the economic benefits and image of the firm, in the long run, is worth the investment; this may imply that these firms are able to estimate the return on investment. Several cases noted that the cost of investment is dependent on how large a project each firm requires and what functions they would like to incorporate; for their firm, the IoT is not significant for them. Therefore, the IoT budget is only allocated in small amounts. It is highlighted that the gap between the total resources and the total that is required depends on the organisation's priority (DePietro et al., 1990). If the organisations see particular technology - such as IoT - as important, they may allocate some resources from other departments to the IT department

(DePietro et al., 1990). In summary, the findings of this thesis confirm the importance of cost regarding the IoT adoption with the prior literature.

7.2.6 Security and Privacy

When discussing data security and privacy, the majority of cases (A, B, C, D, F and J) mentioned the cloud platform that keeps data it receives from the IoT device. The study highlighted that the majority of the cases were concerned about the potential for data leaks and loss, given that the cloud can be retrieved through the internet. With regard to data leaks, there is a great deal of confidential and classified data that the firms possess and would not want a third party to gain access to. Case Study C places great emphasis on private firm information regarding its sales and supplier transactions. Although data protection is the vendors' responsibility, the case studies want some sort of guarantee that it is indeed protected and that no unwanted access would be conceivable. In addition to this, the service providers themselves may access and use the information without permission (Hsu & Lin , 2016). Therefore, the service providers need to build trust among their cloud customers and ensure safe-keeping for all sensitive data. The cases, Case C, for example, typically lack trust in local service providers and have more belief in international providers such as Amazon (Gangwar et al., 2015).

Implementing the IoT in manufacturing firms can create several potential entry points for cyber-attacks (Sadiku et al., 2017). It can cause damage to reputation and revenue of an organisation if sensitive data were to be leaked (Wong & Kim, 2017). The most extreme case would be if cyber criminals took control of physical devices (Weinberg et al., 2015). Because of this concern regarding the cloud platform, some cases, such as Case C, prefer to only use local servers in order to reduce this risk. In addition, Case J limits its access to top management for some of its data. Gangwar et al. (2015) suggested that various security measures, at both vendor and user level, need to be implemented. These may include, but are not limited to, access control, identity and configuration management. Furthermore, Kowatsch and Maass (2012) argue that data security affects the willingness to provide information for IoT services, thus it cannot fully utilise the system (Kowatsch & Maass (2012). In addition to data leaks, data loss is another concern for firms, thus a backup process is required. The participants emphasized that the problem is not with the protection because data could be lost, but the problem lies with having no backup and no recovery arrangements, or worst case scenario, a company having no policy regarding data protection. Some cases (B and F) accept that the data security risk is unavoidable; ergo the possible risks, the damage potential of the risks, and the way to solve each case when it occurs should be evaluated. Case D has a protocol for security and privacy when it comes to any newsystem development.

By contrast, some cases (E and H) believe that security and privacy is not a determinant regarding IoT adoption. With pertinence to the data stored on the cloud platform, they believe that keeping data with a reliable cloud server provider is safe. Therefore, the relationship exists between the security concern and the technology support provider The reliability of the vendor reduces the concern regarding data security. Heiser and Nicolett (2008) found that in some cases, firms may seek out suppliers that are more sophisticated regarding their security and continuity expertise than they themselves are because they have no ability to assess the security of a sophisticated offering themselves. Some literature even demonstrates that they felt cloud platforms were far more secure than traditional in-house platforms. This supports Ashford's

(2009) argument that cloud computing is more secure than traditional computing. Case E believes that they have a skillful software team, hence this matter is not a concern. Dong et al. (2017) supports this by stating that in the case of the IoTs, experience undermines the relationship between perceived privacy risk and the adoption intention as the knowledge regarding the IoT systems enhances user skills and the capability of reducing risks. In addition, some cases (Case H) believe that they were not the target for a cyber attack due to their small size. They consider that their data is not considered to be valuable and could be disclosed. In summary, the findings of this thesis confirm the importance of security and privacy regarding the IoT adoption with the prior literature. The relationship between security concerns and technology support providers is identified in this thesis.

7.2.7 Trialability

This study found that testing is mandatory for almost all the case studies. The case studies mention the proof of concept and the technology/system development procedure of which testing is a part of those policies. Case F commented that the testing is even more important for emerging technology, such as the IoTs. The explanation as to why trialability is a significant barrier to IoT adoption in Thai manufacturing firms may be that the perceived difficulty of IoT testing is high for them. Sanchez et al. (2014) stated that IoT experimentation is difficult to conduct, as its architecture is complicated, and hardware and software resources are required. The testing for some case studies (Case A) is to invest gradually before fully implementing the IoT. Fujitsu (2010) suggested that when firms start the adoption process, they typically need to run trials on less-sensitive workloads, such as websites and PC applications.

Case Study J identifies that for the car manufacturing industry, there are various inter-linked processes. Therefore, if one point of the system fails, then the entire production line is halted. Hence, on-going testing is required. This comment is supported by Islam et al. (2015), who stated that organisations may be reluctant to adopt the IoT because it might disrupt their business processes. The IoT adopter may value innovation. However, they will realise the benefit only when the technology is successfully integrated with the systems within the organisation's infrastructure (Atzoriet al., 2010). The reason is that the IoT may change an organisation's infrastructure, especially if the current systems are unsuited to the IoT (Boo et al., 2013). Case D suggests that the evaluationteam should include the software developers and the operations team that are responsible for the manufacturing processes that will implement the IoT system. Furthermore, the manager emphasises that whilst the firm is utilising this agile working method, on-going testing is required.

By contrast, only Case G argues that testing is not required, but they state that they would undertake research on the IoT before implementing it. This might be because the firm believes that the cost of the IoT investment is not high. There is evidence to suggest that technology that can be tested without sustaining significant cost is more likely to be swiftly adopted (Chiyangwa & Alexander, 2016; Rogers, 2003). Given that cloud-based systems are often available for a quick demonstration, it may be that SMEs find them easy to trial, especially when compared with traditional business computing systems. In summary, the findings of this thesis confirm the importance of trialability regarding the IoT adoption with the prior literature.

7.2.8 Organisational Structure

The case studies expressed the effect of organisational structure in four dimensions:

1) Adaptability
2) Flexibility
3) Hierarchical structure
4) Openness.

The majority of the case views that the open structure is a driver that enables new ideas and innovation to be created, which will then initiate their IoT adoption intention. This result is consistent with other studies that indicate that openness and innovativeness act as factors that increase the tendency of new innovation adoption (Hirschman, 1980; Goldsmith et al., 1995; Kirton, 2003). In addition to cloud computing, which most of the cases adopted along with the IoT, the openness to change was used as a moderator to explore the impact of culture on cloud computing adoption within SMEs (Ogbonna & Harris, 2005). This observation is in line with Caldeira and Ward (2003) and Rivard, Raymond and Verreault (2006), whose studies revealed that significant resources to the firms, when exploited carefully, leads to the adoption of information technology innovation for competitive purposes.The decision that involves employees will contribute leads to ICT innovation adoption (Macpherson,Jones, Zhang, & Wilson, 2003). Furthermore, when employees are involved in the change process, it ensures that they are aware of the changes that may result from technology adoption and that they understand the impact of such change, thus leading to a higher success rate of the change initiative (Nguyen, 2009).

Regarding the flexibility of the organisation, this study found that inflexible structure is a driver to the IoT adoption, as it creates a systematic and clear direction towards adoption of the IoT. The people within the organisation will have the same IoT mindset. However, this is in contrast with several studies, which have demonstrated that flexible structure positively affects technology adoption. For example, Vukicevic (2018) and Burns and Stalker (1961) found that organisations that are more flexible and have changing conditions will adopt technology more than those with stable conditions and set rules. Management should build a flexible and agile environment within their firms in order to accept innovation (Tomic, 2017). Nevertheless, the study participants argue that flexible structure brings increased work and requires regular change, making technology adoption slow.

Regarding the hierarchical structure, several of the case studies, (H and C, for example) believed that their flat structures acted as a driver to IoT adoption. The case studies explained that a flat structure has more top management to initiate innovative projects such as the IoT. The line of approval for technology adoption decision is short, hence the adoption decision could be made faster. This finding is consistent with Damanpour (1992), who found that organisations with less bureaucracy tend to adopt technology more efficiently, as a high level of bureaucracy means that ICT innovation adoption decisions would have to pass through several departments within the firm to gain approval. In addition, Oliveira and Martins (2011) revealed that smaller firms, with few layers of management to pass through, were quickly enabled to change direction rapidly and become more flexible so as to achieve business agility as and when required; this then enabled the rapid transitioning into new technology. This is consistent with related technology adoption such as cloud computing (for example, Alshamaila et al., 2013).

Regarding the adaptability of firms, this thesis found that it is a driver to IoT adoption. This is because those firms that have a large number of employees of the younger generation tend to be adaptable to technology change. This adaptability to change allows for increased business agility (Marston et al., 2011), thus the push for IoT adoption. It should be noted that not only the organisational structure affects the IoT adoption decision, but also vice versa. Some case studies (for example, D and G) believe that the IoT would help reduce the missed or delayed communication, especially for firms with complex organisational structures. In summary, the findings confirm the importance of organisational structure regarding the IoT adoption with prior literature.

7.2.9 Top Management Support

The discussion on the top management support is organised into the following categories: as

1) Training
2) Communication,
3) Resource allocation
4) Innovative competition
5) Strategy/vision on technology.

Regarding the training, Case E hires specialists, such as vendors or university professors, to train their employees how to work and develop software and machinery. Case B sends out their employees and executives to workshops related to IoT and cloud systems. In particular, the leader of the organization will be sent first, becoming the champion leader, and he/she will teach the other employees within the organisation thereafter. The reason may be that the existence of technology leaders can lead to the adoption of information and communications technology innovation (Kamal, 2006). Hofer and Charan (1984) noted that there should be training facilities to manage the transition project. The participants of this study believe that maintaining the cloud would not be easy without training and that the training will minimise resistance against adoption. Furthermore, Lee, Kao and Yang (2014) suggested that Industry 4.0, especially AI and IoT,requires management skills regarding technology adoption.

Regarding the communication on the IoT adoption, most of the top management in the case studies (E, F, G and J) sent out the message to their employees outlining the need for the IoT. The majority of them tried to convince their employees to accept the IoT adoption. The management required that their employees should take some time off their routine task to work on the IoT project. A few of the top management forced their employees to work on the IoT project, regardless of the willingness of the employees. This finding supports Bruquea and Moyano (2007) study, who found that technological adoption within SMEs was driven and influenced by top management, as the leader's role is significant when it comes to the introduction of emerging technology, such as the cloud. The rest of the employees within the organisation would be convinced of the need to adopt it.

In term of the resource allocation for the IoT project, top management guides the allocation of resources for IoT adoption, the integration of service and the re-engineering of process within the firms (Hsu & Yeh, 2016; Wang & Wang, 2016). The findings indicate that the case studies (F and J) have a significant budget for the IoT. One case stated that the cost control departments in SMEs typically strictly approve of the technology adoption, as it is not the core business.

However, for the IoT adoption, it is exceptional. This emphasises how important the IoT is to them, as for some other technologies, it was found that management likes to see real benefits that they may be convinced about new, emerging technology, and then the required resources are released for successful adoption (Tashkandi & Al-Jabri, 2015). This argument is also supported by Tan and Teo (1998).

Moving on to the innovation competition within the firms, some case studies (for example, B and E) mentioned the innovation competitions among their employees that served to create an innovative culture and initiate the IoT project. Those competitions are typically held among the software team who create new innovations, not among the technicians who operate the machinery. This competitive culture was found to build on a democratic approach to decision-making, whereby employees' ideas are exploited for competitive purposes. In these cases, this has led to the adoption of cloud computing for sustainable competitive advantage (Subba, 2014).

Regarding the strategy and direction concerning IoT adoption, IoT strategy and project implementation guidelines are crucial (Kiran & Wynn, 2022). The majority of the case studies (for example, B, F, I, J) had Management of Change Policy Strategies with regard to their technology adoption. With the Management of Change procedure, everyone within the firms has the same mindset about what the firm needs to do to achieve digitalisation. Some cases (for example, Case D) state that everyone on the IoT project has an assigned specific task. Furthermore, the medium to long-term plan of the IoT is mentioned. The case studies argue that when top management is pushing, the technology adoption is quick and effective. In summary, the findings of this thesis confirm the importance of top management support regarding the IoT adoption with the prior literature.

7.2.10 Organisational Size

The case studies expressed the discussion regarding the organisational size in two dimensions: financial resources and organisational structure. Most cases (A, E, F, H) mentioned that the issue revolves around the financial resource. Some interviewees stated that that the larger firms have more advantage when it comes to adopting the IoT, as they have more money. Case H points out that larger firms could gain greater benefit, as larger sized businesses require more IoT applications in order to monitor the factory, thus the return from the IoT can be maximised. By contrast, resource scarcity is the most important challenge that the SMEs face with regard to implementing the IoT within manufacturing (Nylander et al., 2017; Warrian & Southin, 2017). In particular, it may be more challenging for SMEs whose products and processes are not related to IT (Wallberg et al., 2017), which is the case for all the participants in this study. SME manufacturers require significant investment to handle the big data from IoT implementation (Schönsleben et al., 2017). The coal manufacturing firm (Case F) states that IoT investment would not be feasible for them and other small coal manufacturers in Thailand. Furthermore, Carcary et al. (2014) indicated that firms with greater financial resources could takemore risks relating to technology adoption. In this study, some firms (Case E) suggests that SMEswould not take a risk by developing new technology if they are still not making enough profit.

However, some others (Cases I and D) believed that the advantage of larger firms is firmly in the past, as the cost of IT investment has been decreasing. In addition, small firms have an alternative way of using the IoT, such as on-premise systems, or subscription model systems for IoT applications which is less costly. One source of literature verified that, due to the scalability and on-demand characteristics of cloud computing, cloud computing is more appealing to SMEs that, as a result of their size, usually have limited resources and IT expertise (Gupta, Seetharaman, & Raj, 2013; Marston, Bandyopadhyay, Zhang, & Ghalsasi, 2011). Therefore, the size of the firms affects the cost concern with regard to this study; the smaller the firms are, the more they have concerns pertaining to cost.

Regarding the organisational structures of different firm sizes and the effect on the IoT adoption intention in this study, larger firms require a change of policies and protocol for new technology adoption, which hinders the IoT adoption intention, as it brings delays and complexity. This is often a critical issue for large firms, as adopting IoT will not only require significant organisational change (Vukicevic, 2018), it will also greatly impact upon larger firms. However, few interviewees (Case C) argued that larger firms might be slower to adopt the IoT, but they do have more efficient and completed IoT systems. This study also demonstrates that SMEs have more acceleration when making a decision to swiftly adopt the IoT. Vukicevic (2018) indicated that SMEs are more adaptable and that the employees working on technological innovations work closely to with the operational employees. Furthermore, even though the required organisational changes from technology adoption in large firms also happen in SMEs, SMEs are more flexible in handling them (Vukicevic, 2018). **Section 7.2.8** indicated that there is a relationship between the size of the organisation and the structure of the firms; the SME typically has a flat structure, which brings greater agility in organisational change, enabling the transition into the new technology to take place more effectively and rapidly. Therefore, this study found that the size of the firms truly creates a different organisational structure, which then affects the IoT adoption. In summary, the findings of this thesis contradict the prior literature, which found that the size of the organisation is important pertaining to the IoT adoption.

7.2.11 Business Partner Influence

In this study, two parties affected the IoT adoption intention: alliances and customers. In some cases, IoT adoption is influenced by the cases' alliances through recommendation and policy deployment. Previously, O'Callaghan, Kaufmann and Konsynski (1992) identified that the technology adoption process is usually started by one partner organisation recognizing the benefits and prospects of a new technology, and they then convince the other organisations in the chain to adopt this new technology. In this study, the alliances are larger, hence it is more likely that the firms in this study have less power than their alliances. This is supported by Hart & Saunders (1997), who state that power in inter-organisational relationships is measured as the level of dependency. The more an organisation is dependent on the other organisation, the less power **it** has and the other organisation will have more power (Frazier, 1983). Furthermore, a study pertaining to cloud computing indicates that partner readiness affects the adoption in terms of technological, financial and human infrastructure. Grossman (2004) and Chwelos, Benbasat and Dexter (2001), demonstrate that trading partner readiness is important to adopt an inter-organisational technology; this is the case for the precast manufacturing firm (Case D) which intends to adopt the IoT for internal systems and data integration purposes.

Regarding the customer influence on the IoT adoption intention, almost all of the cases (A, B, C, D, E, G, H, I and J) are influenced to adopt the IoT by their largest customers. They would adopt

IoT to increase customer satisfaction, as the IoT enables quick response to the demand, increase the variety of products and possibly reduces the price. This is critical, especially for some firms that focus on a customer-centric strategy, such as the gas producing case (Case B). Moreover, case I believes that increased customer satisfaction brings increased sales and a number of customers. Furthermore, some cases (G and H) believe that the IoT would increase the standard of their factory as perceived by their customers. Therefore, the relationship exists between the business partner influence and relative advantage factor. In this study, the customer influence strengthens the relation between the relative advantage factor and IoT adoption intention. This finding is supported by Yoon and George (2013) and Lasi et al. (2014) who state that external pressure, such as consumer pressure, can push businesses to adopt technologies. It helps them improve their relationship with customers (Abazi, 2016). Several studies - Zhu et al. (2003),Son and Benbasat (2007) to name but two – have demonstrated that customers are seen to significantly influence IT adoption. In summary, the findings of this thesis confirm the importance of business partner influence regarding the IoT adoption with the prior literature. The relationship between the business partner influence and relative advantage was found during the writing of this thesis.

7.2.12 Technology Support from Vendor

The result of this study demonstrates that the case studies would require support from vendors throughout the adoption process. Most of the participants were still going through a learning curve concerning the use of the IoT. Thus, the first phase of the adoption would fully make use of support given by the vendors. Once the firm creates knowledge and experience with the IoT, they will use permanent employees to manage the system. Therefore, the relationship exists between the compatibility factor and technology support from the vendor. In this study, the knowledge and experience compatibility strengthens the relationship between technology support from the vendor and the IoT adoption intention. The knowledge factor proved to be significant in **Section 7.2.2**.

Ericsson (2015) stated that using external consultants is one option regarding closing the knowledge gap, as a firm cannot manage all aspects of the IoTs. Prior research highlights a correlation between ICT suppliers support and the end-user adoption decision with suppliers acting as a source of knowledge and capability (Weigelt & Sarkar, 2009) or assurance (Frambach & Schillewaert, 2002). Robey, Boudreau and Rose (2000), indicate that support from IT vendors would eliminate the need for cloud adopters to learn about cloud services without the requirement for developing in-house knowledge competencies. Case G suggests that for non-software businesses, using outsourcing is appropriate when it comes to new technology development, as it would save time and money wasted from trial and error. Therefore, vendor selection is critical. In some cases (Case B) the vendor's support is crucial, as they utilise the IoT for safety purposes. The vendor selection issue is evident from a study by study Illa and Padhi (2018) on cloud -computing adoption; they demonstrated that SMEs should acknowledge that there is no single cloud service provider that can provide end-to-end IoT solutions. Therefore, firms have to select particular products from various providers and effectively integrate them to meet the needs of the business (Illa & Padhi, 2018). However, most of the participants (A, B, C, D, F, G and H) could not find high-quality vendors. Case A believes that IoT technology is too recent for most Thai vendors and they lack the requisite expertise.

Furthermore, after the adoption process, Case studies A, B, C, G and H indicated that they would require additional support from IoT vendors to improve and adjust their systems in order to ensure compatibility with their current operations and IT infrastructure. Case A stated that the IoT system is unreliable and subject to frequent breakdowns within the coal industry. However, this maybe just because of the harsh working environment. Studies on the IoT, found that approximately 40 percent of the IoT value require communication and data integration between different IoT systems (Bughin et al., 2015; Manyika et al., 2015). The entire ecosystem of an organisation needs to be integrated (Bughin et al., 2015). Therefore, for effective IoT implementation, manufacturing SMEs require support from IoT vendors. As the compatibility between devices and systems is significant for the long-term strategy of the firms, the standardisation for the communication between devices and systems needs to be effectively initiated (Bao et al., 2014).

By contrast, few cases (E, I and J) do not require significant support from vendors after adoption. Case J believes that the IoT should be in the accounting department, not manufacturing, as the cost-related data would be integrated using the IoT. Case E adopted the IoT entirely in house and they argued that they did not require support from the technology provider because they have a software business and therefore have the required expertise. In summary, the findings of this thesis serves to confirm the importance of technology support from vendors regarding the IoT adoption with the prior literature. The relationship between compatibility and technology support from the vendor was found in this thesis.

7.2.13 Competitive Pressure

The case studies have emphasized that the relative advantage factor has more impact on the IoT adoption decision than competitive pressure. Furthermore, they argue that the manufacturing industry is obsolete in Thailand, and that this results in less competition concerning technology adoption. The filter producing case (F) believes that Thai manufacturing is dying, since the neighbouring countries have lower labour costs, Thai industries are moving to these countries. A recent example is Samsung, which moved its production facility to Vietnam (Bangkok post, 2015). This is a possible explanation for the insignificance of this factor to the IoT adoption intention among the case studies. As the IoT has only recently emerged in Thailand, only a few firms have adopted it within their manufacturing sectors. In fact, some cases (A and E) noted that since they were the first ones in the industry to adopt the IoT, there was no effect from competitive pressure. They argued that technology adoption in similar organisations is typically at the same pace. This implies that after the adoption of the IoT, the pressure would be on the follower whether to adopt the IoT or not. This argument is supported by Nikbin and Abushakra (2019), which found that social influence significantly affects IoT adoption. It means that when competitors have adopted IoT, entrepreneurs will have a higher intention to adopt the technology(Nikbin & Abushakra, 2019). Furthermore, in some cases (Case G) their peers in the same industry would not allow them to visit their factories, thus there is no effect from the competitors on the IoT adoption intention.

By contrast, few firms (B, F and I) believe that there was a direct threat from other competitors within their industry, such as pricing competition, and the IoT would differentiate them from competitors by having a greater variety of products due to the fact that the IoT enables customized mass production. Therefore, the competitive pressure affects their IoT adoption intention. Previously, Rosas et al. (2017) demonstrated that organisations adopt the IoT to increase competitiveness. In summary, the findings of this thesis contradict the prior literature, which identified the importance of competitive pressure regarding the IoT adoption.

7.3 Research Question Three: What Guidelines Can be Developed to Guide Practitioners in Assessing the Suitability of Manufacturing SMEs in Adopting IoT Technologies?

This section considers research question three by discussing the implications of the conceptual framework **(Figure 20**) to the practitioners. The guidelines for SMEs' owner/managers and IT vendors/consultants to assess the suitability in adopting IoT technologies are discussed. For the SMEs' owner/managers, the study results may assist them in evaluating and planning their technology adoption strategies and to ensure effective adoption practices. First, the relative advantage, which is found to be the most significant determinant in this study. The owner/managers could consider the application and benefits of IoT adoption **(**see **figure 8)** and decide if any of them would be practical for their manufacturing activities. For example, the digital/connected factory would be suitable for the firms that have multiple factories. This application applies digital twin (virtual machine) technology, which enables operators to access a physical machine and overcome the challenge of geographical distance (Jiang, Guo, & Wang, 2021; Nguyen, Zeadally, & Vuduthala, 2021). To develop an efficient method that can remotely monitor the operations of a physical machine, firms are required to bring the virtual machine technology to Cyber-Physical Cloud Manufacturing (CPCM), systems that include many physical machines and cloud servers. Cloud servers would work as a centre for every application acquiring information (Nguyen et al., 2021). Another example is the real-time traceability capability of the IoT. It would be suitable for the firms that produce perishable products, such as fresh foods, as firms could trace the entire supply chain in order to control its quality and time management throughout the processes, from the start of production to the delivery.

This study found that what caused the most concern is the compatibility of the IoT with the technological infrastructure and its ability to easily integrate with IoT systems. Therefore, owner/managers should seek reliable IoT vendors/consultants, as they would play a significant role, especially in the first phase of the adoption. It would save time and money wasted from trial and error by hiring IoT vendors/consultants. Once the firm creates knowledge and experience with the IoT, they could use permanent employees to manage the IoT system. After the implementation, they would still require additional support from IoT vendors to improve and adjust their systems to ensure compatibility with their current operations and IT infrastructure. It should be noted from the case studies in this thesis that the vendors' selection is critical, as it is difficult to find competent vendors in a developing economy such as Thailand.

Furthermore, the cost-benefit analysis and feasibility study for the IoTs must also be evaluated as the firms are potentially required to install new hardware/software, especially internet networks and sensors. In addition, a significant initial capital investment of adapting the existing systems might be required. This is dependent on each firms' existing systems and IoT applications. For example, predictive maintenance application of the IoTs has been evaluated by calculating Net Present Value (NPV) (Franceschini & Midali, 2020). To calculate the cash flows, a differential between the costs of the previous maintenance and those of the predictive was considered (Franceschini & Midali, 2020). An example of the cost analysis in this thesis is the filter manufacturers (Case H), which decided to replace the relay system with the IoTs. The firm uses Genesis, Genesis 64 and Open Platform Communications (OPC) servers (a driver to gather all PLCs and to communicate between the machines) for the IoT software. RS485 protocol is utilised to communicate with IoT devices, such as sensors. The IoT costs approximately 10,000 Baht per machine. With the OPC server, the internet and the LAN wiring it is 200,000 Baht for 10 machines. Fortunately, the cost of IT equipment is projected to reduce over time (Muparuri & Gumbo, 2021). Therefore, firms that typically have limited resources and IT expertise currently have an alternative way of using IoT technologies, such as on-premises systems or subscription model systems for IoT applications, which are less costly (Ok, Kwon, Heo, & Suh, 2021). For example, Rehman, Mahmood and Mustafa (2021) suggested that cloud computing and Hadoop systems can be the solutions in terms of investment for SME manufacturers to analyse big data from IoT implementation. The entire IoT platform can be maintained by storing in the cloud, which is a more flexible option than developing from zero in the firm's own data centres as SMEs can meet their business goals faster than traditional data centres and avoid or minimise the software technical investment cost (Alsharari, Al-Shboul, & Alteneiji, 2020; Rehma et al., 2021). Overall, the cost concern could be reduced by observing the successful cases of IoT adoption in the same or similar industries in order to be confident about the security, reliability and expected benefits of the technology. It is evident from this thesis that some firms visit different types of factories and apply only some critical functions of the IoTs; therefore, potentially not maximizing the adoption opportunity that IoT offers.

The case studies within this study suggest that IoT technologies should be tested before being fully adopted, in order to see the benefits and risks in advance. The opportunity to test IoT security, reliability and privacy issues may decrease the risks for the organisation (Bures et al., 2021). The testing suggested by this thesis is to invest gradually before fully implementing the IoT. In particular, when firms start the adoption process, they should run trials on less-sensitive workloads, such as websites and PC applications first. This thesis suggests that the testing/evaluation team should include both software developers and the operations team responsible for the manufacturing processes that will implement the IoT system. Furthermore, the case studies in this study emphasise that on-going testing is recommended throughout the adoption processes. This thesis suggests that the top management within the firms could help create the adoption intention in four ways:

1) By sending employees to workshops related to the use of IoT technology
2) By communicating clearly about the need for the IoT system
3) By allocating significant budget for the IoT adoption
4) By having clear strategic direction on the IoT project.

Vendor specialists should be hired to train employees how to operate and develop both software and hardware within the manufacturing processes. Employees and executives should be sent to workshops related to IoT and cloud systems usage. Priority should be placed on ensuring that key decision- makers within the firm are fully conversant with the IoTs and the the opportunities it offers. Furthermore, the budget allocated for the IoT project should be significant enough to ensure the IoT project managers are motivated and that they understand the significance of the investment. In addition, the top management needs to convince their workforces that they will not be replaced by increased mechanization or technology adoption.

Reskilling and up-skilling of existing employees through workshops/training should be provided. Regarding the hierarchical structure, this thesis found that flat organisational structures act as a driver to the IoTs adoption. The case studies explain that a flat structure has more top management that are able to initiate innovative projects, such as the IoTs. It is critical that the firms' approval processes for a technology adoption decision are short, otherwise opportunities will be lost. Therefore, responsive management structures are essential to encourage effective IoT adoption.

For IT vendors/consultants, knowledge and understanding of the factors affecting IoT adoption intention will enable them to design suitable strategies for the widespread adoption of IoT technologies for both customers and suppliers. IT vendors/consultants could minimise any feelings of uncertainty, and stress the need to embrace technological change. First, relative advantage and observability are the significant drivers to IoT adoption. Therefore, vendors need to highlight the benefits that the IoTs would offer and demonstrate successful implementation cases. Furthermore, the findings reveal that testability is a significant factor in ensuring that the adopter would be able to anticipate the benefits of the IoTs, thus vendors should allow their customers to test the IoT products or services before their customers decide to acquire them. This study found that SMEs have a cost concern regarding IoT investment, as it is a relatively recent technology and potentially expensive. Thus, there is a need to evaluate the cost/benefit of adoption and potential return on investment. Therefore, IoT vendors/consultants may provide or suggest feasibility studies, or cost/benefit analysis to their customers, as a means to encourage adoption.

This thesis found that compatibility was a significant barrier. This study found that technology support from vendors/consultants reduces the concern regarding the compatibility with existing infrastructure and IT department expertise towards IoT adoption. Therefore, the IT vendors/consultants should seek to identify the optimum IoT system that can be customized to fit with their customers' existing systems. In addition, they should provide a consultant, or appropriate training, in order to reduce the compatibility concerns. With regard to security concerns surrounding the IoTs, the vendors should incorporate the new technological advances to make customers feel more comfortable and have increased confidence in their vendors/consultants. Additionally, as most adopters in this study acknowledge the role of IT suppliers in resolving and minimizing security and privacy issues, IT vendors should improve their reputation as reliable suppliers and ensure that their platforms are compliant with the relevant standards. In particular, the study participants emphasise that the issue is not with the protection because data could be lost, the actual problem is when there is no backup procedure or recovery arrangements regarding data protection.

7.4 Summary

This chapter presented and discussed the findings from the case studies. This was accomplished by integrating findings from each case and from the literature review. This discussion of the first research question confirms that relative advantage and business partners are the most significant drivers to the IoT adoption intention and compatibility is the most significant barrier hindering the adoption intention. In contrast to the literature, complexity, organisational size and competitive pressure are not significant determinants in this study. Having identified the key factors in research question one, the second research question discusses the importance and influence of those factors. The relationship between the factors found in this study is also discussed. Moreover, this chapter considers research question three by discussing the implications of the conceptual framework (**Figure 20**) to the practitioners.

With regard to the technology context, the compatibility with existing infrastructure is highlighted in terms of cost concerns and technical issues. However, as the majority of firms have support from vendors, the technological concern is reduced. In contrast, the cost factor is still a concern, as most of the participants are not able to estimate the breakeven point and return on investment of the IoT. Nevertheless, some firms argue that the expense of the IoT project would be less in the long run. In addition, they would utilise only some functions of the IoT to save costs. Furthermore, the cost concern strengthens the need for the observation factor; this is evident in some case studies where they visit different types of factories and select only critical functions of the IoT from those factories. This study found that the observability increases the confidence in the technology, which in turn positively affects the adoption intention. In addition, the IT department/expertise concern is disregarded in this study, as most of the firms rely upon vendors. Regarding the complexity, it is not found to be a barrier to the IoT adoption in this study. The case studies argue that the perceived complexity largely depends on an organisation's level of knowledge and expertise.

Based on the interviews, the participants perceive that their employees have a high level of knowledge and experience compared with the complexity of the IoT. Another explanation for theinsignificance of this factor is that the expectation of the IoT utilization in most of the cases is low, hence they do not require complex systems in the first place and the knowledge and experience of the firm is not highly required. The difficulty is encountered later in the process, whereby most of the participants believe that top management can provide the training. Regarding security and privacy, the case studies believe that keeping data with a reliable cloud server provider is safe. Therefore, trust in vendors reduces the concerns regarding data security. Overall, it can be seen in this study that the technology support from vendors is emphasised in order to reduce the concerns regarding compatibility, security and privacy. Moreover, the cost concerns strengthen the worries regarding the compatibility factor and the need for observation.

With regard to the organisational context, the organisational size is insignificant in this study. The majority of the case studies argue that large and small firms may benefit from the IoT in different ways and times. However, the size of the firms affects the cost concern in this study. The smaller the firms are, the more they have concerns regarding the cost of the IoT investment. This study found that the size of the firms actually creates a different organisation structure, which then affects the IoT adoption. Larger firms are more complex and require a change of policies and protocols for new technology adoption. This hinders the IoT adoption intention because it brings delays and complexity. This study has demonstrated that SMEs, having a flatter organisational structure, typically have accelerated decision-making processes. Regarding the organisation structure, there are contrasting opinions as to whether this factor should be a driver or a barrier. It depends on each case and which dimension of the organisational structure they discuss. In contrast to the literature, this study found that an inflexible structure is a driver to the IoT adoption because it creates a systematic and clear direction for adoption. The employees within the organisation will all have the same mindset regarding IoT implementation. The participants in this study argue that flexible structure increases workload and requires frequent change, making technology adoption slow.

With regard to the environmental context, for the business partner influence two parties have been identified to affect the IoT adoption intention: customers and alliances. Several of the case studies have alliances, and they were influenced to adopt the IoT either by recommendation or policy deployment. Furthermore, the largest of the customers were found to significantly affect the IoT adoption intention. It was found that the influence of the customer strengthens the relationship between the relative advantage factor and IoT adoption intention. Most of the cases would adopt the IoT to increase customer satisfaction, as the benefit of IoT is to enable quick response to the demand, increase the variety of products and possibly reduce the price. By contrast, the influence from suppliers was uncommon for most of the case studies, as they are in the manufacturing industry, thus they are at the top of the supply chain. Regarding the technology support from vendors, most of the participants are still going through a learning curve pertaining to the IoT, thus the first phase of the adoption would use the vendors' full support. Once the firm creates knowledge and experience with the IoT, they will use the permanent employee to manage the IoT system. Therefore, in this study, less knowledge and experience strengthens the importance of technology support from vendors. Regarding the competitive pressure on IoT adoption, it is not found to be a barrier in this study. The case studies argue that the manufacturing industry is obsolete in Thailand, and that this will result in less competition regarding technology adoption. The next chapter will present the conclusions.

Chapter 8: Conclusions

8.0 Conclusions Chapter

This chapter provides the conclusion of this thesis. This study has considered the usage and deployment of the IoTs within manufacturing SMEs in Thailand. The chapter summarizes the contribution to knowledge achieved, the implications for policy and practice, study limitations, further research opportunities and reflections on the research process.

8.1 Contribution to Theory

This section outlines the theoretical contribution that has been achieved within this thesis. Specifically, how the technology adoption theories in a manufacturing SME context within a specific geographical context has been further developed. Several theoretical contributions are noted. Firstly, this study provides novel insights through a qualitative approach into the usage and applications of the factors affecting the decision of whether to adopt the IoT in the context of manufacturing SMEs in Thailand. The perception of whether the factors are drivers or barriers is discussed in **Section 7.1**. The level of significance and the influence of each factor is analyzed in **Section 7.2**. This thesis has made a contribution to the improved understanding and awareness of the IoTs within the SME manufacturing industry in Thailand, where there is an acknowledged gap in the literature. The majority of the studies already undertaken relate to general IoT adoption within manufacturing, or within large manufacturing organisations (Akimana et al., 2017; Bogers et al., 2016; Burkett & Steutermann, 2014; Kagermann et al., 2013) and do not specify the countries/areas where the data collection took place. This can be an issue as both consumer and organisational behaviour in each country can be different (Prahalad, 2012; Zanello et al., 2016). Understanding how the IoT is being adopted throughout emerging economies is an important dynamic that has been largely ignored within the existing literature. This thesis offers novel country level insights. Furthermore, there is a lack of research that compares and contrasts all the relevant factors that affect the IoT adoption in manufacturing SMEs, for example, the technological, organisational and environmental factors.

Secondly, this thesis presents a revised conceptual framework **(Figure 20,** below**)** that highlights the factors that affect the adoption decision of whether the IoT within manufacturing SMEs in Thailand is implemented. The initial conceptual framework **(Section 4.2)** is adopted from general IT adoption models (DoI, TOE, TAM, UTAUT) and literature of IT adoption models in their relevant contexts. The revised framework is recontextualized to reflect the reality of IoT behaviour and adoption within Thailand. The conceptual framework is modified and extended based on the case study analysis and is to be used as a tool to effectively understand the influential factors impacting IoT adoption within a Thai manufacturing SME context. Overall, the framework presents all actors and core relationships with all potential moderating effects.

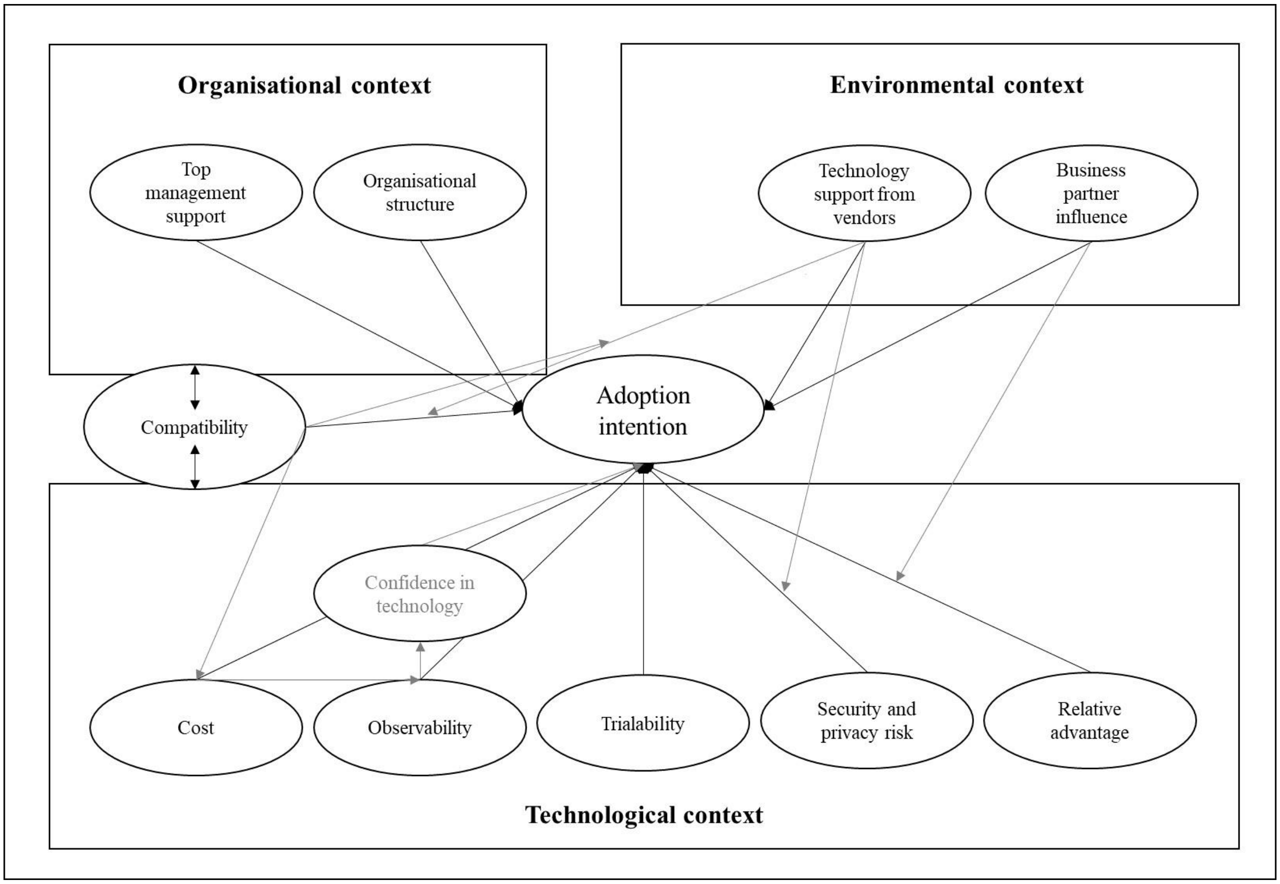

Figure 20: Revised Conceptual Framework Presenting the Factors Affecting Adoption of IoT in Thai Manufacturing SMEs

The proposed framework considers the technology factors, which are:

1) Relative advantage
2) Observability
3) Cost
4) Security
5) Privacy
6) Trialability (Balaji & Roy, 2016; Christensen & Huang, 2018; Kamin, 2017; Park et al., 2017; Shin, 2015).

This framework considers the organisational factors, which are:

1) Organisational structure
2) Top management support (Hsu & Yeh, 2016; Vukicevic, 2018).

The compatibility is included in both an organisational and technological context, as it explains the fit between technology requirements and organisational readiness, such as the technological infrastructure, skilled employees and financial resources (McMullen et al., 2015; Sinha & Mukherjee, 2016). Furthermore, this framework considers the impacts of environmental factors, such as business partner influence and technology support from vendors (Abazi, 2016; Bughin et al., 2015; Manyika et al., 2015).

The relationships between the factors and a new factor, which has not been demonstrated in previous IoT adoption studies, are found within this thesis. The knowledge and experience compatibility factor strengthens the relationship between technology support from the vendor factor and the IoT adoption intention. Prior studies have shown a correlation between ICT suppliers support and the end-user adoption decision, with ICT suppliers acting as a source of knowledge and capabilities (Weigelt & Sarkar, 2009) or assurance (Frambach & Schillewaert, 2002). This study also demonstrates that the technology support from the vendor factor reduces the concern regarding the compatibility with existing infrastructure and the IT department expertise towards IoT adoption. However, the compatibility with existing infrastructure increases the cost concerns, as manufacturers have to invest in IoT equipment and its effective integration into their operating systems (Müller, Buliga, & Voigt, 2018; Tomic, 2017) and the cost concern in turn increases the significance of the observability factor. Most IoT adopters would think twice about adopting such technology whist discounting its benefits (Tu, 2018). The proof of success would increase confidence in the technology benefits (Tu, 2018).

The observability factor creates the new factor within the framework **(Figure 20),** thus highlighting confidence in the IoT technology, which creates the adoption intention. Lin (2011) states that confidence is one of the most effective tools for decreasing uncertainty and risks, and for generating a sense of safety in technology; the lower the technology uncertainties, the more confident participants will become as they can anticipate the technology benefits (Tu, 2018). Furthermore, this study demonstrates that the reliability of vendors (technology support from vendor factor) reduces the concerns regarding data security toward IoT adoption. Heiser and Nicolett (2008) found that firms might seek out suppliers that have superior expertise than they do because they have no ability in-house to assess the security of a sophisticated technology system adequately. Lastly, the business partner influence strengthens the relationship between the relative advantage factor and IoT adoption intention.

It was found that the previous studies robustly supported complexity, organisational size and competitive pressure factors (Aguila-Obra & Padilla- Meléndez, 2006; Belso-Martinez, 2010; Chan & Chong, 2013; Gangwar, Date, & Ramaswamy 2015; Gutierrez et al., 2015; Leminen et al., 2012; Raymond & Uwizeyemungu, 2007; Wang et al., 2010). However, this study negated those earlier results and found that these factors are not valid in the context of this study, especially the complexity factor, which is found unanimously to not affect the adoption intention. It is highlighted in this thesis that most respondent firms perceive that complexity depends largely on the level of knowledge and expertise of an organisation. The participants in this study recognizes that their employees have a high level of technical knowledge and experience and are able to deal with the complexity of the IoTs, thus it is not a major concern

(Dong et al., 2017). Therefore, it is essential that if an organisation wants to effectively deploy the IoT, it must have suitably experience and trained staff (Ericsson, 2015). This study increases our understanding of how to effectively embed and utilise the IoT within a manufacturing SME context within a developing economy. Furthermore, this study builds upon prior literature regarding technology adoption, especially for the relevant or similar technology to the IoT; for example, Matias and Hernandez (2021); literature on the technology adoption on the manufacturing industry in Thailand, such as Chang (2021); and literature on the technology adoption in the SME sector, for instance, Trawnih, Yaseen, Al-Adwan, Alsoud and Jaber (2021).

8.2 Contribution to Policy

This section discusses the contribution made to policy from this study. This thesis offers insights for policy makers to implement and accelerate IoT development and utilization among Thai manufacturing SMEs. It is critically important for the Thai manufacturing SME sector to effectively embrace the IoT so as to increase efficiency and effectiveness. For policy makers, this research has significance for several groups, including the manufacturing SME community, governmental decision-makers (Department of Industrial Promotion (DIP), Ministry of Digital Economy and Society), the academic community and the private sector in general.

The manufacturing industry in Thailand contributes 25 percent to the total GDP (World Bank, 2020), hence it is important for the government to pay attention to this industry sector. Within Thailand, the SMEs within the manufacturing industry are struggling due to the competitive pressure from neighbouring countries, as they have lower labour costs (Bangkok Post, 2015). This issue was confirmed during this study, an example being Case study H, the filter producer. The management is adopting the IoT to be able to compete with global manufacturers and to ensure the growth and survivability of the manufacturing industry in Thailand, the manufacturing SME community should remain the central focus of the DIP and encourage IoT usage in order to improve the business sustainability, efficiency and profitability. IoT adoption must be considered as one of the key strategies needed to achieve operational sustainability, increased efficiency and productivity and, thereafter, being able to compete with global enterprises. Furthermore, university graduates, school and college leavers alike should be encouraged by a supportive legislature, enterprise supporting programmes, trade organisations and business centres, to consider a technology related career as a viable and prosperous career route. It is vital that the key policy makers ensure that the manufacturing SME sector is aware of the opportunities offered by the effective deployment of the IoTs. A practical contribution of this thesis is that it has identified there is a lack of policy makers that support the IoT vendors and customers relationships and thus to ensure that there are appropriate regulations to support both IoT suppliers and customers to create an ecosystem. The government could allow firms that invest in IoT adoption activities - such as increased robotics and process automation, conceptual design solutions, engineering design and system integration - to benefit from tax holidays, exemption of import duties on machinery and raw materials related to the innovation activities. Furthermore, incentive policies to attract foreign investors who work or invest in technology-based production activities and services could be established. In addition, a state-owned Digital Economy Promotion Agency (Depa) should establish an IoT Institute in the government's digital park so as to draw investment from foreign firms and promote the Thai tech startup ecosystem through innovation development. This will create opportunities for vendors in artificial intelligence, IoT, or 5G technologies. Depa could partially co-invest with those vendors and help them with related infrastructure and intellectual property capture.

The findings of this thesis demonstrate that observability is a significant factor that manufacturing SMEs need to consider in order to adopt the IoT (Shin, 2015; Sinha & Mukherjee, 2016). Therefore, the Department of Industrial Promotion should offer examples of effective IoT adoption practices via the internet, to help ensure that SMEs are fully aware of successful implementation cases. Furthermore, this study indicates that the internet is not reliable and not fully accessible in Thailand, and this does hinder the IoT adoption intention. For example, internet access is inferior in rural locations. Therefore, the Ministry of Digital Economy and Society should seek to ensure that broadband infrastructure is available throughout the country and SMEs have access to fast broadband services as a priority (Chen et al., 2017; Schwab, 2017). Lastly, regarding the data privacy and security concern, which has been found to be a significant barrier in this study, the governments should consider improved legislation relating to data protection, and work together with large telecommunication organisations to ensure this happens (Airehrour et al., 2016).

8.3 Contribution to Business Practice

This thesis offers insights for owners/managers within organisations and technology consultants/vendors that they may implement and accelerate IoT development and utilization among Thai manufacturing SMEs. For the owners/managers of the firms, this study can be utilised as a basis to consider whether to adopt the IoT in their organisations. The study results will assist the owners/managers of SMEs to more effectively understand adoption strategies and increase knowledge regarding IoT technologies benefits and drawbacks. This can help ascertain whether there is a need for IoT within their firms. Furthermore, this study's proposed conceptual framework could help owners/managers evaluate possible adoption strategies and ensure effective adoption practices.

SMEs' owners/managers could apply the conceptual framework as a reference for developing policies that could guide IoT adoption within their organisations. Furthermore, the experience obtained by using this framework to evaluate the adoption of the IoTs may then lead the owners/managers to use it for other potential technologies and improve their insights by matching specific decisions regarding future adoption. An example of such a use is given in this thesis knowledge regarding relative advantage. As it is found to be one of the most significant determinants to IoT adoption (Alshamaila et al., 2013; Sin, et al., 2009), the owners/managers could evaluate the potential benefits of the IoT explained in this study, as a road map to evaluate and plan their technology adoption and implementation. In that way, they can identify how IoT systems can enable them to accomplish tasks more efficiently, effectively and productively. In addition, based on the findings, the owners/managers should be careful when selecting the IoT vendor, as the findings in this thesis indicate that the vendors would play a significant role, especially in the first phase of the adoption.

For the technology vendors/consultants, SMEs represent a majority of businesses and a major market section for IT service providers. Therefore, it is appropriate for IT suppliers to establish a good working relationship with SMEs, as their support can encourage the adoption; IT vendors/consultants may minimise the feeling of uncertainty and stress the need to embrace technological change. Hence, IT vendors/consultants could use the conceptual framework developed in this study for understanding the specific problems faced by these SMEs. Knowledge and understanding of the factors that affect the adoption intention of small firms to will enable IT consultants to design suitable strategies for the widespread adoption of IoT technologies and sell them to their customers.

8.4 Study Limitations

This section considers the limitations of the thesis and potential areas for further research. One significant limitation is that the findings are difficult in their transferability to other contexts as the study has been undertaken within a single country specific context, hence the findings may be limited in their applicability to Thai firms only. This may be due to the Thailand business context as the business structure, nature, culture and size varies from location to location and country to country (Jones et al., 2014). Further to this, this study is limited to only the SMEs that operate in the manufacturing sector. Other industries within different sectors may have different perspectives regarding IoT adoption. Therefore, it may be inappropriate to consider transferability of the results of this study to the whole population in other industries. Nevertheless, the results of this study offer useful insights for similar studies in neighbouring countries, such as Vietnam and Cambodia. While this study has focused on exploring the phenomenon from the internal business perspective, it would have been useful to obtain additional insights from the perspective of other stakeholders, such as customers, suppliers, or policy makers, so as to enable a wider range of valuation that would give rise to further understanding of the adoption behavior of the IoT. Unfortunately, this was not possible due to the impact of the Covid-19 pandemic.

There was only one interviewee in each firm due to the impacts of the Covid pandemic on the case studies (**Section 6.1**). So the data collection opportunity had to be maximized in terms of the quality of data collected. Furthermore, this study examines the data collected from the SMEs at just one point in time, and when the data had been collected and analyzed, the researcher did not revisit the source on multiple occasions. Therefore, further longitudinal study for the case studies could be undertaken to identify long-term usage and adoption trends. A further potential limitation is the focus of this study framework, namely technological, organisational and environmental factors. Alternative perspectives could be employed when considering the usage of the IoT within a firm.The findings should be used carefully as other potentially significant factors may have not been included. In addition, this study adopts a qualitative approach to data collection. Alternative methodologies could be considered in further studies. The final study limitation is that the majority of the case studies provided only limited access to their files, which was exacerbated by the coronavirus pandemic. For reasons of confidentiality, the analysis focused mainly on the data collection throughout the qualitative interviews and publicly available information. Accessing the case files would have provided the opportunity to include additional organisational factors impacting on the adoption of the IoT. In addition, the face-to-face interview, which is preferable, was not possible in some firms due to restriction imposed by the Corona virus pandemic.

8.5 Future Research Opportunities

This section considers the future research opportunities. First, the study findings noted that cost of the IoT investment is a major concern for several firms. This study found that the concern regarding the compatibility with the existing infrastructure and the need for observation of the successful case of IoT adoption might mainly be from the cost of investment. Therefore, further studies could be undertaken to validate the relationship between compatibility and observability factors, alongside with cost factors in general technology adoption models or in other contexts. In addition, individual unique perceptions of technology might have an effect on their decision to adopt the IoT. Therefore, cognitive, emotional and contextual factors may be further studied and added as a new context in the framework to predict the adoption of the IoT from a different perspective. Investigating whether variables such as gender, age and ethnicity influence IoT usage and adoption may be impactful. Such studies will further provide holistic information regarding the IoT and thus provide further contributions to the literature.

Another research opportunity is to implement other research approaches. This study uses a case study method, which allows the interviewer to explore the IoT adoption in depth. However, a deductive research method, such as a quantitative study, may be carried out to further test the validity of the finding across the population of Thai manufacturing SMEs. As this research is limited in the sample size and generalizability of findings through qualitative research, the quantitative method would provide an opportunity for a large-scale, empirical study of the SME population to be carried out in the future (Jones et al., 2014). Thus, further research that employsa survey strategy, or a combination of survey and case study strategy (mixed method), with a larger population can then provide more structured, statistical and generalisable results (Jones et al., 2014). Furthermore, focus groups could be organized for owner/managers to further discuss issues related to the currently adopted IS innovations. This will highlight the factors that impact on the adoption of new IS innovation and help researchers to further understand the reasons behind adoption of the new technologies. Moreover, future investigations could consider interviewing different stakeholders - end users, customers, suppliers, partners, to give example - in the form of case studies to allow for further reliable comparisons.

Furthermore, the conceptual framework developed in this study could be applied and evaluated throughout different countries to understand the variations due to differences in country specific nature and culture, and to produce international samples. It may be of value to undertake the comparative studies between the IoT adoption in both developing and developed countries. In addition, a replication of this research across different industry sectors would provide data for comparison and also test the wider generalizability of the proposed framework. Furthermore, as

larger firms in the Thai manufacturing industry may display similar or different results, further research could be conducted to investigate the factors affecting IoT adoption in large organisations in the Thai manufacturing industry, and the results compared with those in this thesis. Further research in other digital technologies, for example, cloud, bigdata/analytics, could also be explored and evaluated by the conceptual framework developed in this study
Lastly, as the IoT is still an emerging technology; a longitudinal or ethnography study should be undertaken to investigate how attitudes and perceptions toward adoption decision changes overtime. Furthermore, it would be interesting to analyse a firm's performance pre/post adoption of the IoT; it is possible that some concerns, such as the cost of infrastructure investment highlighted in this study, may gradually reduce overtime. As the IoT continues to advance and mature, lower cost options, such as on-premise systems, will become available and lessen the IoT investment concerns. Thus, a time-series analysis would be interesting to both academics and practitioners. The conceptual framework would then be more reliable and accurate to use in reality.

8.6 Reflection

This section considers personal reflection regarding the researcher's experience while writing this thesis and discusses how the research process and study has been undertaken. Having completed this thesis, a reflection is given to express personal development throughout this project. The completion of this study was personally a very challenging process due to the limited experience of undertaking research. At the beginning of the project, I was struggling with an unclear picture of the thesis as a whole. I was disappointed with my limited competency and lack of knowledge. However, my supervisors guided me through the process of developing an appropriate focus for the study. At first, I thought my supervisors were being harsh on me; however, when I saw the progress of my thesis, I could not have been more thankful for my supervisors. Their constructive criticism helped me think analytically and actually brought out the better of me. I really appreciate their time and expertise given toward the completion of this study. One of the most significant lessons I learned from my supervisors and from undertaking a PhD is to look at the broad picture first, then scope down little by little. Doing this will give me a comprehensive and accurate result, as every aspect is considered. The most important challenge during the initial preliminary stage was to narrow the domain of the research and focus on its aims and objectives. The original idea of the research was focused on the broad technology adoption. This then became more focused on the IoT adoption within the manufacturing sector as the project progressed. Finally, the gap was been identified and the research topic was decided. In the literature reviews stage, gathering and merging the theoretical framework was difficult, as there was lots of overlap between the factors. After studying various models, I now understand the need to have a broader theoretical approach to my research, as using several theories when studying technology adoption within SMEs will improve my understanding of every aspect of the factors that affect the adoption process. Lack of experience with regard to planning and implementing qualitative interviews was a further challenge that I needed to be overcome.

Additionally, interviews result in large amounts of data, hence reducing the process was time-consuming and sometimes exhausting. Another challenge I faced was the process of trying to gain access to interview top management within the manufacturing SMEs. This was even more difficult during the Covid-19 pandemic, as they were all busy adapting to the situation. However, with the help of existing contacts and networking, I overcame this challenge. This interviewing process helped me to develop my communication and interpersonal skills, as I had to communicate with participants in a professional manner in order to obtain the data. In addition, the pandemic affected my mental health; I was living alone for a year and did not have a proper working place.

The PhD study is a long journey. Continuous rewriting and setting weekly targets are a significant part of the PhD process and a major pressure. As the IoT is an emerging technology, there was a need for me to be aware of new literature. The PhD study taught me to develop a long, medium and short term plan; for example, I needed to plan how many chapters would need to be completed each year, how many topics needed to be done each month, how many subtopics needed to be done each week and how many words I needed to write each week. The long period of doing a PhD was sometimes exhausting. However, thinking about the success of gaining my PhD would give me motivation to carry on.

Appendices

Appendix 1: Cover Letter

School of Management
Swansea University Bay
Campus
Fabian Way
Swansea
SA1 8EN

27th November 2019

Dear Sir/Madam

As your business is an innovative manufacturing small and medium sized enterprises (SMEs) operating in the United Kingdom (UK), I am writing to ask if you would consider taking part in my PhD research study. This study examines the influence of the factors that affect the adoption intention of the IoT in manufacturing SMEs in the UK and Thailand. This research is approved by the Swansea University Research Ethics Committee, and is supervised by Professor Paul Jones and Professor Gareth Davies at Swansea University, School of Management. I will be examiningthe adoption of IoT within a range of SMEs and would welcome the opportunity to share my results with participating firms. I would be most grateful if you could assist my research by allowing me to interview key decision makers regarding the adoption of IoT in the firm.

The interview questions will be sent to you in advance to familiarize you with the terms and questions of the interviews. This interviews should take no longer than an hour and will be arranged at a time and location at your convenience. To ensure accuracy of our discussion, the interview will be recorded anonymously with your permission and you will be provided with a script to ensure you are satisfied with the accuracy of the information. This research will only be used for the purposes of this research. After the interview, I would send a full transcript of the results to you.

Please note that your participation is voluntary and you will be free to withdraw at any time. All data collected from the interview is kept securely on the computer of the 1st Supervisor (Professor Paul Jones) with password protection and is not disclosed to a third party in any form,and destroyed once the research process is completed.

I have attached an information sheet about the project with my contact details should you wish to discuss anything regarding the research or ask further questions. If you are interested in being involved, please contact me by email which can be found below or in the information. A consent form will also be signed off once we are in agreement. I look forward to hearing back from you. If you require any further information please do not hesitate to ask.

Yours Sincerely

Yose Wungcharoen
Doctoral Researcher
Swansea University School of Management
Email: [redacted]

Appendix 2: Participant Information Sheet

Participant information sheet

My name is Yose Wungcharoen, a PhD Candidate at Swansea University School of Management. This research is approved by the Swansea University Research Ethics Committee and is under the supervision of Professor Paul Jones and Dr Gareth Davies. I am conducting a study into the factors influencing the adoption of the internet of things (IoT) within manufacturing SMEs in the UK and Thailand. You are being invited to take part of the study. Your detail will be anonymized in the final publication of this thesis and for all subsequent publications.

Before you decide, it is important for you to understand why this study is being conducted and what it will involve. Please carefully read the following information and ask if there is anything that is unclear or if you would like more information.

Research Title

IoT adoption in Thai SME manufacturers

Who will conduct the study?

Name of the researcher: Yose Wungcharoen, a PhD candidate

Organisation: Swansea University School of Management, Bay Campus, Fabian Way

, Swansea SA1 8EN, Wales, UK

Duration of the research: three years

What is the aim of the research?

To explore and understand the influences of the factors that affects the adoption intention of the IoT in manufacturing SMEs in the UK and Thailand, and provide meaningful insights in those factors. This study is using a case study design to look at those factors which may be technological, organisational or external to the firm. The study adopts an interpretive approach within this case study design which means that it is relying on the perception of key decision makers within the SMEs to gain an understanding of the underlying factors affecting their decision to adopt IoT. The result of the case study will enable the development of a conceptual framework to assist manufacturing SMEs to maximize their deployment of the IoT.

What would I be asked to do if I took part of the study?

The researcher intends to interview one or more key decision makers who would be able to provide the strategic, technical and operational perspective regarding the factors influencing IoT adoption and who are involved in the information system adoption decision makers. The interviewees will be asked to participate in a telephone or face-to-face interview with the researcher. The interview should last no more than an hour. A summary of the interview questions will be sent before the interview so that you can have time to prepare and have insight into the issues to be covered in this study. With your permission, the interview will be audio recorded to enable the interviewer transcript the interview for effective analysis. It is important to you to understand that if you are concerned about any of the questions in the interview, you can skip those questions. Moreover, you can stop the interview at anytime. In addition, you may be asked for further interview at a later stage if the researcher has any issuesrequiring clarification.

What happen to the data collection?

All data collected from the interview is kept securely in a computer of the director of study with password protected and is not disclosed to a third party in any form, and destroyed once the research process was completed. Regarding the confidentiality and anonymity, the participant information sheet confirming their anonymity and confidentiality are sent. Participants' details (individual names, organisation names) have been anonymized in this study by replacing their company names with pseudonyms to protect the participant's right to privacy and anonymity. Furthermore, your detail will be anonymized in the final publication of this thesis and for all subsequent publications.

What happens if I do not want to take part or if I change my mind?

Your participation is entirely voluntary, and you will be free to withdraw at any time. It is up to you to decide whether or not to take part of the study. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time without giving a reason.

What happen to the outcomes of the research?

Participant will be provided with a copy of the outcomes of the research. In addition, any publication that may arise from this study will be carried out following standard Swansea University procedures.

Contact for further information

If you have any concerns about the research or any further questions, you can contact the researcher, Yose Wungcharoen at:

Yose Wungcharoen

PhD Candidate

School of Management

Swansea University Bay

Campus

Fabian Way

Swansea

SA1 8EN

Wales, UK

https://www.swansea.ac.uk/som/

Tel: [redacted]

Email: [redacted]

Alternatively, you can email the researcher's supervisors, Professor Paul Jones at [redacted]; Dr Gareth Davies at [redacted]

Appendix 3: Consent Form

CONSENT FORM

Title of Project: IoT adoption in Thai SME manufacturers

Name of Researcher: Yose Wungcharoen

TO WHOM IT MAY CONCERN

If you are willing to participate please complete and sign the consent form below

Please initial all boxes

☐ I have read and understood the invitation letter, information sheet and the researcher has answered any questions I have about the project.

☐ The researcher has explained to me the purpose of the research, and the type of questions I will be invited to answer and that I have voluntarily agreed to participate as a representative of my organisation.

☐ I understand that my participation is voluntary and I am free to quit at any time without giving a reason.

☐ Within the confines of the law, the researcher will not give any personal information about me to anyone else.

☐ I understand that the researcher will ensure that my answers remain anonymous which means that the report will not reveal my identity.

☐ I understand that reports and publications may be written about this research, and that nothing identifying me will ever be made public unless I have agreed and in which case I will be given a pseudonym.

☐ I give permission for my answers to be recorded for the purposes of undertaking this research.

☐ I understand that my answers will not be used for any other purpose. I have read all the above points; I understand them and would like to take part in the research.

_____________ ____________________ ____________________

Name of Participant Date Signature

Appendix 4: Statement of Research Ethics Approval

SCHOOL OF MANAGEMENT, SWANSEA UNIVERSITY

FIRST STAGE ETHICAL REVIEW FORM

To be completed for all research involving human subjects OR datasets of any kind OR the environment

Name of PI or PGR Student	Yose Wungcharoen
Staff Number or Student ID	[redacted]
Supervisors*	Professor Paul Jones, Dr Gareth Davies
Date Submitted	
Title of Project	IoT adoption in SME manufacturers
Name of Funder / Sponsor*	
Finance Code / Reference*	
Duration of Project	3 years

Aim of research project (*250 words*):

To validate the influences of the factors identified from literatures that affects the adoption intention of the IoT in manufacturing SMEs in Thailand and the UK, and provide meaningful insights in those factors to fulfill the gap. The research questions are as follow:

1. What are the factors affecting adoption intention of IoT in manufacturing SMEs in Thailand and in the UK?
2. Why and how do those factors affect adoption intention of IoT in manufacturing SMEs in Thailand and in the UK?
3. Why do those influence factors affect IoT in manufacturing SMEs in Thailand and in the UK differently?

* *Complete if appropriate*

***Risk evaluation**: Does the proposed research involve any of the following?*
*✓ **Tick** those boxes for which the answer is **YES***
*X **Cross** those boxes for which the answer is **NO***

Participants

☒ Will the study involve recruitment of patients or staff through the NHS or the use of NHS data or premises and/or equipment? If this is the case, the project **must** be reviewed by the NHS. Please see the following NHS online tools for help with this http://www.hra-decisiontools.org.uk/research/ and http://www.hra-decisiontools.org.uk/ethics/

☒ Does the study involve participants aged 16 or over who are unable to give informed consent? (e.g. people with learning disabilities: see Mental Capacity Act 2005. All research that falls under the auspices of the Act **must** be reviewed by the NHS)

☒ Does the research involve other vulnerable groups: children, those with cognitive impairment or in unequal relationships? (e.g. your students). This **may** require NHS review, and will typically require the researcher to get **Disclosure & Barring Service (DBS) clearance** (formerly CRB checks)

☒ Will the research harm or pose any risk to the environment? (e.g. research in environmentally sensitive areas (e.g. SSSIs); permission needed to access field sites; transport of samples between countries (e.g. soil); sampling of rare or hazardous material (e.g. invasive species) that could deplete or endanger)

Please describe the participants involved in your research (if no participants, state 'none'): *max 250 words.*

The target firms will be manufacturing SMEs in the UK and Thailand.
The data collection process will involve face to face interview with the following:

1. **CEO/ Owner/Manager:** Set overall strategic directions and plans for the firm, as well as the responsibility for guiding actions that will realise those plans; set up a vision and direction on innovation.
2. **Strategic Manager:** Top management with power to create innovation strategy, make important IS/IT decisions and allocate resources for the adoption of new technology; consider the integration of service, and re-engineering of process in the firms.
3. **IT/IS manager:** Manage IT, IS and electronic data operations; consider compatibility of IT/IS with operations department by designing, developing and implementing coordinate systems, policies and procedures as it affects the functional requirements; ensure security of data, network access and backup systems.
4. **Functional manager (Operations/Plant/Manufacturing manager):** Drive continuous improvement and optimisation of all processes; develop processes that will maximise safety, quality and productivity; plan for available material, work in process, and arrival time of new material; monitors the process in a plant and transmits data on the condition and status of assets to IT system; utilise data from IT department to optimize the operation performance.

Recruitment

☒ Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? (e.g. students at school, members of self-help group or residents of nursing home?)

☒ Will it be necessary for participants to take part in the study without their knowledge and consent at the time? (e.g. covert observation of people or use of social media content)

☒ Will the research involve any form of deception? (e.g. misinformation or partial information about the purpose or nature of the research)

☒ Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?

Please explain the recruitment of participants involved in your research (if no participants, state 'none'): *max 250 words.*

Using a snowball sampling technique, one manufacturing SME in the UK and one in Thailand are selected as a pilot study. The next step after identifying the cases is to prepare a cover letter, participant information sheet, and a consent form. The cover letter states the purpose of the research and inviting key decision makers in the firm to participate in this study. The participant information sheet explains the aim of the study, the rationale to select the companies, the nature of the interview, the time-frame of the interview, the location of the interview, how the data will be used and how confidentiality will be maintained throughout the study. In addition, a summary of the interview questions will created. Moreover, a statement of research ethics approval from the Swansea University research ethics committee will be created. All these documents will be given to the participants. The identified organisations are then contacted by email. After contacting the first company in the UK and Thailand, the potential organisations with their names, contact address, telephone numbers, location, email address and webpage address will be provided by the existing subjects and will be contacted for collecting data. The intention is to collect data from 10 Thai firms and 10 UK firms, or until data saturation for a comparative study.

- [x] Does the research involve members of the public in a research capacity? (e.g. participant research; participants as co-producers or data collectors)

Research Design

- [x] Will the study discuss sensitive topics or require the collection of sensitive information? (e.g. terrorism and extremism; sexual activity, drug use or criminal activity; collection of security sensitive documents or information)
- [x] Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?
- [x] Is pain or more than mild discomfort likely to result from the study?
- [x] Will the study involve prolonged or repetitive testing?
- [x] Are drugs, placebos or other substances (e.g. foods or vitamins) to be administered to study participants, or will the study involve invasive, intrusive or potentially harmful procedures of any kind? (If any substance is to be administered, this **may** fall under the auspices of the Medicines for Human Use (Clinical Trials) Regulations 2004, and require review by the NHS)
- [x] Will tissue samples (including blood) be obtained from participants? (This would fall under the terms of the Human Tissue Act 2004. All research that falls under the auspices of the Act **must** be reviewed by the NHS)

Please summarise your methodology in detail and provide reflective comments with regards to the design of your research: *max 250 words.*

The methodology adopted in this thesis is an interpretivist, qualitative research approach that applies a multiple cases study strategy. Interpretivism is choosen based on the research question and the complex and subjective nature of IoT adoption from the analysis literature and the exploratory nature of the research proposition. The interpretivist position influences the selection of qualitative research method. Furthermore, the qualitative research and interpretivist exploratory study leads to a case study strategy. Particularly, the multiple-cases study will be adopted as it will enable the development of theory by identifying the factors affecting IoT adoption in manufacturing SMEs. A snowball sampling technique will be used for identify participating firms. Semi-structured interviews will be the primary data source (the conceptual framework developed in Section 4.1.7 will be used to develop the initial interview questions), supported by the documentary sources.
The intention is to collect data from 10 firms in the UK and 10 firms in Thailand, or until data saturation for a comparative study. Thereafter, within-case and cross-case analysis will be analysed through five stages: initial set-up, interpretation, categorisation, analytical generalization and factor definition that will lead to the identification of common themes and categories, thus having a potential to create the conceptual framework of factors that affect the adoption of IoT adoption in manufacturing SMEs.

Data Storage and anonymity

- [x] Will the research involve administrative or secure data that requires permission from the appropriate data controllers and/or individuals before use?
- [x] Will the research involve the sharing of data or confidential information beyond the initial consent given?

- [x] Will the research involve respondents to the Internet or other visual/vocal methods where respondents may be identified?

Please describe how you will store your research data and for how long, and, if appropriate, how you will ensure anonymity of your data subjects: *max 250 words.* All data collected from the interview is kept securely in cloud and is stored in a computer of the director of study with password protected and is not disclosed to a third party in any form, and destroyed once the research process was completed. Regarding the confidentiality and anonymity, the participant information sheet confirming their anonymity and confidentiality are sent. Participants' details (individual names, organisation names) have been anonymised in this study by replacing their company names with pseudonyms to protect the participant's right to privacy and anonymity.

Safety and Risk

- [x] Has a risk assessment been completed?
- [x] Is there a possibility that the safety of the researcher may be in question? (e.g. in international research: locally employed researchers)
- [x] Will the research take place outside the UK where there may be issues of local practice and political or other sensitivities?
- [x] Could the research impact negatively upon the reputation of the University, researcher(s), research participants, other stakeholders or any other party?
- [x] Do any of the research team have an actual or potential conflict of interest?
- [x] Are you aware of any other significant ethical risks or concerns associated with the research proposal? (If yes, please outline them in the space below)

Please describe the health and safety considerations in relation to both participants and researchers (*250 words max): If there are significant concerns an appropriate risk assessment and management plan must be attached.* The researcher will carefully assess the possibility of harm to himself and the participants, and make sure to keep the harm minimised physically and emotionally. The safety of the areas to do the data collection will be ensured. The firms studied in Thailand and the UK to do the data collection are at low risk, in low crime areas. In addition, the interviews will be conducted in safe office environment with prior approval of all parties. Moreover, the interviews are invited by email with all details confirmed. The interview will be conducted between 9 a.m. to 5 p.m. in public offices. Participants will be fully briefed regarding the data collection process.

Other significant ethical issues or concerns: (If None, then please state 'None') None

If any answer to the questions above is __YES__, then a __Second Stage (Full) Ethical Review MAY__ be required.

If the project involves __none of the above__, complete the __Declaration__, send this form and a __copy of the proposal__ to **<u>Amy Jones the School of Management Research Support Officer:</u>** [redacted] Research may only commence once approval has been given.

Declaration: *The project will be conducted in compliance with the University's Research Integrity Framework (P1415-956). This includes securing appropriate consent from participants, minimizing the potential for harm, and compliance with data-protection, safety & other legal obligations. Any significant change in the purpose, design or conduct of the research will be reported to the SOM-REC Chair, and, if appropriate, a new request for ethical approval will be made to the SOM-REC.*			
Signature of PI or PGR Student	[redacted]		
Signature of first supervisor (if appropriate)	[redacted]		
Decision of SOM-REC			
Ethical Risk Assessment	Green X	Yellow ☐	Red ☐
Signature of SOM-REC Chair or SOM-REC deputy Chair Date	[redacted] 22/11/2019		
SOM-REC Reference number (office use only)			

Appendix 5: Case Study Research Instrument

<u>Case Study Research Instrument</u> <u>Questions</u>

<u>regarding the firm demographic</u>

1. Could you tell me about the background and demographic of the firm (e.g. number of employees, revenue, asset, year of establishment and growth, product and service, customers and suppliers)?
2. What is your role in the firm (strategic, operation, IT)?

<u>Questions regarding the level of IoT adoption and use in the firm</u>

3. Could you describe the existing IS and their usage (e.g., EDI, SCADA, MRP, etc.)? Whatare the positives and negatives of the existing IS?
4. What are the barriers your firm face when developing/adopting IoT innovations?
5. What areas/applications in the manufacturing site does your firms use IoT (e.g. vertical and horizontal integration, decentralised IoT-based factory automation, managing the manufacturing site unit remotely, reducing the need for intermediaries advanced facilitymanagement, enabling autonomous warehousing, mass customization)?

Questions regarding the factors affecting adoption of IoTTechnological factors

6. Does the ability to promote firm's identity as a creative and innovative firm is a reasonwhy your firm intend to adopt IoT? why or why not?
7. Is the greater economic value of the IoT compared with the existing IS or previous IS oneof the factors that make your firm decide to adopt IoT? How do you think about the economic value of the IoT compared with the existing IS or previous IS?
8. Do you think that the ability to offer more convenience of the users and is easier to use inthe manufacturing site is an objective of IoT adoption? In what way?
9. Do you think that the ability to increase more efficiency in the manufacturing site is an objective of IoT adoption? In what way?
10. How about the alignment of IoT with existing values of the firm (e.g. culture, skill of employees, vision, mission, strategies, goals)? do you think it affect the adoption intention? How?
11. Is it important to have people with experience or knowledge regarding IoT or relatedIT/IS before deciding to adopt it? Or they could learn it later?
12. What are your concerns about the integration of IoT with exiting or previous IS infrastructure? Will it be a barrier to the adoption intention?

13. To what extent does the complexity of IoT hinder the adoption intention? What aspects ofIoT make it difficult to adopt?
14. How do you test the IoT before deciding to adopt it? If you could not test the IoT, wouldyou still adopt it?
15. Have your firm seen the successful cases of IoT implementation before deciding to adoptit? If you could not demonstrate the usefulness and reliability of IoT, would you still adopt it?
16. How do you feel about the direct cost of buying, maintaining and repairing systems or service related to IoT compared with your budget/financial resource? Is it a barrier to theintention to adopt IoT?
17. Are there any security and privacy concerns (e.g. data, organisation, and system security)your firm has toward IoT? Do you think these potential risks affect the decision to adopt IoT?

Organisational factors

Top management support

18. To what extent does top management support bring about the need of IoT adoption? In what way (e.g. set up a clear vision and direction on innovation, create the innovative culture, send out the messages about how important technology is to their subordinates,allocate sufficient resource)?
19. To what extent you think the size of a firm affect the IoT adoption intention? Why (e.g. resources, risk taking, agility)?)
20. How do you think of the organisational structure of your firm in term of the flexibility, adaptability and formalisation? how you think it affect the IoT adoption intention positively or negatively?

Environmental factors

Technology support from vendors

21. Do you use or plan to use the IoT service provider or in house adoption? If using IoT service provider do you think you require or will require a lot of support from vendors? Ifyou could not find good quality IoT service providers, would you still adopt IoT?
22. Have your suppliers or customers influenced your firm to adopt IoT?
23. Does your firm adopt IoT because your competitors have adopted it?

<u>Round up questions</u>

1. Is there anything that you would like to add or ask?
2. Do you and your firm would like to remain anonymous in the reporting of the thesis?

3. Would you like to review the material before publication? Would you like to have theresult of this study later?

Glossary

Electronic Data Interchange (EDI): Moves from a paper-based exchange of business documentto electronic.

Supervisory Control and Data Acquisition (SCADA): Uses computers in the mass production to create automation, supervisory control and data acquisition.

Manufacturing Resource Planning (MRP): Controls the information flow of the material in operations.

Appendix 6: Transcription of the Interview with a Water Technology Firm

Researcher: Introductions

Researcher: First of all, Could you tell me about the background and demographics of the firm?.

Participant: OK. So before we are based in... 20 minutes from Swansea. And I think we've got about 19 employees, maybe no more than 25. I don't think. And so the company was incorporated on the 2nd of September, 2010. And so worrywarts technology company and we develop design and operate solutions for water purification and for example, industrial effluent processing.

Researcher: And know how much revenue do you make?

Participant: I'm sorry. I don't know. I can get back to you on that one. All right.

Researcher: Oh, that is fine and um..

Researcher: And so the main product is the.

Researcher: The main product is machine for the water purification

Participant: Machine for water treatment. Yes, so we design electro calculation and..Umm.

Participant: Pieces of equipment. But we also design water treatment plants and incorporating lots of different pieces of kit.

Participant: So does the two main. Definites.

Researcher: So you do the service after you sold out. Don't you?

Participant: Yes, we do. Either sell the equipment itself or we design a plan. Oh, build the plan. Run the plant.

Researcher: And what is your role in the film?

Participant: So I'm in the technical team, a technical leader. So my background is in science. And so I assistant sort of developing the technical solutions and monitoring of data and the analytical side of things, really.

Researcher: And now about the existing information system. What do you use, Currently?

Participant: Ummm so we do SCADA.

Participant: And so we may use this to monitor flow rates in one of our water treatment plants. And so it was in the SCADA technology. We can. Look at and control the flow rate in the plant.

Participant: So the positives of this is we can remotely control the flow rate and stop the flow.

Participant: If an issue arises and we can reveal the flow rate remotely. And so, for example, if there's a blockage or an issue that the operator would be able to see this and then the advantage is that only authorized users can control it, SCADA. And this reduces the risk of errors by somebody unauthorized trying to control it..

Participant: And then the negatives of the SCADA, I suppose, is there's a limited number of licences, so many feel people can have the technology.

Participant: And so yeah, that is a limit to the number of authorised users, which is a pro under comment was.

Researcher: So would you say that you are using the Internet of thing at the moment?

Participant: Yes. It's a SCADA plus the internet, isn't it?

Researcher: Yeah.

Researcher: And now so when you first adopted the internet of things in your firm. Ummm what were the barriers that your firm faced?

Participant: Umm so I think some of the barriers. I wasn't around when it was brought into the company, but umm costs and training people up. And also technology like that can develop quite quickly. So I'm just keeping up with technological advancement.

Researcher: Yes.

Researcher: And the areas and application in the factory that you are using now?

Participant: Yes. So we use it to control the flow of water treatment plants remotely, for example, by setting the flow rate, stopping the flow and monitoring the volume of treated effluent. And so, for example, is very important for Welsh water or any other water company that if a company is discharging effluent. Umm not only if you've got to make sure that all of the analytical parameters are within discharge, consent. And but you've also got to tell Welsh water how much volume of water is being discharged. And so the SCADA is reducible for that. And it allows us to monitor the flow rate and provides the information required to welsh water.

Researcher: Can you do the predictive maintenance as well or only monitoring? can you control it? can you fix the problem?

Participant: Ummm we can the flow remotely. Umm which can help to fix the problem. In terms of actually physically fixing the problem, then an operator of would need to go inside, for example, if there was a blockage or a leak, then somebody would need to go in and resolve the issue. But at least this SCADA allows us to monitor and stopping the flow itself can sometimes help resolve an issue.

Researcher: The next section will be about the factors that affects your firm intention and...

Participant: That's fine.

Researcher: Umm the ability of the IoT to promote the firm's identity as a creative and innovative firm. Do you think that that's relevant?

Participant: Yes, I think hydro does promote itself as an innovative company.

Participant: And we do focus on sort of creative approaches to water treatment and so currently. We do it, SCADA. And I think.

Participant: Using as a types of IoT would definitely be of interest to us and would be something that definitely open to.

Researcher: Yes.

Participant: Yes, we do see ourselves as being an innovative company.

Researcher: So you do it because you want to create an innovative image of your firm.

Researcher: Yes. It's one of the reasons. And about the economic value, do you expect to have more cost saving of ......or to increase more revenue?

Participant: Yeah, I think it's economically viable. And so, for example, with the SCADA system that we use at the moment to control the flow rate and in the water treatment plant and it does reduce travel costs and human.

Researcher: Yes.

Participant: Because it means that on the weekend, for example, somebody is able to quickly monitor what's happening in the water treatment plant just from the comfort of their own home on their mobile phone. So that saves having to have weekend cover actually being there in the plant constantly. So, yes, can be really financially viable, particularly, as I said, with travel and, you know, human resources costs.

Researcher: And umm How about the the employees in the factory do you think the main objective to adopt the IoT because you can make them easier to control the machine?

Participant: Yes, it's really convenient that we can control and review instrumentation remotely. And so they said it's really convenient and you know, somebody being able to do it from their mobile phone at their home or from the office here. And so, for example, we've got a site in Bridgend. And it's only 45 minutes from here. But being able to do it remotely, it could save 45 minutes of travelling each way.

Participant: So, yes, it's very convenient.

Researcher: And do you think it would increase the efficiency in your manufacturing site somehow?

Participant: Yes. So it means that the operator can make more efficient use of their time. Andso it can reduce the time spent moving from one part of a site to another part of the site as what treatment plans can be quite large and. So, yeah, they can manage the time a lot better by being able to remotely control and monitor the water treatment plant.

Researcher: Umm about the alignment of the IoT with your firm culture, your skills of employees and the number of employees do you think...

Participant: No, hold on just a second, so bear with me.

Participant: I have to answered most of these questions and I have only brought one page, but I've got two pages to bear with me. Just a second. I could answer them just off the top of my head. but i think it would be more efficient if I just get my piece of paper.

Participant: I will be back to that.

Researcher: Good.

Participant: Are you ready for me to.

Researcher: Yes. please carry on. **Researcher:**

So about the innovative culture...**Participant:**

the alignment.

Researcher: the firm mission and vision.

Participant: Yes umm...

Researcher: Sorry.

Participant: No too keen haha.

Researcher: Do you think that creates the IoT adoption intention?

Participant: Yes, so. IoT is well aligned with the existing values of the firm. So hydros key values are small footprint, high yield solutions. This is just from our website actually. Broad range of treatment options, rapid install, modular and easily transportable systems. Ideal for remote locations where infrastructure is limited. Record of deployment is. In high risk areas, reduces large volumes and easily maintained and operated and IoT is very useful in remoted or rural locations and introduces the need for treatment plants to always have an operator onsite andIoT means the tightest treatment plants can be easily maintained and operated. When the operators both on site and off site. So that ties in well with some of the key values of hydro industries.

Researcher: And is it important that your firm and your employees have experience or knowledge about IoT before deciding to adopt it?

Participant: And I think it is useful to have people with experience and knowledge before deciding to adopt it because it would help with resolving any issues and. Sort of help with staff training and but I think it's probably not essential and the processes could probably be learnt via external training or learning on the job. but It could definitely help, I think.

Researcher: So it didn't affect your firm intention that much?

Participant: Not that I am aware of.

Researcher: Yeah.

Researcher: And the integration with your previous existing previous information system infrastructure using a. Was there a problem with the integration?

Participant: No, not that I'm aware of. And I think using SCADA system went smoothly and I haven't heard of any major barriers.

Researcher: So let's move on to the complexity of the IoT. Do you think the complexity of the IoT would make...Did make your firms hesitant to adopt it?

Participant: Ummm So I think the complexity of the water treatment plants means that the IoT scope is really large and. So I suppose the complexity of the IoT and the complexity of the water treatment plants can make it a bit difficult to know exactly what's available and what can be done. And so, for example, a water treatment plant typically consists of lots of different pieces of equipment and lots of different valves, lots of pumps in line analysers. So tying everything in with IoT I think is challenging. And currently we've only used it for monitoring the flow and that probably is a lot of scope for adopting it further.

Researcher: So you think it affects your firm intention to fully adopt it?

Participant: Yeah. Yeah.

Researcher: How do you plan to test the IoT system before deciding to adopt it? To fully adopt it?

Participant: Yes, I think if there was a way to test the IoT system.

Researcher: Yes.

Participant: For example, if there was any sort of trial error or anything like that, then we would be keen to do that. And however, if it wasn't possible to test the IoT, but we were confident it would meet the requirements, then we would still be interested and keen to adopt it.

Researcher: So it does not affect the intention?

Participant: No, I think as long as we were confident that it would meet what we needed to do Ummm.

Researcher: Have you seen the successful cases of IoT adoption in any other firms before?

Participant: Personally, I haven't. And I think some of my colleagues Ummm.

Participant: Have and so I think the different options were researched before deciding on this SCADA system and. But in my point of view I haven't, but as a company, I think we have.

Researcher: Do you think that creates the intention to adopt the IoT?

Participant: Yes, I think it's sort of encouraged us to go down that pathway.

Researcher: Yes. About the investment cost of the IoT. How do you feel about it? Like compare with your financial resources.

Participant: I'm not entirely sure about the cost. Sorry. it is something that Rick would be able to help out on this one?

Participant: Yeah, I've got no idea sorry.

Researcher: How about the security and privacy concerns?

Participant: Yeah. So I think with similar to losing at the moment that aren't any major security or privacy concerns and because it's flow rate data.

Participant: Remote monitor and also can stop the flow rate as well.

Participant: And this only authorised users who can access the software and those authorized users to monitor it regularly. So if there were any issues are security breaches, then it should be picked up fairly quickly. And I suppose if we were to adopt IoT for more and put more control through IoT, then security is definitely something that we'd have to consider carefully.

Researcher: So all these potential risks do affect the decision to adopt...?

Participant: Yes, It affected. Yeah. Currently, it's not a huge concern in the way that we're using IoT but for future development and adopting it more likely.

Researcher: And so... Does top management in your firm support the technology adoption somehow like? creating you culture to set up a creation on innovation, or sending out a message about how important technology is to everyone.

Participant: Yes, senior management sort of frequently emphasise that we are an innovative company and they do encourage the adoption of innovative solutions. There's not a specific team. All sort of dedicated resources for IoT adoption and. But there is an emphasis on developing new technologies and utilising new technologies.

Researcher: So do think that indirectly create an intention to adopt IoT?

Researcher: Yeah. indirectly yes. This is just your opinion about the size of the firm. Do you think smaller size or larger size would have more advantage to adopt the IoT?

Participant: Yes, I think well, we're a small company and I do think it's particularly useful for us as a small company because it can reduce human resource requirements and provide small flexibility within the workforces. But I do think that these advantages would also benefit larger companies too.

Researcher: And so do you think it is not that different?

Participant: No, I think the positives would probably be relevant to all smaller firms and larger firms because all sized firms want the most efficient use of the time.

Researcher: Umm about the organisational structure of your firm in term of flexibility, adaptability. What do you think about all those, like you think that affect the IoT adoption intention? positively or negatively?

Participant: Yes. So we are a small company, as I said.

Participant: And so we are required to adopt some flexibility and adaptability. With regards to our roles and responsibilities within the company. And I think this is amended by the fast paced nature of the company. And so I think this can make it more challenging to adopt the IoT because. This, as I said, there's no team dedicated to IoT adoption. And so actually making time to focus on adopting IoT is a little bit challenging sometimes.

Participant: So this always makes interest but actually making the time to do it. Yes.

Researcher: And do you plan to use the IoT service provider you do the in-house adoption?

Participant: Arrr. So I think. With regards to we'd probably look at a service provider first. And then once the system was set up, we probably wouldn't expect that, which require a lot of support and. But then if. There wasn't a suitable IoT service provider then I think we would consider an in-house adoption. We have got some people who are very good to sort of technical, program design, that sort of thing, so. And definitely be considered.

Researcher: So you think you wish to adopt the IoT in-house in a case that you couldn't find good?

Participant: Yes. Probably yeah.

Researcher: So who is your supplier?

Participant: And I'm not sure. SCADA...but I don't know who is a supplier.

Researcher: Well, I mean, for the water purification machines.

Participant: All right. And so some of the equipment we designed and built ourselves. And and then some of the equipment we purchased from various sort of providers. Yes. We've got a long list of suppliers.

Researcher: So have you got an influence from your supplier or customer to to think about a an IoT adoption?

Participant: I don't think that would be hugely influenced by suppliers. And to my knowledge. But I think if a supplier did suggest a suitable of IoT, then it is something that would definitely consider and be interested in. And with regards to the customer requirements, then we are very customer driven. And so we definitely try to meet the needs of the customer. So, for example, ifa customer did request IoT usage, then we'd do everything to make sure that and this need was met. And our use of SCADA currently was influenced by customer requirements. So, yes, I think to date it's been more influenced by the customer requirement than the supplier.

Researcher: So last question about competitive pressure. Does your firm thing about adopting IoT because your competitors have adopted?

Researcher: or you found it from?

Participant: Umm so I think. The current use of IoT was driven by our customer and. Customers, but we do sort of we keep informed on new technology is being used in industry and by our competitors. So it is something that we. Try to keep aware off and try to keep updated on what other water treatment companies are using, and so definitely could influence.

Researcher: No competitors that you have known have adopted the IoT?

Participant: I am not sure myself, sorry.

Researcher: So is there anything that you would like to ask?

Participant: No I'm fine, thank you.

Researcher: So we have finished the interview now. Thank you very much. I appreciate that. Come on.

Participant: Oh, yeah. If you've got any further questions related, just drop me an email.

Researcher: Thank you very much.

Appendix 7: Transcription of the Interview with an Industrial Gas Manufacturing Producer

Researcher: Introductions

Researcher: Could you tell me about the background of the company?

Participant: In English or Thai?

Researcher: Thai please.

Participant: Ok Thai. This firm produce industrial gas. Such as Nitrogen, Helium, Argon, etc. Itis a foreign firm from Europe. In Thailand, we have three small factories and one office. The concept of operation…we operate 24 hours a day because some of our customers such as refinery requires 24 hours gas through pipeline system. In the past it was all manual, but now weuse half local and half distributed control system (DCS) from central.

Researcher: for the central controller… from head office in Thailand?

Participant: Yes. We actually have a geographic-specific alliance who agreed to co-brand some products in Singapore in the past and now we co-brand some products in Thailand. They are big and they have alliances in Indonesia, Vietnam, Thailand, Phillipine.

Researcher: You are in industrial manufacturing industry…Who are the customers and suppliers?

Participant: We have two types of customers. First, refinery, automotive, rubber, electronic. And the second type of customers are IM…It is industrial merchandise. They order small batchat one time such as from laboratory, hospital, anything that does not consumes gas a lot.

Researcher: So… are we at the top of the supply chain?

Participant: Yes .

Researcher: sorry, I may have to ask you some questions repeatedly when I do not get your point?

Participant: that is fine.

Researcher: Does your firm separate strategic, operation and IT clearly?

Participant: Yes.

Researcher: ok. How about the authority to make decisions? Are the pretty much from Singapore?

Participant: Making decision on what?

Researcher: Such as which system should we implement in the factory in Thailand

Participant: From Thailand. The thing is everything should be the same for factories in each countries…same platform.

Researcher: I see.

Participant: From the group. They could recommend which system should we use.

Researcher: right……Can you hear me?

…………He hang up the phone….

……calling again…. After 2 minutes…..

Participant: sorry I need to hang up the phone because of my employees called me….so, the group will decide what to use

Researcher: for the management in the factories, the managers are from Singapore? Or from our country.

Participant: the managers are Thai

Researcher: Arr

Participant: The MD is fixed from the group. The organization from the top is MD, director, managers.

Researcher: Yes.

Participant: if its below director, we can just get approved from MD right away. There is no need to inform the Singapore office.

Researcher: Umm. Sorry…No

Participant: But each MD will be in the position for three years

Researcher: What is your role in the firm?

Participant: I am office tool manager and process engineer (Production managers)

Researcher: OK.

Researcher: Next will be the questions regarding IoT. Before using IoT, which application doyou use?

Participant: IoT is what ? could you explain it to me?

Researcher: It is simply SCADA + Internet

Participant: Ok, clear, whats next? Are we going to talk about the thing inside the factory only? Not the administration task?

Researcher: Yes.

Researcher: So, the previous system…..do you use SCADA? Or what?

Participant: We used to use DCS in plant. There is no connection through the internet. The IoT from your explanation….. we then use SCADA once we have more data ….so we can look into the data from operations from everywhere in the world. So we can extract the information right away, do not need to go to the factories. Next, we thought about data control. We will bring remote operation to the factories. Not only SCADA…meaning that.. operators can operate plant through this remote system as similar to the DCS in control room from everywhere in the world. We control in from the center. The benefit of using this system is that we can easily see the information. For example, when I have a meeting abroad or in the country side, I could monitor plant all the time….there is an alert system….the breakdown of machines or low level inventory will alert and warn me. It will alert me through SCADA and send information to my email. It depends on how critical it is for each situation. For the central system will reduce the cost of hiring operators, also optimise the processes…the alliances firm has almost 30 plants all around Asia. Therefore, any events usually occurs similarly in each plant. We could hire specialist to analyses data and do preventive maintenance. Predictive…optimise…so, we can get more effective. We are willing to take more risks as we have specialist. This is the role of IoT in our factory. In the future, every data will be kept in database. In the past we use paper base system. We called it log book…from now on we use tablet to fill up the data and report the situation through platforms

Researcher: Yes…and most of the time you use IoT for monitoring and predictive maintenance?

Participant: Arr if you say…first monitoring, second controlling.. meaning that control efficiency, inventory Third, predict. It means we predict to optimise to simulate the data, scenario, situation that we used to use experience to make decisions. Now we can be more effective.

Researcher: Yes

Participant: Problem. I have talked about all the benefit. But the problems… the main problem occurs when we communicate with more people, human resource is important. We need to engage our employees so that they can use. The equipment and platforms needs to be easy to use.In addition…the problem is that if it is difficult to use, operators do not feel like they would like to use it.

Researcher: this is the real problem that occurred in the first place?

Participant: It is the problem from the beginning and still happen. But we are trying to get rid of it. Because we do not have good programmer, we need to fill out the information on the program that the interface looks complicated. In the past we used tablet to fill out the information and tablet is too small, so operators did not want to use it. Furthermore, the internet in the factory is not stable. This year we improve everything. Instead of letting operator fill out the information on the tablet by hand, they could just take a photo of the gauge on each machine and it will transform the picture into numbers. Operators then feel like using it. If we set up this kind of systems but can not make them use it, it is useless.

Researcher: yes

Participant: Or if some data is difficult to collect. For example, in the factory there are 2000parameters and they are sent to the database every five minutes. The process engineers in myteam will have too much workload to analyse all the data. But if we use PowerBI (Business analytic program by Microsoft). To do data dashboard, presentation. This makes it easier to analyse data .

Researcher: Yes.

Participant: Do you know Power BI?

Researcher: sorry no.

Participant: Search for it, is it from Uk? Try it

Researcher: Yes.

Participant: so, the IT job is to support function, support operation, support facility, the internet, to make it easier to use…make equipment stable. And operators just need to simply use them. My job is to analyse and report result. The main goal is to be customer centric. Anything that satisfy customer, response as quick as possible, solve problems easily.

Researcher: So…after implementing IoT, does it affect your customers in anyway?

Participant: of course directly. For example, in the past customers phone in to order. But now since we have application for them, they could simply look into the data on applcaiton. Or some data they could just look at the date online. This makes them feel like they can trust us. They could rely on our product. Or when they request damands, we can plan for them, so they loss less product.

Regarding indirect benefit to customers, as we catch up efficiency, reduce cost, we can propose less price to our custmers. Second, if there are any problems, we can…for example, about maintenance. In the past there were a lot of breakdown, but since we implement predictive maintenance, we analyse data, we reduce failure. Therefore, they will feel the stability of our firm. Third, we can predict the demand of each product from each customer. Hence we know who dislike or like what?.............what we have done so far is to satisfy customers, focusing on customer centric.

Researcher: Yes….. so the last section the most important sections about the factor affecting the IoT adoption intention. I will ask you about each factor one by one

Participant: yes.

Researcher: some factors, you might feel like it common senses. I need to apologize in advance.

Participant: Umm

Researcher: So…first technology factor. When you first decided to implement IoT, is it because you want the firm to look innovative and creative?

Participant: No No No…I would say that in many organization did not think of that. First we analyse from the problem why …. First we want more productivity, better production and cost reduction and more stability. Because when we first look at the problem, we know that we want more customer, we want more marketshare, therefore, we did some analysis to find out what is the need of customer, what they want, I we will serve their need. It is like if the customer ok withit, if they say using document is just fine, nobody would invest a lot in IoT. But because the customers have more requirement , more things, we then need to invest.

Researcher: Ummm

Participant: do you agree?

Researcher: Ummm

Participant: Customer want something more means that more speed …period time and response time. They want less price. We definitely need to optimise everything, manage cost. And all of this can be managed by your IoT.

Researcher: Yes.

Participant: Clear?

Researcher: Next, what do you think about the cost reduction compared with previous IS

Participant: a lot a lot a lot

Researcher: Umm. So, you expected to reduced significant cost in the first place?

Participant: No. it is not like that. When we want to spend money on Capex, we need to …do….umm what is it called….business model. Therefore, we will know how much do we need to invest. Usually want 3 years payback period. I could say that the possibility to invest more is increasing a lot. I did not touch the finance much, but I know that it is evident that what we invest and what we do really satisfy the shareholder in term of profit. So this investment is definitely worth it.

Researcher: umm so investing IoT makes it easier for employees to use ?

Participant: Arr this is the problem. Like I said, to make it successful, we need to make it easier for them to use. But there is no way to make it successful at first, we need feedback. We need to do like continuous improvement…gradually adjust everything until internal customers satisfied (employees). It is necessary to make it easy to use. But it cant be done at first because programmers could not consider and cover every aspect in one time. We need to try it first so we can know the problems. We need development along the way. Is that clear?

Researcher: Ummm. And how about the convenience to use? Did it affect your firm's decisionto invest in the first place?

Participant: definitely definitely

Participant: when we want to do something, we need it to be convenience to use at the end. If it is difficult, why would we do that?

Researcher: Yes. I agree.

Participant: when we do something, we need to analyse how it will make things better and easier. But when we use it, some problems might occur. Which we need to fix them later.

Researcher: Next, about the increasing in efficiency in factories. Like you mention, it is one of the factor that makes you want to invest in IoT…

Participant: The main factor.

Researcher: Ok

Participant: If I were you and I need to be presenting all this, the main factor is actually profitability.

Researcher: Yes

Participant: Company is not charity. What factors will increase more profitability…increasing revenue, which IoT can help with that. Secondary, not only selling more, we need to reduce cost such as increase efficiency. So…the main main goal is we want money. What can make more money we need to think of that.

Researcher: Umm.. how about the cost of IoT. But you already mentioned that you do forecasting…

Participant: Yes, we need to do model at first. How much to invest, how much to borrow, how much we can expect from investment.

Researcher: I see.

Researcher: How about security and privacy, do you concern about these? Like data leak or something like that.

Participant: Umm this is important. So every system needs to be done under security and privacy. For example, when we use computer, we need to confirm the VPN in application you proof that we are real employees. Another example is that we could not just install more applications without permission first. Everything needs ID and password. Classification for authorization. All these are managed by IT team. We call it security management system. When we would like to change anything on system, engineering term "MOC" or management of change in which security is one part of it. We need to ensure that the information will not leak out. How do we do that. We send employees to workshop and we have training. We have good system. We also do tesibility. Such as try to leak out virus. All in all, security is very important. Especially, the company from Europe, UK, Germany that have brunch in Thailand because whenthey got fine from leaking information, the fine itself could not cover the profit from the brunch in Thailand.

Researcher: Umm. So you can say that security affect the decision to invest in IoT?

Participant: Yes Yes

Researcher: Next, the fitting between culture, strategy, goals with IoT?

Participant: Umm the point is we do not just invest in IoT. we need to find the requirement first always. So I think there is no point in this question.

Participant: there is no one just want to invest because we know there is an app. This may be in my firm only. We need requirement first. Therefore, requirement, culture, strategy comes before IoT.

Participant: Like I mention and need first then I try to find the systems that matched my need

Researcher: So, about the experience and knowledge about IoT or related technology. Before implementing IoT, did you have a lot of them?

Participant: Um…so it is in order like a pyramid, from top to local leader who will be sent to train first. Then we test the technology and then try to use it. Then we officially launch it. Its common.

Researcher: Yes…

Participant: Plan do check act that's it

Researcher: I see. So it is not the concern for your firm then, in this regard before implementing IoT?

Participant: No it is. It is.

Researcher: Yes.

Participant: If we implement it but it does not work…we need to make sure that it works. We need to plan when to use it, when to send people to training about systems. Champion leader who achieve the training will teach other people thereafter.

Researcher: Yes. How about technical staff. Do you concern about the fitting with previous system. I mean is it difficult to adopt IoT with previous system?

Participant: Yes. But we need to validate to see how much do we need to get rid of old systems and is it worth it? We need to estimate if we could get significant return or not. If it can increase profit we would get rid of the old system. If not, we would try to syncronise with it first or try to find other IoT service provider.

Researcher: I see.

Participant: before doing that…I will say this again…it is very critical…MOC or managementof change in every aspect…cost, security, usability, profitability, business model from implementation. We would do it 6-12 months before adopting.

Researcher: I got you. And Thai employees would involve with IoT…?

Participant: Everyone. More or less. Every level. But it just depends how we classify them. are they users, developer, owner…who is stakeholder…ok?

Researcher: About triability you mentioned that you could test the IoT before implementing…..if we can not test any IT systems, normally, we would not implement them, right?

Participant: No we would not.

Researcher: Have you observed the success after implementation from other factories?

Participant: Yes. We have model pilot plant. When we do this, we do not do it in every factories. For example, Thailand will be responsible for testing.. because of some strategic reasons. If it works we could apply it to other countries. The goal is to implement systems similarly in every factories in the world.

Researcher: I see.

Participant: it depends on the environment of each countries such as culture, economic, demographic. Type of customers, cost of labour. Some countries may not have a chance to try anything.

Researcher: Therefore, the evidence that we successfully implement some part of the systems sometimes does not affect the decision to implement in other countries as each countries have different influence factors?

Participant: that is correct. But at the end. The policy of the group is that they try to have everything the same for each country, meaning that they want to connect everything together. So the major function might be the same, but minor function may be flexible depending on each country.

By doing this they could use only one team of developers, one service centre. Only in some rare case, they would use different functions.

Researcher: Umm…next about the support from top management, do you have support in what way? You mentioned about the training.

Participant: I would emphasise on MOC again. I would look at a part in MOC which tell me the procedure to achieve this task of implementing technology. Training engineer is one of the step to achieve as well. And I would look into MOC to find relevant person. For example, to train engineers, MD needs to allocate budget for that at …amount.

Researcher: I see.

Participant: Therefore, everyone has the same mindset that the firm need to do digitalization. We have separate duty clearly.

Researcher: about the size of the firm, do you think It affect adoption intention?

Participant: I do not know because i have worked for only at this firm.

Researcher: Ohh I see.

Participant: but my revenue is 3000 a year. I think it would be worth it to implement IoT.

Researcher: I got you.

Researcher: the structure of your firm, is it flexible? Culture in your firm

Participant: what do you mean?

Researcher: is it flat, adaptable?

Participant: It works from BOD to continent to hub (south east asia) > country > MD >4-5 directors> 20 managers. About the structure when approving something, it is not too difficult butit is fixed to be assigned for specific person. It will auto link to that person directly to approve it.So, it is not flexible, but it is clear. So, it helps with the adoption. There is clear direction part. IoT decision will be assigned by procedure to specific person, hence it is convenience. It is very systematic. So it is not a barrier to adopt IoT as everyone has a mindset in the same direction.

Researcher: I see.

Participant: Are you almost finised?

Researcher: nearly.

Participant: because I have another meeting now.

Researcher: Ok that’s totally fine. You can hang up first.

Participant: wait how longer will it take?

Researcher: about 10 minutes

Participant: 10? Umm then I will call someone else first.

…..5 minutes after….

Participant: Hello are you there?

Researcher: Hello

Participant: Ok, let’s continue.

Researcher: Ok, from the previous call, the IoT adopter… do you use in house or outsources?

Participant: Both of them. it depends

Researcher: I see.

Participant: like I said, if it is related to support, It will be from IT department, but if It is technical things, outsource will join us.

Researcher: Ok, so do you require much assist from outsources?

Participant: a lot, quit a lot like 70 per cent.

Researcher: then, the support from vendor is very critical for the IoT adoption intention?

Participant: yes, definitely.

Researcher: next about your customers, do they have influence on the decision to adopt IoT?

Participant: No, Oh like I said we implement it because we want more profit. So the customers did not force us to do so. But if we do it to increase turnover, sell easier, customer like It more, we would adopt it as we are customer centric. I am not sure if I should say that it influences adoption intention?

Researcher: Umm I see. So, it is quite indirect?

Participant: Yes.

Researcher: Next question is about the competitors.

Participant: Yes. They do it as well?

Researcher: what is that? Sorry.

Participant: they adopt IoT as well?

Researcher: because they have adopted IoT, that is why you want it as well?

Participant: Yes, It affects our decision.

Researcher: Ummm

Participant: Definitely, but most of the time we would be a first mover. Actually, some function we do it first, some function others do it first and we copy them if we see good result from them……it is like change in organisations in the same industry will be quite in the relatively same period, they do we will do, we do, they will do as well.

Researcher: Ok, its done

Participant: Ok, if you have anyfuther questions, please let me know.

Researcher: Thank you very much for your time.

<u>Follow up interview</u>

Researcher: Hello. From the last interview, I need some clarification on some question. This will not take a lot of time. Are you free to talk now?

Participant: Yes. Please go on.

Researcher: for the question regarding the complexity of IoT, was it a barrier to the adoption intention?

Participant: No it does not. I do not think it is difficult. It depends on how good we can train our employees and how good we can synchronize the database.

Researcher: Ok..I see. How about the alignment of IoT with the existing firm value such as culture, skills of employee, knowledge of the firm, do you think it affects your intention to adopt IoT in the first place?

Participant: Um….I do not think so. Like I said last time, we did it mainly because of we thinkit will be profitable and to enhance our customer centric goal.

Researcher: I got you. And the impact of top management support on adoption intention such as the creating innovative culture, e.g. having innovation competition…do you think those influence the IoT adoption intention somehow?

Participant: we do have innovative competition that will reward the winner. In addition, we have the workshop and competition to improve our efficiency in the factory. I think these things help to push people to be more innovative, so it affects the IoT adoption intention more or less.

Researcher: I can see that. And how about the cost, I mean…I know that you first priority is the profit…but the cost do you feel that it is a huge investment compared with your financial resources? Was it a concern for your adoption intention?

Participant: Yes Yes…it requires significant investment. Therefore, we invest a little by little, not all at once.

Researcher: Umm…Ok…move on to the last question… the MOC as you mentioned in the last time. I wonder if having this strictly organisational structure that everyone will be assigned specificly for some tasks help with the adoption of IoT ?

Participant: It is a requirement, I see it as a must thing to do…like a regulation.

Appendix 8: The UK Economy and Its Main Sectors.

Overview of the UK Economy

The purpose of this section is to profile the economy of the UK. The UK consists of England, Wales, Scotland and Northern Ireland. The UK is a leading financial centre (InterNations, 2016), the second largest economy in Europe after Germany (Focus Economic, 2018) and the fifth largest economy in the world by GDP, after the US, China, Japan, and Germany, respectively (Focus Economic, 2018). Furthermore, the UK economy is mainly driven by domestic consumption which accounts for 65 per cent of aggregate demand; the service sector is the most significant contributors to its economy (Riley, 2018), employing nearly 80 per cent of the 31.75 million people in the workforce (Chepkemoi, 2017). In addition to strong domestic consumption, export significantly contributes to the UK's GDP.

The UK was the tenth-largest goods exporter in the world and the fifth-largest goods importer (CIA, 2019). The main exporting products are aircraft, computers, electrical machinery, metals, medical apparatus, mineral fuels, pharmaceuticals, plastics, spacecraft and vehicles. (Workman, 2019b). The largest export receiving countries are the US, Germany, France and Switzerland, respectively (CIA, 2019; EU, 2017). Moreover, the main imports are computers, electrical machinery, furniture, iron steel, medical apparatus, mineral fuels, pharmaceuticals, plastics, spacecraft and vehicles; the UK's major importers are German, the US and China in order. (CIA, 2019; EU, 2017).

The UK is considered a high-income country (World Bank Group, 2019). Southern England and Greater London have the largest economy in the UK, followed by Scotland, Northern Ireland and Wales (InterNations, 2016). Since the banking crisis, the UK is among advanced economies that have presented the strongest recoveries; the current GDP value is at 2622.43 Billion dollars (CIA, 2019) and the GDP growth is at 1.9 per cent a year (Lightfoot & Taylor, 2018), compared to 1.7 per cent a year in euro-zone (Lightfoot & Taylor, 2018). However, the UK fiscal deficit has decreased by 75 per cent since 2010, and the public sector debt is high at 86 per cent of the GDP in 2018 compared to 71 per cent in 2010 (Riley, 2018). In addition, employment in the UK has been increasing steadily (Unemployment is now at a 43 year low (Riley, 2018)), but the increase in average output per worker has not improved (Riley, 2018). Therefore, the future economic growth will depend on increasing the amount that each employee can produce as the UK is reaching full employment (IMF, 2018a). The currency is the Pound sterling, which is the Fourth largest reserve currency after the US dollar, Euro and Japanese Yen (CIA, 2019). The inflation rate is steady at 1.9 per cent (Trading Economics, 2019a). The falling trend in inflation is being helped by an appreciation in the external value of the pound (Riley, 2018). Furthermore, the UK government spends the lowest capital investment compared with the other countries in organisation for economic co-operation and development (OECD) (Riley, 2018). This means that the UK's capital stock of machinery and building is obsolete, and this is one of the factors behind the economic slowdown (Riley, 2018).

This section considers the SME contribution to the UK economy. SMEs are significant to the UK economy as it is generating 52 per cent of all private sector turnover and accounts for 99.9 per cent of the total number of private sector businesses (BEIS, 2018) (99.5 per cent of businesses in every industry are SMEs (BEIS, 2018)); almost 20 per cent of SMEs operate in construction (BEIS, 2018). Moreover, the total number of employment in SMEs is nearly 60 per cent of all private sector employment in the UK; 96 per cent of the private sector are micro businesses (BEIS, 2018). This means that 95 per cent of the businesses in the UK employs fewer than nine people. Furthermore, 0.6 per cent of private businesses is medium-sized and less than 4 per cent are small businesses (Merchantsavvy, 2018). Considering the trend in the past decade, the number of businesses without employees has been increasing significantly (faster than the total number of businesses) (Merchantsavvy, 2018).

According to the Office for National Statistics (2018), nearly 80 per cent of the UK firms fail within the first year, while 44.1 per cent of the firms in the UK survives for five years or more. Furthermore, 11.6 per cent of businesses in each industry fails each year, whereas 14.6 per cent of businesses are born each year (Merchantsavvy, 2018). There are some concerns about the current state of the UK economy. First, there will be a negative impact on trade costs if the UK leaves the EU (EU, 2017; InterNations, 2016; Riley, 2018). Second, the growth has been slow down due to slow capital accumulation, the decline in the migration from the EU (less workforce), lower productivity, and lack of people with science, technology, engineering & mathematics (STEM) skills (EU, 2017; InterNations, 2016; Riley, 2018). Third, the consumer and public debt (above 87 per cent of GDP) are high due to the low-interest rate, while the real estate price has been increasing (Pariona, 2017). As a result of high debts, business investment has been depressed, and consumption has been constrained because of slow income growth (Nordea, 2019). Finally, population aging will create spending pressures as the government needs to either increase taxes and fees or the quality of health service and pension will be affected (IMF, 2018b).

Overview of Main Sectors and Industries in the UK

This section considers the overview of main sectors and industries in the UK (Worldatlas, 2018). The main sectors in the UK are service (EUbusiness, 2018), which contributes to almost 80 per cent of the GDP (World Bank, 2018). The service sector employs more than 80 per cent of the active population (Nordea, 2019). Moreover, London is the largest financial marketplace in Europe and can be comparable to New York (Yeandle & Wardle, 2019). The most essential services are banking, e.g., Barclays Bank, Citigroup, HSBC, insurance, e.g., Aviva, and business services such as Legal and General Group (InterNations, 2016). In term of the retail industry, four firms dominate the UK grocery market: Asda (owned by Wal-Mart Stores), Morrisons, Sainsbury's and Tesco (30 per cent or retail market in the UK and the third largest retailer in the world by revenue) (Reuters, 2011). However, the online retailing, such as Amazon is gaining market share from the traditional retailing (Masters, 2018). Another significant sector is in the manufacturing sector. Even though it has been declining in the past years, the manufacturing sector is still significant to the UK economy, contributing 21 per cent to the GDP (CIA, 2019; EUbusiness, 2018). The UK is the world's eleventh largest manufacturing country, and some of the industries located or headquartered in the UK are important and on a global scale. In particular, civil and military aerospace industry, e.g., BAE Systems, Rolls Royce, and pharmaceuticals, e.g., GlaxoSmithKline, AstraZeneca (InterNations, 2016). Furthermore, the automotive and construction industries are amid the largest employers of the UK workforce (ONS, 2019a). They employ about five million people between them (ONS, 2019a). In addition, the high potential industries are information and communication technologies, biotechnology, aviation industry, renewable energies and defence (Nordea, 2019). Moreover, Mining contributes to the economy as the UK possesses considerable mineral resources, such as coal, gas, and oil reserves, but they are declining (Nordea, 2019). The least contribution to the GDP is agriculture sector (less than 1 per cent) (CIA, 2019). However, it is a very productive sector as it is producing nearly 60 per cent of the food demand in the country (EUbusiness, 2018). The main activity in the agriculture sector is livestock farming, especially sheep and cattle (Defra, 2018a) and the main crops are barley, beetroot, potatoes and wheat (Defra, 2018a). The next section will consider the UK manufacturing industries, which will be the focused industries in this research.

The UK Manufacturing Industries

This section considers the UK manufacturing industries. The UK manufacturing is ranked 8 out of 40 in the world in term of global competitiveness (Deloitte, 2016; Worldatlas, 2019) which is lower than only one country in the EU, Germany (Deloitte, 2016; World Economic Forum, 2019). The UK contributes 2 per cent to the world manufacturing output, whereas China, Germany, Japan and the US contribute about 50 per cent to the world manufacturing output (Kiprop, 2019). In term of the economic output in the UK, manufacturing industry accounts for 10 per cent of the total output, 44 per cent of the exports and 8 per cent of the total jobs (Rhodes, 2018a). Over past decades, the value of the manufacturing output has been almost stable (ONS, 2019d), but employment has been decreasing (Trading Economics, 2019b). This explains why productivity in manufacturing has been growing significantly. Moreover, the manufacturing trade deficit is expanding due to the decline in manufacturing's share of the UK economic output (service industry is growing) (ONS, 2019b; Rhodes, 2018a). This is caused by relatively high production cost, lack of raw materials, demand growth in distant nations such as China and India (Li, 2018; Rhodes, 2018b). The proportion of manufacturing jobs are concentrated in East Midland and West Midlands (ONS, 2019c; Rhodes, 2018a). The key and promising manufacturing industries in the UK are automotive, aerospace, food and beverage, and pharmaceutical industry.

Automotive

This section considers the automotive industry, one of the largest manufacturing industries in the UK (ONS, 2019d), the fourth largest in Europe, and the ninth largest exporter of cars in the world (SMMT, 2018). Contrary to the trend among European countries, the UK automotive industry is reaching record growth (Business Sweden, 2017). The industry's productivity has increased by 61 per cent since 2008 (Make UK, 2017a). The automotive industry generates 82 billion Euros in turnover a year and employs over 186,000 people in the UK (SMMT, 2018).

Over 80 per cent of the production is exported to more than 100 countries which account for 12 per cent of the total UK export (NMCL, 2016); the major receiving countries are China and US (Statista, 2019). There is a high degree of foreign ownership; Jaguar and Land Rover, Nissan and BMW are the most influential brands in the industry for several years (Sinoscan, 2017). The West Midlands is the most concentrated area of the industry, which is responsible for half of the total economic output and 36 per cent turnover (Make UK, 2017a). The key characteristic of this industry is the R&D investment, which is second only to the pharmaceutical manufacturing industry (Make UK, 2017a); the two focus investment is on autonomous and connected vehicles, as well as electric and ultra-low emission cars (Business Sweden, 2017). One of the key observations is that the industry relies significantly on overseas suppliers (Business Sweden, 2017). However, most of the automotive manufacturers are looking for local suppliers with high engineering products (Business Sweden, 2017). Although the UK market for cars has been decreasing due to the policies on diesel taxation and air quality (Sinoscan, 2017), the government are supporting the industry by collaborating with Automotive Council to improve the supply chain competitiveness and encourage the investment in electric, connected and autonomous vehicles (Make UK, 2017a). Moreover, the fourth industrial revolution significantly changes the automotive supply chain (Business Sweden, 2017); the interconnectivity becomes a principal for many businesses as it can more offer cost-effective option than outsourcing, and increase flexibility and transparency in the supply chain (Business Sweden, 2017). However, car manufacturers are implementing IoT in their products but not in their operations (Deandres, 2014). Furthermore, the current visibility in the supply chain in the automotive industry is still low (Business Sweden, 2017). Thus, there is an excellent opportunity for enhancement. All these emphasise the importance of IoT in the automotive industry; IoT and Big Data can improve efficiencies in collective supply chain management and data flow (Deandres, 2014).

Aerospace

This section considers the aerospace industry, the largest in Europe, the second only to the US in the world (NMCL, 2016; Sinoscan, 2017), and the fourth largest aerospace exporter in the world (Workman, 2019c). The focus on innovation and high technology intensive products leads the UK aerospace manufacturing output increasing at the second-fastest pace of any manufacturing sector over the past decade at 37 per cent (Make UK, 2017b); the aerospace industry contributes 12 per cent to all manufacturing R&D expenditure, the third highest after pharmaceuticals and the automotive industry (Finnegan, 2015). The main sub-industry is the parts for civil and military aircraft, such as rotors, turbojets, turbo propellers and other engine parts and sub- assemblies (Make UK, 2017b). Moreover, the industry's productivity has increased by 50 per cent since 2009 (NMCL, 2016). The aerospace industry generates 29 billion Euros in revenue a year and employs over 120,000 people in the UK (BizVIbe, 2013). The industry is driven by export, which is generating almost 90 per cent of aerospace turnover (Business Sweden, 2017). Out of the total number of exports, nearly 80 per cent contributes to engines and part of aircraft in which the UK is specialised (Make UK, 2017b). The aerospace industry is not concentrated in any particular area. The industry is evenly distributed. However, The South West has the highest number of employment (ONS, 2019e). The dominant firms in the UK market are Boeing and Airbus (Business Sweden, 2017); the UK is currently the Boeing's third-largest source of supply in the world, followed by US and Japan (Sinoscan, 2017).

The key characteristic of the aerospace industry is clear visibility of the order pipeline due to the consistent demand for new aircraft, as well as long lead time and order booked (Make UK, 2017b). Airlines, which are the end customers, will order parts from OEMs and sign them with long-term contracts (Make UK, 2017b). This provides businesses in the supply chain with investment and innovation certainty and high-quality standards (uktradeinfo, 2019). Furthermore, the Aerospace Growth Partnership (AGP) influences in ensuring the continued growth and competitiveness of the UK aerospace supply chain (AGP, 2019). The aerospace supply chain tarts from OEMs, who make and design aircraft, spacecraft and satellites (uktradeinfo, 2019). They are supplied major critical parts by Tier 1 manufacturers, who source the components from Tier 2 suppliers, and the Tier 3 manufacturers provide raw material to the tier 2 suppliers (uktradeinfo, 2019). In the UK, the majority of the manufacturers are Tier 1 suppliers, e.g., Airbus, Bombardier, GKN Aerospace, Rolls-Royce (Make UK, 2017b).
The key to success of the aerospace industry in the UK is the continuous innovation, such as the increased use of composite material, the development of 3D printers and collaborative robots (to create the part from inside out instead of making it from a solid block of material) (Nickels, 2015). This can improve the process efficiency, and the products will be lighter. Moreover, the manufacturing processes in the aerospace industry are complex, require several steps which operators need to follow (there are thousands of steps in the assembly line of an aeroplane – it comprises of around 400,000 bolts, and screws alone need 1,100 different tools (Marcus, 2016)), and have many checks points to ensure the quality (EC, 2017). Therefore, unlike other industries, the use of automation and robotics are low; most of the assembly process are done by workers (EC, 2017). However, IoT plays a significant role to support workers by connecting the workers and their tools to the IoT platform, increasing the labour efficiency (EC, 2017). For instance, Airbus employees use smart glasses to scan an aeroplane's metal skin and identify the appropriate size of the bolt which is needed in a given hole as well as the rotation

force necessary to install it (Marcus, 2016). Another example is from Rolls Royce which built in the sensors that detect maintenance issues in real-time and visualise them to the engineers around the world (Make UK, 2017b).

Food and Beverage

This section considers the food and beverage industry, the largest manufacturing industry in the UK (BizVibe, 2013; ONS, 2019d), accounting for 19 per cent of the total UK manufacturing output (FDF, 2019) with 400,000 people in the industry (BEIS, 2018). Despite creating more output than the automotive and aerospace industries combined, the industry cannot meet the domestic consumer demand (Make UK, 2017c), especially for fruit and vegetable and meat (Defra, 2018b) due to the inappropriate climate. The industry output is quite stable as the food products are necessary. Over the past years, the industry has been growing the output at 21 per cent per year (BDO, 2018). The majority of the industry is SME (FDF, 2019). The UK food and drink manufacturing industry mainly serve the domestic market; Only 9 per cent of the products are exported (Make UK, 2017c). Therefore, this is the least export-intensive manufacturing industry in the UK (Make UK, 2017c); the major receiving countries are France, Ireland and US (FDF, 2019; ONS, 2019f) but there is a trend of the shift to Asia and the Middle East (FDF, 2015; ONS, 2019f). Considering the sub-industries, food processing dominates the industry (almost 90 per cent) which the processing, preservation and production of meat is the largest category, whereas the manufacture of drinks contributes to 16 per cent of the food and drink industry (Make UK, 2017c; ONS, 2019f). Soft drinks, mineral and other bottled waters are the most significant categories, followed by the manufacture of beer and the distilling, rectifying and blending of spirits (ONS, 2019f) (55 per cent of world whisky exports and 71 per cent of the world in exports are from the UK) (Make UK, 2017c). Furthermore, food and drink manufacturers source their raw materials from the agricultural sector, which the majority of is domestic (Make UK, 2017c). Geographically, Scotland has the largest share of both production and turnover in the UK (Scotland Food & Drink, 2018). The weakness of the food and beverage industry are low-profit margin due to high competition and low investment in R&D or innovation compared to other manufacturing industries (Make UK, 2017c). However, this can be an opportunity as there is a large room for improving the production process through IoT and robotic technology, such as a system of batch production and fully automation production lines allow food to be produced faster with higher quality and less waste. For example, the National Centre for Food Manufacturing partnered with Olympus Automation launched APRIL, the automated processing robotic to mix, load and manufacture ingredients on an industrial scale (Make UK, 2017c; Newfoodmagazine, 2018; OAL, 2019). Another example is smart packaging which can help improve food quality and safety by implanting IoT devices with sensors into food packaging (Kuswandi & Moradi, 2019; Make UK, 2017c). This can measure the change in microbial activity, temperature, pH, etc. to provide a more accurate method for detecting food spoilage instead of using best before dates (Kuswandi & Moradi, 2019).

Pharmaceutical

This section considers the pharmaceutical industry, the second fastest growing industry after aerospace industry (EEF, 2018; Make UK, 2017d); the output is increasing since 1990 at about 50 per cent per year (Make UK, 2017d). The pharmaceutical industry generates 12.6 billion Euros to the UK economy and employs over 53,000 people in the UK (BizVibe, 2013). This industry is one of the two highest technology-driven industry (the other one is the aerospace industry) (Caglayan, 2019). Moreover, the industry is dominated by a few large firms; the two largest pharmaceutical manufacturers in the world are GSK and AstraZeneca (Gautam & Pan, 2016; Make UK, 2017d). The industry can be categorised into two sub-industries: the manufacture of basic pharmaceutical products and the manufacture of phartechnomaceutical preparations. The second category accounts for 95 per cent of the output (Make UK, 2017d). Almost half of the demand from the entire industry is from abroad (Make UK, 2017d). This makes pharmaceutical industry the third most export-intensive manufacturing industry after aerospace and mechanical equipment industry (Make UK, 2017d); the main receiving countries are Germany, US and Netherlands, respectively (ONS, 2019f). The UK is the fifth largest pharmaceuticals exporter in the world after Germany, Switzerland, US, and Belgium (ONS, 2019f). In term of domestic demand, this industry relies on one dominant customer, NHS (ONS, 2019f). The essential characteristic of the pharmaceutical industry is high productivity and the highest R&D spending among the manufacturing industries (CIA, 2015). Moreover, this industry has a volatile growth and high rate of mergers and acquisition activities (Gautam & Pan, 2016; Make UK, 2017d). Geographically, the North West region is responsible for 38 per cent of output and 43 per cent of turnover (Make UK, 2017d). From the customer perspective, they care for the quality standard and safety for usage (Pachayappan, Rajesh, & Saravanan, 2016). Therefore, maintaining the accurate low temperature (to mitigate chemical reaction) and appropriate moisture and humidity level are critical for the flow of the product in the pharmaceutical supply chain (Pachayappan et al., 2016). With the IoT adoption, pharmaceutical firms can track, and monitor the goods from the suppliers to customers in real-time (Pachayappan et al., 2016). In addition, an example of the recent IoT development in the pharmaceutical industry is a digital medicine, a drug with ingestible embedded sensors that can record when it is taken (Elenko, Underwood, & Zohar, 2015). The information is transmitted to a mobile application so that the patients can track the ingestion of the pill (Elenko et al., 2015;). This innovation helps the patient increase their uptake of vital medication as there is evidence that a significant number of patients with asthma, depression and human immunodeficiency virus (HIV) do not take medicines as prescribed (et al., 2015; Make UK, 2017d).

Summary

UK manufacturing is facing a highly competitive market globally. The main competitors are low-cost manufacturing centres, such as China and Eastern Europe (Resnick, 2018). The solution to this is increased productivity by innovating the manufacturing industry (Targetjobs, 2018).
However, over recent years, there has been limited investment in machinery, equipment and technology in the manufacturing industry, except for the average value manufacturing (The Manufacturer, 2019). The R&D spending has been decreasing from 84 per cent since 1985 (Rhodes, 2018a). Furthermore, the manufacturing industry has the lowest number of skilled employees than other industries, potentially a barrier to productivity growth (Rhodes, 2018a); the estimated lack of people with STEM skills is about 40,000 (Hoyle, 2016). In addition, the UK has been a slow adopter of robotics in manufacturing, compared to the US, Germany, South Korea, and other leading manufacturing nations (IFR, 2018). The is because the UK industry relies on food manufacturing which is typically labour intensive and has not been through advances in automation that other industries have seen, such as aerospace and automotive industries (Paritala, Manchikatla & Yarlagadda, 2017). Nevertheless, to support the manufacturing industry, the UK government formulate several policies: the most impactful policies are funding for higher education in STEM, change to corporate tax, and increased integration with EU (Pettinger, 2017). An example of the policies is “Building a Britain fit for the future” (BEIS, 2017). This policy aims to identify the weakness such as shortage skills and underinvestment in R&D (BEIS, 2017), cooperation between the industry and government, and develop solutions to the challenges: artificial intelligence (AI) and data, ageing society, clean growth and future of mobility (BEIS, 2017). Moreover, the government

found the Catapult Centres which aim to enable businesses to access equipment, expertise and information needed to develop and exercise innovations (Hepburn & Wolfe, 2014; Kerry & Danson, 2016). The centre is based at the seven research centres, such as the advanced manufacturing research centre (AMRC) in Sheffield (Kerry & Danson, 2016). After all, the performance of the UK manufacturing is on an upward trend (The Manufacturer, 2019). The digitalisation with IoT is a critical enabling innovation for growth (The Manufacturer, 2019). Therefore, UK manufacturers have to realise the potential of digitalisation and have a clear strategy and strong leadership to ensure that their organisations can keep up with global competitors (The Manufacturer, 2019). The next section considers the SME sector, which is the focused of this thesis.

Appendix 9: Applications and Challenges of IoT in Manufacturing.

This section considers the application and challenges of IoT within manufacturing. IoT enables agility in the autonomous processes (Houyou, Huth, Kloukinas, Trsek, & Rotondi, 2012). Each unit in the autonomous system is independent and can be configurable by itself (Akimana et al., 2017). Automation can displace lower-skilled workers, but it will increase demand for higher-skilled labour, such as data scientists, mechatronics engineers and software engineers (Rüßmann et al., 2015). IoT enables horizontal integration of many manufacturing resources and capabilities used in the various stages of manufacturing (Kagermann et al., 2013) and it can allow vertical integration between all parties (Kagermann et al., 2013), thus reducing the need for intermediaries (Porter & Heppelmann, 2014). This provides new manufacturing services and application to leverage the advanced interconnections, such as smart machines, autonomous warehousing and the autonomous exchange of information, taking action and control of each other independently within production systems at the shop floor level (Kagermann et al., 2013). Furthermore, IoT creates new operation systems where physical assets within the factory have a unique ID that is intelligently connected to the network and digitally visible to the overall supply chain at unit level and in real-time, which will reduce the work-in-process inventory (Bogers, Hadar, & Bilberg, 2016). Coordinating product and information flows will be no longer required (Buckley & Strange, 2015). In addition, IoT systems enable robots to be more autonomous, interconnected and cooperative in a more safe and productive way (Akimana et al., 2017). For example, Kuka, a supplier of robotic equipment, is providing autonomous robots that can detect its surroundings and cooperate with workers in the factory (Akimana et al., 2017). Yumi is another example of a dual-armed robot in an assembly line that can observe and analyse which parts should be assembled next (Rüßmann et at., 2015).

IoT moves supply chains away from being centralized, to become decentralized; manufacturers can focus more on localization and customization (Bogers et al., 2016); it provides tools for designing innovative 3D printers with machines and databases, allowing supply chain managers and designers to quickly respond to market trend, identify new customer segments, create new design, update existing designs and test the market at less time and cost (Bughin, Chui, & Manyika 2015; Porter & Heppelmann, 2014). This results in creating more value for the customer (Bughin et al., 2015; Porter & Heppelmann, 2014). IoT can connect the local computer-aided design (CAD) software into the machines by globally sharing real-time and graphic- intensive information (Burkett & Steutermann, 2014) and implementation of IoT within manufacturing offers benefits, including 48 per cent less downtime, 49 per cent less waste and a 23 per cent increase in new product (Divers, 2016). The detail of the applications and benefits of IoT in manufacturing are as follows:

Digital/Connected factory

This section considers digitally connected factories; operation managers can manage the factory unit remotely by taking advantage of process automation and optimisation (PWC, 2015).

The data from partners, such as OEMs, can be sent to the main factory in real-time (PWC, 2015) and as a result, IoT reduces the transaction costs related to international production (Buckley & Strange, 2015). In addition, IoT enables a shift of manufacturing; low labour countries will become countries that have a high innovation (Hartmann et al., 2016). For instance, decentralized IoT-based factory automation, which utilised the digital twin concept, enables European manufacturing enterprises to reshore their operations from low-labour locations, such as Asia, back to the EU (Hartmann et al., 2016; Jiang, Guo, & Wang, 2021). This can have a great impact on the economy of a country and its employment rate (Hartmann et al., 2016). Particularly, IoT enables reshoring through assisting integration with advanced manufacturing technologies, such as 3D printing, or robots, therefore, requiring fewer workers and less labour-intensive processes (Fuller, Fan, Day, & Barlow, 2020; Hartmann et al., 2016; Minerva, Lee, & Crespi, 2020). The next section considers facility management.

Facility Management

This section considers facility management: predictive maintenance and energy management. IoT can maximize the machine uptime and minimise the equipment failure by monitoring their current status, condition and health (Tomic, 2017) and then predicting the failure rate and production outcome. A decision is then able to be made about when maintenance tasks need to be carried out before a failure or machine breakdown occurs (Divers, 2016). The analysis of the sensor data collected from IoT-enabled devices can sense the machinery status, predict the output variation, and warn management about the unusual situation, or even automatically make adjustments to respond (Li, & Li, 2017). For instance, United Parcel Service, Inc. (UPS) were replacing all their important vehicle parts every two to three years, thus wasting money on good condition parts. However, since UPS introduced implant sensors on each vehicle, which can monitor the parts' condition and alert the company when a part must be repaired or replaced, much time has been saved, as well as millions of dollars (Hessman, 2014).

The concept of regularly monitoring machine and equipment conditions in order to effectively understand their operating condition and schedule maintenance, when required, was further expanded upon by designing a smart system for handling a fleet of computer numerical control (CNC) sawing machines (Lee, Ardakani, Yang, & Bagheri, 2017). With the real-time status of the blade, and data analysis from the set of algorithms, the CNC machines can be more effective in evaluating the fine-tuning of speed, and they also provide accuracy of performance (Lee et al., 2017). Tomic (2017) states that if the top 100 European manufacturing companies can have zero defects within the factories, they will save on cost by 160 billion dollars. Supporting this, the World Economic forum (2015) states that the most widely cited application of IoT in manufacturing is predictive maintenance.

Furthermore, being capable of providing an accurate operating condition within manufacturing environments, such as temperature and humidity, leads to energy saving (Papakostas, O'Connor, & Byrne, 2017). Heating, ventilation, and air-conditioning systems (HVAC) can be optimized to detect more sensitively the temperature and humidity in particular zones (Fichtinger, Ries, Grosse, & Baker, 2015). Additionally, the choice of inventory control policies and the level of automation can impact energy performance (Fichtinger et al., 2015); for instance, automatic indoor climate control for heating, cooling and lighting will result in decreasing energy consumption by up to 40 per cent, compared to when manual control is employed (Bourgeois, Reinhart, & Macdonald, 2006). The next section considers facility production flow monitoring and quality control.

Production Flow Monitoring and Quality Control

This section considers the use of production flow monitoring and quality control in order to offer better management of operational cost and correct quality problems. The processes from raw materials to the finished product, and the defects, are monitored carefully at all stages of the product cycle and analyzed and identified in real-time (PWC, 2015). This results in eliminating both waste and unnecessary work, and serves to increase operational efficiency (IoT, 2018). The production processes can be redesigned to reach high efficiency (Yang et al., 2018). The control software can automatically make decisions and drive actuators to decrease the deviation from the original plan with the real-time data collected and analyzed (Yang et al., 2018). In addition, large numbers of multisource information and machine-learning algorithms are capable of generating the optimal decision automatically (Yang et al., 2018); machine learning technology can increase the level of independence to control production processes and solve the disruptions at the factory level (Yang et al., 2018). Semiconductor manufacturers, for example, decrease product failures by linking single chip data captured at the testing stage of production, with the process data captured early on in order to identify the pattern that causes faulty chips and improve the production quality at an early stage (Rüßmann, 2015). Another example of this is the Boeing Company, which uses smart glasses in their Arizona factories to support wire harness assemblers: paper maps were replaced with virtual maps, decreasing the error rate from 5 per cent to almost zero per cent (Tita (2015). Additionally, assembly time reduced by more than 30 per cent. Dalmler also deployed smart glasses when undertaking their operations (Tita, 2015); quality control employees utilised them to view inspection checklists and forward images or videos to their colleagues who could fix the issues (Tita, 2015). The next section considers inventory, logistics and supply chain optimization.

Inventory, Logistic and Supply Chain Visibility and Optimisation

This section considers inventory, logistic and supply chain optimisation and smart warehousing. The materials, equipment and products can be tracked and traced globally by an IoT device as they move along the supply chain; this device could be an RFID tag attached to each pallet in the warehouse (PWC, 2015). IoT systems connect all parties in the supply chain through data sharing via inventory, shop floors, purchasing, maintenance or logistics (Yang et al., 2018). As a result, all these departments will understand and realise how the flow of material, production cycle time in real-time (Yang et al., 2018). This empowers the effective implementation of lean manufacturing since demand, supply and feedback data can be accessed by all parties via ERP or other central systems, resulting in eliminating data asymmetry issues (Yang et al., 2018; PWC, 2015).

Furthermore, as IoT reduces the distance between manufacturers and suppliers, operational managers can provide precise estimates of available materials, work in process and arrival times of new materials (Fan, Tao, Deng, & Li, 2015; Reaidy, Gunasekaran, & Spalanzani, 2015). The ability to have real-time visibility on the inventory and order status will lead to lower safety stock levels and reduced shared costs within the supply chain (Papakostas et al., 2017). IoT enables third party logistics (3PL), distribution and allows other parties in the supply chain to innovatively improve the flexibility, integration, agility and responsiveness of their logistics processes (Reaidy et al., 2015; Zhong et al., 2015). For instance, a logistics company implant IoT devices to their containers to not only track their movements, but also to monitor and adjust the temperatures of goods inside, which is crucial for cold supply chain produce, such as fresh foods and drinks (Lawson, 2016). A study has revealed that 25 per cent of the produced food supply is lost within the food supply chain as a result of spoilage because of adverse storing conditions (Kummu, De Moel, Porkka, Siebert, & Varis, 2012).

Smart warehousing is another large area within IoT enabling robotics (Akimana et al., 2017). The first robot was the startup ‘Kiva Systems’, the company owned by Amazon that develops mobile robots that are utilised for pick and pack operations within warehouses (Guizzo, 2008; Kim, 2015). ‘Locus robotics’ has built a successor to Amazon’s Kiva robots (Ackerman, 2016). They can work together with human employees to fill orders and navigate autonomously by using radar; the location of a pre-mapped area is verified with cameras and 2D barcodes (Ackerman, 2016). ‘Fetch Robotic’ is another company that has created two robots to automate flow in the warehouses (Ackerman, 2015). They both use a laser to detect human activity and follow the employees around the site (Ackerman, 2015). The first robot is called ‘Fetch’: a mobile manipulator to pick items from the racks, and the second robot, ‘Freight’, can then autonomously transport the order to the cargo (Ackerman, 2015). Another example of the robotics used is ‘Otto’, a robot that can load heavy material to a weight of up to one and a half tons and localize itself with high accuracy by using an existing warehouse map (Ackerman, 2015). Many organisations are trying to solve the package delivery problem through aviation solution (Pandit & Poojari, 2014). For instance, Amazon invented the Amazon Prime air project, which is able to transport packages to the customer within 30 minutes by way of using drones. This can be seen as future transportation (Pandit & Poojari, 2014). The next section will consider plant safety and security.

Plant Safety and Security

This section considers the overall safety of the workers, and the security of the plant. IoT improves safety conditions in the factory by monitoring key performance indicators (KPIs) of health and safety and then sending notifications of any safety hazard or unsafe conditions to the workers in real-time to prevent potential accidents before they occur (Papakostas et al., 2017). Examples of this practice include Honeywell and Intel; they have been in cooperation to invent a wearable system of sensors that can monitor a worker’s breathing, heart rate, motion, posture and toxic gas exposure and then transmit that data to the control room (Papakostas et al., 2017). An example of how IoT can help to decrease the rate of accidents within the workplace is the use of forklifts, which are the cause of around 100,000 accidents in the US every year (Gilchrist, 2016). A solution for companies to solve this problem is to use smart forklifts with IoT implementation, thus creating the interconnected system of cameras, sensors and warning signs (Tomic, 2017). Not only this can reduce the time required to locate the stock or the correct product by sensing a location of each aisle and each product on it to the driver, but also the camera and sensors attached to the forklifts can warn the driver of an upcoming obstacle, or other workers that may be in the area (Tomic, 2017). In addition, if the forklift trucks have a high level of interconnectivity, they are able to communicate with each other and enable drivers to know who is near to the required products; thus, productivity is again increased (Tomic, 2017). The next section will consider a smart product and process.

Smart Product/Process

This section considers smart product and process in order that more customized products are created and the workplace is enabled to become more flexible. Big data from the embedded devices, or new system-on-a-chip (SOC) devices, such as Intel® Curie™ or Samsung Artik™ can be analyzed to aid the designer to extract what the customer requires in order to improve the customer satisfaction rate (Papakostas et al., 2017). The usage pattern and the information about the actual/in-use/low and upper limits of product usage variables can be obtained and predicted and used as part of the design process with the aim of improving the product characteristics, or developing new products (Wellsandt, Hribernik, & Thoben, 2015). Customers are able to co-design or participate in some aspects of the development process in the interest of creating customer products (Herterich, Uebernickel, & Brenner, 2015). The deployment of IoT within the virtual manufacturing chain and decentralized automation systems in the factory reduce lot size and enable mass customization (Hartmann, 2016). Moreover, IoT enables mass customization because the factory will become more agile (Tomic, 2017). The integration of IoT with 3D printing, which is to prototype and produce individual components, can reduce costs, transport distances and stock that is on hand, as manufacturers will no longer require various productions of several components (Rüßmann et al., 2015). For example, aerospace firms use 3D printing technology to apply new designs that decrease aircraft weight and reduce expenses for raw materials, such as titanium (Rüßmann et al., 2015).

Challenges of IoT in Manufacturing

This section considers the critical challenges of adopting IoT within the manufacturing industry; because IoT within manufacturing is in an early stage, there are key challenges which manufacturers need to overcome. In order that vertical and horizontal integration in manufacturing can be created, data integration is a major challenge (Sadiku, Wang, Cui, & Musa 2017), especially for manufacturers that have international operations: centralised data management systems must be able to integrate various data types (PWC, 2015) and data needs to be cleansed, aggregated, aligned and transformed in preparation for a business decision to be made (PWC, 2015). In order to ensure that this happens, several technologies and skilled labours are required. Partnerships within the supply chain need to build systems to collect, integrate and distribute manufacturing data in a way that aligns with their business objectives (PWC, 2015). All these factors bring up significant questions for adopters, as they are not able to estimate the return on their investments; this is because IoT is a new and conceptual technology (Tomic, 2017). The manufacturer has to invest in IoT and its integration into current operating systems (Tomic, 2017) and the estimation is more difficult for enterprises that want to integrate IoT with more advanced technologies, such as 3D printing or SOC devices.

To ensure that IoT devices can work together within the existing infrastructure and with existing devices, standardisation is needed (Conwey, 2016). Another challenge is cultural resistance (Tomic, 2017). Management needs to convince workers to adopt IoT because the workers are apprehensive about being replaced by machines (Tomic, 2017) or robots, such as 'Amazon Robotics', which can automatically pick up heavy products and transport them at long distance (Kim, 2015). In particular, management should build a flexible and agile environment in firms in order to accept innovation (Tomic, 2017).

Cybersecurity is one of the most demanded features of IoT system, as implementing IoT within manufacturing can create a large number of possible entry points for cyber-attacks (Sadiku et at., 2017). It can be costly for a business both in terms of reputation and money if the firms' sensitive or personal information is compromised by a cyber-attack. The last major challenge is that of the size of production facilities, which is one specific characteristic that could make the implementation of IoT much more complex and expensive (Tomic, 2017).

In summary, IoT based manufacturing enterprises allow higher agility and adjustability that can shift the manufacturing sector from product oriented to customer-oriented (Tomic, 2017). The adoption of IoT in manufacturing leads to increased resources and operational efficiency, nearly zero defects and a shorter time to becoming available on the market (Jeschke et al., 2017). The interconnectivity and digitalisation between all entities - customers, machines, products and workers - will create a more competitive environment, a more sustainable operation and will eventually increase the overall profits in the industry (Tomic, 2017). From the literature reviews, the majority of studies undertaken relate to the IoT adoption within manufacturing in general or large manufacturing organisations. This raises the question of what would be the critical challenge of implementing IoT in manufacturing within the SME sector? There is a need for further research in this area, the majority of the studies do not specify the countries/areas where they they collected the data from. This can be an issue, as it affects how enterprises should adopt innovations or technologies; for instance, both consumer behavior and organisational behavior within both developing countries and developed countries can be different. The next section considers IoT in SME manufacturers.

Appendix 10: IoT Usage in Manufacturing Industries

IoT Usage in Stone Mining and Manufacturing

This section considers the IoT usage in the stone mining & manufacturing industry. In recent years, mining has moved from being human and animal powered to electric and diesel-powered machines. However, these heavy machines lead to safety concerns (Duff, Roberts, & Corke, 2003; Dragt, Craig, & Camisani-Calzolari, 2004). Automation and emerging technologies are identified as potential means to increasing productivity and safety in mining, as the sensing, control and computing technologies are advancing (Chehri, Fortier, & Tardif, 2007). The communication system that is established in all working processes have the potential to be combined with security mechanisms; these systems are able to exchange data between employees, interact with machines and monitor the environment of mining, such as the miner position (Chehri et al., 2007).

The mining industry is considered one of the key industries for applying IoT-related technologies(Da Xu, He, & Li, 2014). Sensors are applied and used in several mining activities: geophone in exploration and blast control, piezometers in dewatering and toxic gas detectors in working frontlines (Molaei, Rahimi, Siavoshi, Afrouz, & Tenorio, 2020). Molaei et al., (2020) found that 70 percent of mining companies believe that IoT would offer an advantage over competitors; 41 per cent believed the IoT would increase efficiency, whereas 44 per cent suggested that it would identify cost saving and growth perspectives (Molaei et al., 2020). Specific areas that benefit from these technologies are production processes and safety (De Moura, Ceotto, & Gonzalez, 2017). For the production processes, the typical mining industry has a high cost for labour and contractors (Laskier, 2017). The IoT, which increases labour productivity, would appear to be an appropriate tool to use in order to reduce costs. The second significant cost in this industry is fuel and energy, primarily caused by vehicle equipment and building at the mine site, and for transportation (Laskier, 2017).

By applying IoT, mines would be able to minimise the consumption of these items or use them more productively by using real-time control systems, energy monitoring systems and advanced engine control systems (Laskier, 2017). The IoT is currently used for remote monitoring and control of the extraction process (Maheswari, Priyanka, Thangavel, Vignesh, & Poongodi, 2020) and is implemented at the station where each step of the extraction process is undertaken to retrieve the material from the ore, then the complete process sensor data will be analysed and stored in the cloud (Priyanka, Maheswari, Ponnibala, & Thangavel, 2019). Furthermore, the API key is applied to establish a communication initially to receive sensor node data from the industrial IoT gateway (Maheswari et al., 2020).

Big data analytics with the IoT would also potentially enable mining operations to become more predictable (Molaei et al., 2020). In addition, real-time monitoring of the equipment would enable those parts to be changed out as required, rather than by schedule (Laskier, 2017). This would extend the working life of the parts, or improve equipment availability as the unplanned breakdown is predicted (Laskier, 2017). Mine safety is a critical issue as many accidents have occurred and the rate of these accidents has been increasing since 1930 (Rico, Benito, Salgueiro, Díez-Herrero, & Pereira, 2008). The result of these accidents have caused both environmental pollution and human casualties (Okusa & Anma, 1980). Therefore, a reliable communication system is also an essential requirement for improved safety in underground mines (Bandyopadhyay, Chaulya, & Mishra, 2010).

The IoT could enable automation, remote monitoring and location tracking so as to reduce the number of accidents taking place (Laskier, 2017). Pre-alarm parameters could flash on screens if any sensor recognises beyond the safety pre-alarm value (Chehri, El Ouahmani, & Hakem, 2019). The health conditions of the workers can be measured by looking at their heart rate and blood pressure (Majhi, Rao, Sahoo, Dash, & Mohapatra, 2020). The IoT device could monitor these conditions remotely by using sensors that will alert the mine manager when the parameter reaches a certain value (Majhi, et al., 2020); the IoT enables the quick passing of a message from the vicinity of the underground working area to the surface in order that a fast rescue operation may take place (Bandyopadhyay et al., 2010). A recent feature of IoT implementation in mining is the availability of a warning system that alerts to exposure of harmful gas, and GPRS communication to monitor potential safety in production (Roja & Srihari, 2018). The IoT will also make an alarm sound when workers are not wearing safety helmets on-site (Roja & Srihari, 2018).

Another utilization of IoT being implemented to further strengthen health and safety improvements is with regards to a deformed or broken tailing dam; the tailing dam is an earth-filled embankment used to store products of mining operations after separating the ore from gangue (Sun, Zhang, & Li, 2012).The pre-alarm system, based on the IoT and cloud computing, is utilised mostly for real-time monitoring of the saturated line and the dam deformation (Sun et al., 2012). The specific examples of applications currently used by stone mining and manufacturing are as follows; evaluation of the correlation between incidents and fatigue (time of day, day in the shift, time in the shift, etc.), improvement of equipment utilization and enhancement of supervisor visibility of project work, maximizing workforce productivity, monitoring worker fatigue status, warning of unqualified personnel in high risk areas, providing real time project management and providing real time root cause analysis (RCA) capability (Laskier, 2017). Regarding the challenges for IoT adoption within mines, the technology infrastructure is required to be compact, robust as mining is typically undertaken in a remote location and has extremely rigorous environments (De Moura et al., 2017).

IoT Usage in Coal Mining and Processing

This section considers the IoT usage within coal mining and processing. Mining safety is the primary concern within mining (Singh et al., 2018). The complex and hazardous characteristics of the subsurface mining environment have raised the demand for IoT technologies to be implemented in order to enable greater mine safety (Xu et al., 2014).

Mining will evolve to become safer due to IoT implementation, as IoT is enabling more mining operations and tasks to occur remotely with less subsurface human involvement (Chehri, Farjow, Mouftah, & Fernando, 2011). Seventy-nine per cent of the mining companies have identified IoT as one of the top three priorities (Accenture, 2015) for business development.

Applications of IoT in coal mining & processing is typically a network connected to the internet through RFID, infrared sensor, GPS and laser-positioning to achieve intelligent identification,exchanging information and communication, tracking location and supervision (Yinghua, 2012).IoT provides a potentially more effective way for coal mines to increase safety supervision and processing by remote monitoring and control and a real-time warning system, resulting in a reduced number of serious accidents (Yinghua, 2012). Ideally, mining automation would reduce injuries by removing miners from dangerous working environments and providing them with automated and remotely controlled machines (Zhou, Damiano, Whisner, Reyes, 2017). Specific applications of IoT technology regarding safety supervision in coal mines is the tracking supervision of underground personal (Zhang & Gu, 2010). Information systems used for accurate location of underground personnel, recognition of the iris of the eye and face, safety training and management of working licenses are potentially other areas of development (Zhang & Gu, 2010). In addition, closed-loop control of personnel, equipment and environment will typically be used on the coal mining site.

Closed-loop control, such as gas air-power being locked to prevent gas explosions, electrical and mechanical equipment being locked to prevent accidents when working with electricity, for example is an important guarantee for the safety of employees working in coal mines (Zhang & Gu, 2010). By adopting IoT technology, closed-loop control of all types of workers, operating equipment and the working environment can be achieved (Zhang & Gu, 2010).

An example of use of the IoT technology in mine is active RFID-based wireless for safety and traceability of the mining areas. The devices are comprised of tag sensors and readers that collect environmental data, tracking people and vehicles, and alerting systems in real-time (Thomas & Rad, 2018). When a worker enters the mine, the software will automatically log the worker in by maintaining a count (Molaei et al.,2020). This tracking of people works both horizontally within deep mine tunnels and vertically across mine elevators. The virtual zones can be defined in mines as being safe to access areas by the workers because an accurate location will always be monitored and available for workers to reference at any point (Liu, Zhang, & Li, 2013). The system can provide the location of individuals approaching restricted zones, which are defined as unsafe areas that a worker should never enter (Thomas & Rad, 2018). When a worker enters an unsafe zone, his or her RFID transmitter will start buzzing automatically (Xu et al., 2014).

Some mining companies have already utilised IoT; for example, Rio (2018) used autonomous, self-driving trucks that had 200 sensors attached, along with GPS receivers and a radar guidance system that could manoeuvre within the mines. The manufacturing was undertaken from more than thousand miles away using 3D visualization of the worksite (Rio, 2018). In addition, Cisco accomplished two projects where IoT successfully improved the safety and efficiency of mines. One project is that of 280 wireless access points which are set up within a gold mine throughout 50 km of tunnels to better connect people and track the location of miners and vehicles (Cisco, 2014). General Electric has successfully implemented an IoT solution to improve efficiency within mines (Vella, 2015) and condition-monitoring devices can collect information such as vibration, temperature and pressure to inform mine engineers of machine health status, and to detect impending failures before they occur, thus reducing the downtime of the machines (Vella, 2015).

Based on IoT technology, different kinds of nanotechnology detectors can be used on major sites by indicating vibration, temperature, density and other essential details (Sharma, Gupta, & Sharma, 2017). Environmental parameters within the mines can be detected and stored and used as an important basis of accident identification and accountability confirmation when accidents occur, providing important references for investigation and appropriate handling of such occurrences (Zhang & Gu, 2010). Furthermore, Warning of serious disaster is an important measure to ensure that safe production takes place within coal mines (Jiping, 2009). However, the existing safety supervising system has low accuracy and can't meet actual needs (Jiping, 2009). Through adoption of IoT technology, the accuracy and effectiveness of warnings can be improved (Zhang & Gu, 2010) and furthermore, whole process monitoring for safe use of explosives could be provided within the mines (Zhang & Gu, 2010). Tracking management of safe explosive production, transportation and storage can be achieved, and accidents caused by a dangerous production environment and dangerous transportation, storage and using of explosives can be avoided (Zhang & Gu, 2010).

Normal, reliable operations regarding significant and critical equipment, such as boring machines, conveyors, elevators and fans are an important guarantee for the safety of the coal mines (Zhang & Gu, 2010). Through the adoption of IoT technology, whole process tracking, management and healthy diagnosis of significant and critical equipment can be achieved, providing a highly efficient guarantee for coal mine safety and operation (Zhang & Gu, 2010). Furthermore, by adopting the IoT, the effective development and execution of emergency plans, training scenarios for rescue teams and the maintenance, provision and readiness of emergency equipment can be more effectively inspected and mastered (Longzhe, 2005). In addition, tracking systems and best route navigation of escape which can be accessed by miners in realtime could help the trapped miners when they are underground (Zhou et al., 2017). When an accident has occurred, the best combinations of emergency plans, rescue equipment and the rescue team can be put together in the shortest time, providing timely and effective support for emergency rescue of workers within the coal mines (Zhang & Gu, 2010)

There are some barriers to adopting IoT within coal mines. First, the information security concern as the system is connected to the global network (Zhou et al., 2017) and the harsh environment of mines, such as extreme moisture-heavy dust and rugged design is an undesirable environment for sensors and other IoT devices to work efficiently underground (Zhou et al., 2017). In addition, the gassy underground atmosphere is potentially explosive, so intrinsic-safety or explosion-proof technology is often required (Zhou, Plass et al., 2017). Therefore, electrical systems, including the IoT sensors and communication nodes, should be designed in such a way that they do not have any components that produce sparks or high surface temperatures, or components that can hold enough energy to produce a spark of sufficient energy that is sufficient to cause an ignition (Zhou et al., 2017).

IoT Usage in Gas Production

This section considers the IoT usage in gas-production. For gas producers, the pipeline network is critical, as it is involved in almost every process in the factory and is a means of transportation from the finished process to the customer; in general, the pipeline is considered as being the most economical mean of gas transportation (Rahmati, Yazdizadeh, & Yazdizadeh, 2017). Normally, the pipelines run through deserts, across mountains or under water; all these transportation methods could damage the pipeline, leading to leakage which could potentially cause an explosion (Li, Yang, & Gua, 2020; Rahmati et al., 2017). Therefore, being able to detect faults within the gas pipeline is of paramount importance (Rahmati et al., 2017).
Gas well inspections are one of the main tasks of gas companies. Gas well inspections via automation systems are required, as both the frequency of inspection and the labour intensity is high and the manual system is complicated, ineffective and requires significant equipment (Li et al., 2020).

However, physical access to these areas is still limited (Rahmati et al., 2017). The natural gas production firm typically faces challenges regarding outdated and inefficient practices and the use of outdated software used during the pipeline network process (Miao, Zhou, & Ghoneim, 2020). The current centralised energy supply system is not appropriate for several users and devices (Miao etal., 2020). In addition, the gas transaction process typically involves a third party, hence traceability is required (Miao et al., 2020). Moreover, gas data that relies on a gas meter is delayed, leading to an energy supply failure. All the above-mentioned issues could be addressed by implementation of the IoT system (Miao et al., 2020).

In the 1980s, gas producers were unable to utilise wireless sensor networks technology as thecosts were high and sizes of these networks were large (Aalsalem, Khan, Gharibi, & Armi, 2017). However, at present, the wireless sensor network (WSN) technology has been utilised in the gas industry, especially the upstream segment, in order to monitor leakage and corrosion detection, pipeline condition and pipeline vandalization (Anupama et al., 2014). There are IoT adoptions with a range of sensors that monitor density humidity, flow rate, pressure level, storage tank and drilling fluid tank level, and temperature. (Toma & Popa, 2018). The IoT system is able to detect and report failures and destructive events on time, decreasing production downtime (Aalsalem et al., 2017). Furthermore, IoT devices are able to sense and collect data - temperature and pressure, for example - from the gas well environment and report results back to the control centre (Aalsalem et al., 2017).

In addition, predictive maintenance of wellhead equipment can also be accomplished since smart objects found on the wellheads are able to warn the control centre regarding the equipment that needs repair or maintenance (Aalsalem et al., 2017). Another example of the use of IoT is that it can measure the mass principle (Mahmoodzadeh, Wu, Droguett, & Mosleh, 2020); mass in closed systems such as pipelines should remain constant and remain unchanged by processes within the system; thus, if the mass flow at the inlet and the outlet are not equal (the mass flow at the inlet is more than at the outlet) it means that there is leakage in the pipeline (Rahmati et al., 2017). The IoT system is able monitor the mass flows at the inlet and outlet in real-time (Mahmoodzdeh et al., 2020). Nevertheless, the IoT system still has some issues regarding its reliability to carry safety-related radio signals and low data bandwidth, in addition to having a short battery life due to high data update rates and physical obstruction (Ali et al., 2015).

IoT Usage in Food Processing

This section considers the IoT usage within food processing. The food processing supply chain begins with agriculture and currently smart agriculture is used, smart agriculture being the application of technologies such as the IoT, Big Data, Global Positioning System (GPS), Cloud Computing and AI into traditional agriculture (Lin et al., 2018). Smart agriculture is utilised to reduce human efforts and optimize resources. The agricultural IoT utilizes sensing nodes found in the target areas such as farmland, greenhouses and pastures to collect information regarding breeding and planting in real-time. Such information - for examples, temperature, humidity, light, gas condensing and soil moisture - are gathered into a cloud base central control system during cultivation and transportation (Lin et al., 2018).

The usage of IoT during food processing will happen after the agricultural stage. The agri-food processing stage is challenging for IoT adoption from a technical and organisational perspective (Verdouw, Sundmaeker,Tekinerdogan, Conzon, & Montanaro, 2019). Manual recording and verification could be replaced with IoT devices in order to find issues and tackle them timely (Lin et al., 2018). However, current traceability systems cannot ensure the information accuracy, reliability and scalabilityof the agri-food supply chain (Tsang, Choy, Wu, Ho, & Lam, 2019). Furthermore, the traceability process is time-consuming and complicated (Tsang et al., 2019). To handle this concern, a batch of food items may have a Quick Response code attached (QR code) that contains information such as product name, list of ingredients, source of origin and food quality-related information (Tsang et al., 2019). Some of the data collected can be from:

1) Temperature monitoring and time taken during the different processing operations.
2) pH and conduction during cleaning in place (CIP) operations.
3) Detection of foreign bodies (e.g. x-ray detectors).
4) Chemical contaminations and microbial contaminants.
5) Monitoring of allergens.

6) Measurements of food quality characteristics, like texture, colour, and flavors (e.g. electronic nose and tongue).

7) Monitor of micronutrients, moisture content, fat content and other food components (Mahalik & Kim, 2016).

In addition, the food safety within the factory can be optimized through an integrated monitoring system of sensors and version control systems along the production line (Ramundo, Taisch, & Terzi, 2016).

Another application of IoT in food manufacturing is the integration of sensors in food packaging; this provides reliable information about each pack of products (Popa et al., 2019). Conventional food inspection technologies are limited to weight, volume, colour and aspect inspection (Popa et al., 2019). However, QR codes, NFC and nanomaterial with combined RFIDs can trace food origin, properties and characteristics that could be read by the final consumers during and after the purchasing in order for them to become product aware (Mahalik & Kim, 2016). More importantly, IoT systems consist of gas, temperature and humidity sensors, which provide the essential information needed for evaluating the quality of the packed product (Popa et al., 2019). Smart packaging for foods focuses upon food safety such as microbial growth, oxidation and improved tamper visibility; food quality such as flavour and aromas, and shelf-life tracking (Kuswandi, Wicaksono, Abdullah, Heng, & Ahmad, 2011).

Furthermore, with the IoT quality implementation certification systems can be adopted swiftly, such as International Organization for Standardization (ISO) standards (Ramundo et al., 2016). In addition, nano sensors can also be used for creating smart labels (Mahalik & Kim, 2016). The labels have reactive layers with nanoparticles that gather environmental information within the packaging and they can send the measured data through wireless protocols (Mahalik & Kim, 2016). The cheapest and the most explored data transfer option is via radio frequency identification tags (RFID (Mahalik & Kim, 2016). Currently, the smallest micro RFID tags are approximately 50 x 50 μm (Ileš, Martinović, & Kozak, 2011). RFID is also used at the macroscale level to provide smart labels together with barcodes and QR codes, also called smart tags (Mahalik & Kim, 2016). The codes can be scanned by operators using smartphones and tablets, and by consumers in order to obtain information about the product, or other content (Mahalik & Kim, 2016).

It is important to note that labels are strictly regulated by the EU through 1169/2011 (Mahalik& Kim, 2016) and Thailand through The Ministry of public health (GMP, n.d.). With regard to logistics and warehousing after the food processing has taken place, temperature, humidity and the levels of different gases inside the containers at the vehicle and pallet can be monitored remotely and the consequent data collected. The data will then be sent via wireless gateways to warehouse management systems that will allow alert messages if there should be a problem. Shelf life can eventually be recalculated in case of problems through specific algorithms (Mahalik & Kim, 2016). All these parameters can be saved to Cloud IT systems and read with smartphones and tablets and they may even be provided to business clients in order for more effective management of the market/supermarket warehouse to take place with a FEFO (First- Expire, First-Out) logic, and provided to consumers through the use of QR codes and NFC tags (Mahalik& Kim, 2016).

There is some difficulty to be found with regard to the adoption of IoT by agri-food manufacturers; living and natural products, such as plants and animals, are not easily integrated with the IoT devices (microprocessors, sensors, antennas, etc. (Verdouw, Sundmaeker, Tekinerdogan, Conzon, & Montanaro, 2019). Moreover, agri-food production depends on natural conditions such as climate, soil, weather, disease and pest pollution, thus resulting in a large variety and variability of agricultural products (Verdouw et al., 2019). In addition, the IoT devices may be required to be used in harsh conditions such as open-air, or cold storage. Consequently, current IoT applications and technologies in the agri-food domain are still fragmented; they lack seamless integration, and more advanced solutions are still in an experimental stage of development (Verdouw et al., 2019).

IoT Usage in Precast Concrete Manufacturing

This section considers the IoT usage in precast concrete manufacturing. Precast concrete products include wallboard, stairs and balconies (Yu, Wei, & Zhi, 2017). Precast concretes are critical for the construction process (Yu et al., 2017). The benefit of prefabrication, such as off- site precast concrete manufacturing, is that it reduces construction duration and increases productivity (O'Neill & Organ, 2016). In recent decades, most housing construction has moved to the prefabricated building, following the industrialization trend (Han & Ye, 2018). The precast processes include design, fabrication, delivery, storage, installation and inspection (Valero, Adán, & Cerrada, 2015). The precast concrete manufacturing plant acts as a housing factory (Wang et al., 2020).

Currently, the main problem found with the precast concrete process is supply chain management, as the precast supply chain comprises several processes, including manufacturing, storing, transportation and on-site assembly (Li, Yuan, & Zhang, 2012). Therefore, information sharing across parties is fragmental (Li et al., 2012). The examples of parties involved are designers, manufacturer, transportation parties, on-site assemblers and operation & maintenance (O&M) (Han & Ye, 2018). Furthermore, the precast concrete component data - such as dimension, materials and reinforcements - for production is not captured from the detailed design phase directly or automatically, and the precast component data is collected manually and recorded on paper. This reduces the completeness and accuracy of data used during the process (Valero et al., 2015). On the construction sites, manual supervision and recording of materials, resources and activities is a time-consuming and difficult task, especially taking into consideration that precast components are numerous and varied (Han & Ye, 2018). As a result, the work efficiency is low and the cost of the housing project is typically over-budget (Shen et al., 2019). Within the manufacturing process, the real- time status on precast components is not available for all parties and the production or delivery schedule is not coordinated with the final on-site assembly plan, and this results in failure to deliver the precast component on time. Hence, the construction duration is prolonged (Wang et al., 2020), and this is not helped due to the current communication modes being by telephone calls or emails, which is limited with regard to accomplishing traceability (Yu et al., 2017).

There are several advanced project management types of software on the market, such as ERP, Building Information Modeling (BIM) and Geographic Information System (GIS), that can be adopted during different processes. However, information compatibility and interchangeability among different software is limited, due to the mismatch of the definitions of semantics and syntax used in different software (Ergen, Akinci, & Sacks, 2007). In summary, there is need to solve the information sharing challenges across parties and make good the means of traceability of information, along with several processes. Typical information management systems in precast manufacturing can be separated into two areas:

1) Manufacture management (concealed acceptance, quality inspection and product-inventory), carriage management (pre-delivery management, transportation tracking);
2) Construction management (warehousing management, installation management and grout-in management) (Yu et al., 2017).

Each process will be operated only when the previous one has been completed (Yu et al., 2017). The entire process starts with design; the detailed design data, including project information, drawing information, material information, embedded parts information and molds information, will be transferred to the production management system when the design work is finished (Han & Ye, 2018). Subsequently, BIM and MES (Manufacturing Execution System) manage the precast concrete components data for production at the precast factory, which comes directly from the detailed design model (Han & Ye, 2018).

Utilising the IoT-based system, the information about precast concretes can be monitored in real-time with information shared to all related units, improving efficiency (Omar, Doh, Panuwatwanich, & Miller, 2014). At the precast factory, the tag deployed in the precast component on the pallet has its specific identifying number (Han & Ye, 2018). Administrators could get the tag ID by utilising the RFID reader and obtain the information on precast concrete from a database (Yuet al., 2017). The embedded RFID tag is fixed onto the steel cage before pouring the concrete (Yu et al., 2017). The information of concealed acceptance would be recorded before pouring the concrete, including codes and parameters (Yu et al., 2017). During the production process, the production inspection such as concrete size, joint bar, reserved hole, embedded parts and surface smoothness will be recorded, then the information will be uploaded to a remoter server (Yu et al., 2017).

For the production-inventory, the number of qualified precast concretes stacked in the yard will be recorded (Yu et al., 2017). The qualified precast concretes will then be transported and stored in the warehouse on the construction site (Yu et al., 2017). By introducing RFID, the real-time tracking and monitoring of materials and resources on the construction sites can be developed (Han & Ye, 2018) and thereafter the precast concretes will be installed and grouted. Grouting is the process of filling the spaces in between precast concretes. The administrator records the information regarding the grouting process, such as information about the members of the grouting team, temperature, joint test, grouting material,grouting amount, operation time and inspection result (Yu et al., 2017). All the information will be upload to a remote server and saved within the database permanently (Yu et al., 2017). Collaborative project teams can update 3D models in real-time. **Figure 21** below provides the work flow of information management system for precast concrete.

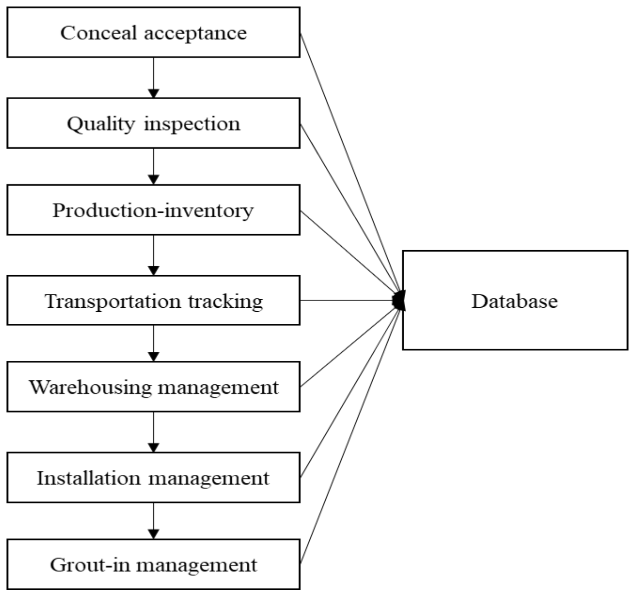

Figure 21: Workflow of Information Management System for Precast Concrete

Source: Author's own

All parties involved in the construction process could discuss design iterations and merge architectural, structural and MEP models and eliminate clashes (Han & Ye, 2018). To ensure the accuracy and efficiency of real-time onsite safety management, RFID technology can be integrated with the neural network safety decision-making model (Chen & Zhang, 2015). In addition, the production processes and delivery schedules can be monitored in real-time and the whole progress management for the prefabricated components can be carried out through the complete information about the manufacture, carriage, installation and grout-in (Yu et al., 2017). The example studies of the use of IoT in precast manufacturing are a streamlined information flow to facilitate the tracking of PCs across different processes (Wang et al., 2020). In addition, Yin et al. (2020) proposed an RFID-based management model to inspect all the steps taken within a precast supply chain, including the materials, production, logistics, and delivery activities. In some other studies, information tracking technologies such as barcode and RFID were proved to enable recording real-time information on PCs and hence, reduce inventories and supply chain costs (Wang et al., 2020). Cloud-based storage is also useful with regards to the IoT.

The status information for each precast component, stored in RFDI tags, can be used to monitor the equipment condition in real time and also to manage maintenance sequences (Valero et al. 2015). In the precast industry, the information obtained from BIM and IoT is not well connected and shared among the stakeholders (Zhong et al. 2017) because the designers, factory manufacturers and on-site assemblers are from different locations (Zhong et al. 2017). Cloud services allow collaboration via the internet to accelerate decision-making from any location, which is an appropriate platform for those stakeholders (Zhonget al. 2017).

IoT Usage in Shop Floors

This section considers the IoT usage on shop floors. Current technology in network systems enables the features of high reliability, high transmission rate and low latency through 5G wireless communication network to make it possible for industrial automation shop-floor (Cheng, Chen, Tao, & Lin, 2018). The construction of large-scale automatic production lines is possible by the adoption of IoT system (Chenget al., 2018). The need for IoT with automation is coming as the manufacturing process involves sub-processes, and different manufacturing equipment on the production line is responsible for separate processes (Cheng et al., 2018). It is critical to collaborate all processes at the right time, with particular importance placed on the assembly line process (Cheng et al., 2018). This automation is appropriate for machinery manufacturing as the machinery products are varied. At present, due to the obsoleteness of the machines, they cannot operate some complicated processing tasks, for example, collaborative assembly between dual robots, or cooperative welding (Cheng et al., 2018). Some manufacturing scenarios within a harsh environment require remote control, normally with automation, to manage multiple robot working (Cheng et al., 2018). All the above-mentioned issues could be handled with IoT-automotive systems (Cheng et al., 2018).

In addition to the IoT with automation usage, the IoT is used with Human Machine Interface (HMI) in manufacturing. HMI enables the users to interact with machines on shop floors (Borkar, Chanana, Atwal, Londe, & Dalal, 2020. In most industries, HMI is utilised for connecting hardware devices (Borkar et al., 2020). For the manufacturing industries, HMI is the way to access information regarding the configuration and performance of machines (Borkar et al., 2020). The global HMI market is growing rapidly (Kartsch, Guermandi, Benatti, Montagna, & Benini, 2019) and this trend is driven by the adoption of industrial automation and the growing of IoT ecosystems (Meattini et al., 2018). The HMI, which provides realistic views of a plant's operation, allows operators to control the machines remotely; with HMI, operators can view alarms and locate any failings in the equipment, which allows them to react more swiftly, as the alarm can be preventative (Borkar et al., 2020). However, HMI still has limitations as it is difficult to retrieve the history of data or analysis of HMI automatically, and HMI is used only once per machine, which means that it is hard to manage aggregately (Borkar et al., 2020). With the IoT, a single platform, the HMI with each machine can be integrated and handled from a single IoT-based web portal (Borkar et al., 2020). An example of HMI with IoT, used on the shopfloor, is at Nanyang

Polytechnic (Zhiqiang, Varghese, Quan, & Ashok, 2019). HMI with IoT in their shopfloor helps create more effectivetwo-way communication between users and shopfloor machines (Zhiqiang et al., 2019); they can use a chat message systems application, which can manage group communication by enabling instant notification and remote control (Zhiqiang et al., 2019). Users can access real-time information, receive instant warning/messages, and remotely control shop floor machines (Zhiqiang et al., 2019). The chat message system comprises four core modules: chat messenger, chat service engine control & communication engine, and local command service (Zhiqiang et al., 2019). Chat messenger provides a chatting interface and group management with enquiries and notifications (Zhiqiang et al., 2019). Chat service engine and control and communication are the cloud-based services that process questionnaire logic and transfer commands and processes data between chat messenger and local command service (Zhiqiang et al., 2019). Finally, local command service is a terminal that implements interface and protocols directly interacting with machines on shopfloors (Zhiqiang et al., 2019); it processes the requests and commands from chat messenger to those machines and generates the information in real-time (Zhiqiang et al., 2019). The result of HMI-IoT adoption is the improvement of manufacturing efficiency (Zhiqiang et al., 2019).

IoT Usage in Textile Manufacturing

This section considers the IoT usage within textile manufacturing. Textile production is capital intensive and fragmented, and operates with a wide range of machinery, such as spinning, dyeing, printing, weaving, finishing and fabric manufacturing (Puranikmath & Babu, 2020). It is process-based and every single process could impact productivity and profitability (Bullón, González Arrieta, Hernández Encinas, & Queiruga Dios, 2017), hence it requires monitoring at every stage and requires integrated systems that will measure the details of each machine (Küsters, Praß, & Gloy, 2017). However, textile manufacturing typically lacks technology, hence the productivity and efficiency is low (Görçün, 2018). The current trend is leaning forward to personalization and variations (Görçün, 2018) and this leads to textile manufacturers needing to adjust to the market requirement in a short time (Görçün, 2018). However, currently, the majority of the textile factory is still designed to produce standard products and cannot produce personalised products (Görçün, 2018). Moreover, the product life cycle in this industry is shorter than ever before (Zuehlke, 2010). All the above present an opportunity for the IoT to help address these problems, as with the IoT, the processes can be more flexible, rapid and agile (Görçün, 2018). Manufacturers can provide quick and effective responses to the customers' requirements (Görçün, 2018). The adoption of IoT in textile is in the early stage of production transformation (Puranikmath & Babu, 2020). With the IoT, textile manufacturers can embed machines with sensors and actuators, creating uniform mass networks (Küsters et al., 2017). The IoT could potentially be used in the textile and garment industries in an efficient way such as to develop E-textiles and control manufacturing processes (Gardetti & Torres, 2017). Adopting IoT in textile manufacturing has potential to create automated processes, higher output and predictability in production and maintenance, as well as in new business models (Puranikmath & Babu, 2020). It is critical to use real-time data in order that effective decision-making processes take place in textile industries, to monitor and receive information at every unit (Küsters et al., 2017) by adopting automation in every section.Therefore, stock management and work coordination are more efficient (Boyes, Hallaq, Cunningham, & Watson, 2018). The automated control could be over the entire textile fabrication processes from fibre, fabric, design, fabric creation to finishing (Gardetti & Torres, 2017).

For example, large-scaled firms in Aachen, Germany use a smart person device to make production more transparent by way of providing production key parameters in a sophisticated way (Fernández-Caramés & Fraga-Lamas, 2018). The tele-maintenance can be utilised to repair machines and the warp tension in a weaving process is able to optimise itself by using IoT (Fernández-Caramés & Fraga-Lamas, 2018). In addition, obtaining real-time information is extremely important with regards to creating a flexible production process (Görçün, 2018). Smart devices can be used to obtain real-time information relating to customer requirements and in addition, customers can directly be participants of value chain processes (Görçün, 2018).

Two sensor types are typically used within the textile factory (Puranikmath & Babu, 2020). Capacitive sensors (Puranikmath & Babu, 2020) can detect the mass variation of yarn linear density in various types of spinning on the spinning machine (Puranikmath & Babu, 2020). Therefore, when yarn stops, or breaks while processing, the sensor can instantly inform the automatic control system attached to the spinning machine (Cherenack & van Pieterson, 2012). The second sensor type is optical, which determines diameter variations (Puranikmath & Babu, 2020). It is used in different types of winding, twisting, spinning and texturing machines and caneffectively determine the visual appearance of the yarn produced (Puranikmath & Babu, 2020).

Overall, textile-manufacturing processes start from fiber/filament and end with the garment, which is the final product. The processes comprise spinning, weaving/knitting, dyeing/printing, finishing, sewing, and cutting. **Figure 22** below provides a flow chart for textile manufacturing processes:

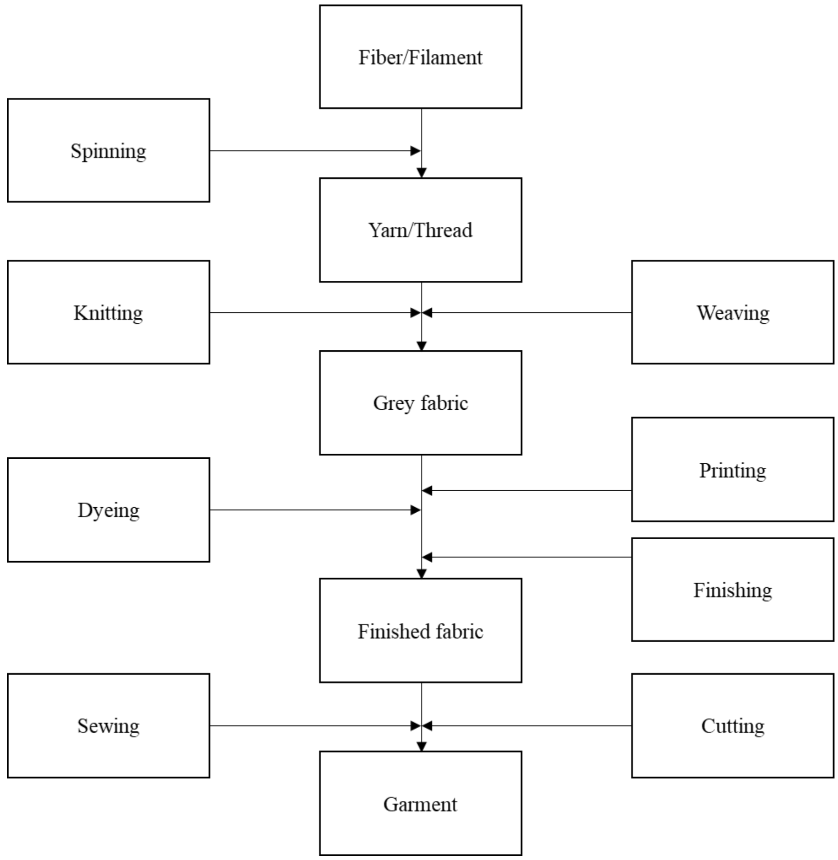

Figure 22: Flow Chart for Textile Manufacturing Processes

Source: Author's own

More specifically, regarding IoT adoption in different textile manufacturing processes, IoT is used significantly during the spinning process (Puranikmath & Babu, 2020). The spinning process comprises different processes, such as bale carding, blow room, comber, draw frame, inventory, lap winder, pre-draw frame, warehousing, winding, roving frame and ring spinning/speed frame/OE spinning (Puranikmath & Babu, 2020). Data is collected from these processes in real-time with an ERP system to control the production and quality and ensure the scheduling system (Manglani, Hodge, & Oxenham, 2019). In addition, drones are also used to examine the spinning unit, thus reducing paperwork due to automated data collection, with improved decision-making, scheduling, and logistics (Chen & Xing, 2015). Therefore, overall automation within the spinning unit improves the productivity and efficiency of the workforce and quality (Manglani et al., 2019).

The next process of adopting IoT involves the weaving processes. In the weaving sections, sectional warping, sizing, weaving loom, configurating, and customising (Patil, 2020) are monitored and synchronized with all the manufacturing and logistics activities. IoT-enabled automation accumulates real-time data of an optimised production schedule, real-time visibility of the manufacturing process and automatic data collection, from yarn purchasing and inventory,to the shipment of the finished fabric (Patil, 2020).

The next process to adopt IoT is a chemical processing, which includes sub-processes such as batching, designing, dyeing, mercerization, printing, singeing and stenter. Automatic monitors regulate the number of beams produced, production efficiency, recipe management, production,machine monitoring, downtime and calculating machine health, and specific energy consumption per kg of yarn, or fabric (Manglani et al., 2019).

The highlight of the IoT solution helps to keep up with trends in order to meet the needs of customers (Manglani et al., 2019). As the textile industry typically has a variety of products, inventory management is critical (Puranikmath & Babu, 2020). With the IoT, a real-time model of the stocks provide an accurate inventory with clear visibility of each particular product (Puranikmath & Babu, 2020). Manufacturers can trace customer needs and work on retail orders to improve efficiency (Suuchi, 2019). The most significant application of IoT in the textile industry is the possibility of using it to design mass customized products (Puranikmath & Babu, 2020). Real-time data andfeedback from customer preferences allows the manufacturer to instantly review the design, make changes and finalize the product design (Suuchi, 2019).

IoT Usage in Rice Manufacturing

This section considers the IoT usage within rice manufacturing. The rice manufacturing processes comprises six stages:

1) Cleaning.
2) Sorting.
3) Husking; separating brown rice from paddy.
4) Polishing and grading (Tangpinijkul, 2010).

The IoT is currently being used in the polishing process; rice polishing is one of the processes that significantly affects the rice grain quality (Chantima et al., 2016). Rice quality can be assessed by its colour and size (Chantima et al., 2016). The polishing machine spins the rice with the wire mesh (Chantima et al., 2016) and the gap between the cone and the wire mesh is adjustable by internal rubber brakes (Chantima et al., 2016). A wide sized gap produces yellow or brown rice (Chantima et al., 2016) and a narrow gap produces whiteness of the rice but it causes the rice to break due to the heating factor (Chantima et al., 2016). At present, the lack of real-time monitoring causes difficulty in meeting the required quality (Chantima et al., 2016), hence rice needs to be re-polished frequently (Chantima et al., 2016). The example use of IoT in rice manufacturing is a wireless colour sensornode for rice whiteness measurement, which can be monitored in real-time (Chantima et al., 2016). Nodes are installed at different locations for monitoring (Shelby & Bormann, 2011). Conventionally, a rice sample is picked up every 30-60 minutes to test the whiteness accuracy (Tangpinijkul, 2010). With the IoT, the real-time measurement can be monitored without sampling (Shelby & Bormann, 2011) as the system will monitor it and the polishing machine will be adjusted automatically between the white colour and the amount of broken rice.

IoT Usage in Automotive Manufacturing

This section considers the IoT usage within automotive manufacturing. At present, the IoT technology with regards to automobile parts is focused on logistics and distribution (Liu & Chang, 2012). Regarding the implementation of IoT within the factory, RFID can monitor the production of automobiles and key components, then upload the data to the data centre so that once the vehicle is finished at the end of the assembly line, which is the last process, the firm can trace back the production detail later. The information can be uploaded in real time to the businesses MES system and WMS system (Liu & Chang, 2012; Wanjari, 2020), which oversees all the events that occur during the production cycle (Wanjari, 2020). The traceability of the IoT could smooth the flow of the assembling process by way of detecting the abnormal speed of the process in real time (Costa, et al., 2017). The examples of such details are that of the supplier information, storage time, production time in each process, operating staff, inspection information and test data (Liu & Chang, 2012). Some car manufacturers use an electronic tag for improving inventory management and quality; with the RFID tag embedded in each car part, the firm can swiftly identify which part of the car is causing the issue, and from which process (Khan et al., 2006). Furthermore, the real-time monitoring function of IoT can both improve the quality and reduce failure rates (Khaleel et al., 2015); it can be used to analyse each process to increase the efficiency of the whole processes (Khaleel et al., 2015).

References

Aalsalem, M. Y., Khan, W. Z., Gharibi, W., & Armi, N. (2017). An intelligent oil and gas well monitoring system based on Internet of Things. In *2017 International Conference on Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET)* (pp. 124-127). IEEE.

Abazi, B. (2016). An approach to the impact of transformation from the traditional use of ICT to the Internet of Things: How smart solutions can transform SMEs. *IFAC-PapersOnLine*, *49*(29), 148-151.

ABB. (2019). *Shaping a leader focused in digital industries*. Retrieved from https://new.abb.com/docs/default-source/media/strategy-update-2019/abb-group-strategy-presentation_2019.pdf.

Abe, M. (2012). *Policy guidebook for SME development in Asia and the Pacific*. United Nations ESCAP.

Abor, J., & Quartey, P. (2010). Issues in SME development in Ghana and South Africa. *International Research Journal of Finance and Economics, 39*(6), 215-228.

Accenture (2015). *Industrial Internet Insights Report for 2015*. Retrieved from https://www.accenture.com/ t20150523T023646Z_w_/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/ Global/PDF/Dualpub_11/Accenture-Industrial-Internet-Insights-Report-2015.pdf

Accenture. (2017). *The future of manufacturing with Io*T. Retrieved from https://www.newgenapps.com/blog/8-uses-applications-and-benefits-of-industrial-iot-in-manufacturing.

Ackerman, E. (2015). *Clearpath's otto robot can autonomously haul a ton of stuff.* Retrieved from https://spectrum.ieee.org/automaton/robotics/industrial-robots/clearpath-otto-can-autonomously-haul-a-ton-of-stuff.

Achimugu, P., Oluwagbemi, O., Oluwaranti, A., & Afolabi, B. (2009). Adoption of Information Technology Impact. *Journal of Information Technology Impact*, *9*(1), 37–46.

Ackerman, E. (2015). *Fetch robotics introduces fetch and freight: your warehouse is now automated.* Retrieved from https://spectrum.ieee.org/automaton/robotics/industrial-robots/fetch-robotics-introduces-fetch-and-freight-your-warehouse-is-now-automated.

Ackerman, E. (2016). *How locus robotics plans to build a successor to amazon's kiva robots.* Retrieved from https://spectrum.ieee.org/automaton/robotics/industrial-robots/locus-robotics-warehouse-automation-robots.

Aerospace Growth Partnership (AGP). (2019). *The Aerospace Growth Partnership*. Retrieved from https://www.theagp.aero/.

Afifi, T. M. A., Ghazal, T. M., & Kalra, D. (2021). The Impact of Deploying the Internet of Things and How Will It Change Our Lives. *Solid State Technology*, *64*(2), 2049-2055.

Agarwal, R., & Prasad, J. (1997). Targeting COBOL programmers for C training: the role of job insecurity and organizational tenure. *Journal of Systems and Software*, *37*(1), 5-17.

Agarwal, R., & Prasad, J. (1998). The antecedents and consequents of user perceptions in information technology adoption. *Decision Support Systems*, *22*(1), 15-29.

Aguila-Obra, A. and Padilla-Meléndez, A. (2006). Organizational factors affecting Internet technology adoption. *Internet Research*, *16*(1), 94-110.

Ahlmeyer, M., & Chircu, A. M. (2016). Securing the Internet of things: A review. *Issues in Information Systems*, *17*(4), 21-28.

Ahmad Wani, T., & Wajid Ali, S. (2015). Innovation Diffusion Theory Review; Scope in the Study of Adoption of Smartphones in India. *Journal of General Management Research*, *3*(2), 101–118.

Ahsan, M., Talib, M. R., Sarwar, M. U., Khan, M. I., & Sarwar, M. B. (2016). Ensuring interoperability among heterogeneous devices through IoT middleware. *International Journal of Computer Science and Information Security*, *14*(4), 251-255.

Aiken, M., Bacharach, S. B., & French, J. L. (1980). Organizational structure, work process, and proposal making in administrative bureaucracies. *Academy of Management Journal*, *23*(4), 631-652.

Airehrour, D., Gutierrez, J., & Ray, S. K. (2016). Secure routing for internet of things: A survey. *Journal of Network and Computer Applications*, *66(8)*, 198-213.

Ajili, A., Salehi, S., Rezaei-Moghaddam, K., Hayati, D., & Karbalaee, F. (2012). Estimating the model of investigating attitude and intention in the usage of variable rate irrigation technology. *American Journal of Experimental Agriculture*, *2*(3), 542-556.

Ajzen, I., & Fishbein, M. (1977). Attitude-behavior relations: A theoretical analysis and reviewof empirical research. *Psychological Bulletin*, *84*(5), 888-918.

Alam, T. (2021). Cloud-based IoT applications and their roles in smart cities. *Smart Cities*, *4*(3), 1196-1219.

Alcorta, L., Foster-McGregor, N., Szirmai, A., & Verspagen, B. (Eds.). (2021). *New perspectives on structural change: Causes and consequences of structural change in the global economy*. Oxford University Press.

Al-Debei, M. M., & Al-Lozi, E. (2014). Explaining and predicting the adoption intention of mobile data services: A value-based approach. *Computers in Human Behavior*, *35(6)*, 326-338.

Al-Momani, A. M., Mahmoud, M. A., & Ahmad, M. S. (2018). Factors that Influence the Acceptance of Internet of Things Services by Customers of Telecommunication Companies in Jordan. *Journal of Organizational and End User Computing*, *30*(4), 51–63.

Al-Momani, A. M., Mahmoud, M. A., & Ahmad, M. S. (2016). Modeling the adoption of internet of things services: A conceptual framework. *International Journal of Applied Research*, *2*(5), 361–367.

Al-Jabri, I. M., & Sohail, M. S. (2012). Mobile banking adoption: Application of diffusion of innovation theory. *Journal of Electronic Commerce Research, 13*(4), 379-391.

Al-Momani, A. M., Mahmoud, M. A., & Ahmad, M. S. (2018). Factors that influence the acceptance of internet of things services by customers of telecommunication companies in Jordan. *Journal of Organizational and End User Computing*, *30*(4), 51-63.

Al-Qirim, N. (2006). The role of the government and e-commerce adoption in small businesses in New Zealand. *International Journal of Internet and Enterprise Management*, *4*(4), 293-313.

Al-Qirim, N. (2007). A research trilogy into e-commerce adoption in small businesses in New Zealand. *Electronic Markets*, *17*(4), 263-285.

Alam, S. S., Khatibi, A., Ahmad, M. I. S., & Ismail, H. B. (2008). Factors affecting e-commerce adoption in the electronic manufacturing companies in Malaysia. *International Journal of Commerce and Management, 17*(1/2), 125-139.

Alexakos, C., Anagnostopoulos, C., Fournaris, A., Koulamas, C., & Kalogeras, A. (2018). IoT Integration for Adaptive Manufacturing. In *2018 IEEE 21st International Symposium on Real-Time Distributed Computing* (pp. 146-151). IEEE.

Alghamdi, S., & Beloff, N. (2014). Towards a comprehensive model for e-Government adoption and utilisation analysis: The case of Saudi Arabia. In *2014 Federated Conference on Computer Science and Information Systems* (pp. 1217-1225). IEEE.

Ali, A. N. A. (2012). Comparison study between IPV4 & IPV6. *International Journal of Computer Science Issues*, *9*(3), 314-317.

Ali, S., Qaisar, S. B., Saeed, H., Khan, M. F., Naeem, M., & Anpalagan, A. (2015). Networkchallenges for cyber physical systems with tiny wireless devices: A case study on reliable pipeline condition monitoring. *Sensors*, *15*(4), 7172-7205.

Alliance Experts (2018). *Thailand manufacturing industry: growth and export opportunities.* Retrieved from https://www.allianceexperts.com/en/knowledge/countries/asia/how-to-export-your-technology-to-the-manufacturing-sector-in-thailand/.

Allen, R. E., & Wiles, J. L. (2016). A rose by any other name: Participants choosing research pseudonyms. *Qualitative Research in Psychology*, *13*(2), 149-165.

Alolayan, B. (2014). Do I really have to accept smart fridges. *An empirical study*. *ACHI*, 186-191.

Alshamaila, Y., Papagiannidis, S., & Li, F. (2013). Cloud computing adoption by SMEs in the north east of England: A multi-perspective framework. *Journal of Enterprise Information Management*, *26*(3), 250-275.

Alsharari, N. M., Al-Shboul, M., & Alteneiji, S. (2020). Implementation of cloud ERP in the SME: evidence from UAE. *Journal of Small Business and Enterprise Development*, 27(2), 299-327.

Altman, E. I., & Sabato, G. (2005). Effects of the new Basel capital accord on bank capital requirements for SMEs. *Journal of Financial Services Research*, *28*(1-3), 15-42.

Aluwihare-Samaranayake, D. (2012). Ethics in qualitative research: A view of the participants' and researchers' world from a critical standpoint. *International Journal of Qualitative Methods*, *11*(2), 64-81.

Akimana, B. T., Bonnaerens, M., Van Wilder, J., & Vuylsteker, B. (2017). *A Survey of Human-Robot Interaction in the Internet of Things*, 1–24. Retrieved from https://www.researchgate.net/publication/318722691.

Al-Qaseemi, S. A., Almulhim, H. A., Almulhim, M. F., & Chaudhry, S. R. (2016). IoT architecture challenges and issues: Lack of standardization. In *2016 Future Technologies Conference (*FTC) (pp. 731-738). IEEE.

Austrailian Securities & Investments Commission. (2019*). Small business-what is small business.* Retrieved from https://asic.gov.au/for-business/your-business/small-business/small-business-overview/small-business-what-is-small-business/.

Anantatmula, V. S. (2008). The role of technology in the project manager performance model. *Project Management Journal*, *39*(1), 34-48.

Andersson, P., & Mattsson, L. (2015). Service innovations enabled by the "internet of things". *IMP Journal*, 9(1), 85-106. Retrieved from https://www.researchgate.net/publication/277579448_Service_innovations_enabled_by_the_inte rnet_of_things.

Anonymous. (2015). IIoT: Defining the terms. *Plant Engineering*, *69*(6), 28. Retrieved from http://search.proquest.com/docview/1753506904?accountid=40690.

Anupama, K. R., Kamdar, N., Kamalampet, S. K., Vyas, D., Sahu, S., & Shah, S. (2014). A wireless sensor network-based pipeline monitoring system. In *2014 International Conference on Signal Processing and Integrated Networks (SPIN)* (pp. 412-419). IEEE.

Aragón-Sánchez A & Sánchez-Martin G (2005). Strategic orientation, management characteristics and performance: A study of Spanish SMEs. *Journal of Small Business Managementt*, *43*(3), 287–308.

Arowomole, K. A. (2000). Modern business management (Theory and Practice). *Proceedings of the Ade-Oluyinka Commercial Press*. Ogun State.

Asghar, M. H., Negi, A., & Mohammadzadeh, N. (2015). Principle application and vision in Internet of Things (IoT). In *International Conference on Computing, Communication & Automation* (pp. 427-431). IEEE.

Asiaei, A., & Rahim, N. Z. (2017). Conceptualizing a Model for Cloud Computing Adoption by SMEs. *Paper accessed from pdfs. Semantic scholar. org on*, *21*.

AsianInfo. (2010). *Map of Thailand*. Retrieved from http://www.asianinfo.org/asianinfo/thailand/pro-geography.html.

Asimakopoulos, G., & Asimakopoulos, S. (2014). Understanding switching intention of information systems users. *Industrial Management & Data Systems*, *114*(4), 583-596.

Aseanup. (2018). *Overview of Business in Thailand*. Retrieved from https://aseanup.com/business-thailand/.

Ashrafi, R., & Murtaza, M. (2008). Use and impact of ICT on SMEs in Oman. The Electronic *Journal Information Systems Evaluation*, 11(3), 125–138.

Ashton, K. (2009). That ‘internet of things’ thing. *RFiD Journal*, 22(7), 97-114.

Attaran, M. (2021). The impact of 5G on the evolution of intelligent automation and industry digitization. *Journal of Ambient Intelligence and Humanized Computing*, 1-17.

Attewell, P. (1992). Technology diffusion and organizational learning: The case of businesscomputing. *Organization Science*, *3*(1), 1-19.

Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of things: A survey. *Computer Networks*, *54*(15), 2787-2805.

Atzori, L., Iera, A., Morabito, G., & Nitti, M. (2012). The social internet of things (siot)–when social Networks meet the internet of things: Concept, architecture and network characterization. *Computer Networks*, *56*(16), 3594-3608.

Atzori, L., Iera, A., & Morabito, G. (2017). Understanding the Internet of Things: definition, potentials, and societal role of a fast evolving paradigm. *Ad Hoc Networks*, *56(3)*, 122-140.

Audretsch, D. B. (1999). Small firms and efficiency. In *Are small firms important? Their role and impact* (pp. 21-37). Boston: Springer.

Auzzir, Z., Haigh, R., & Amaratunga, D. (2018). Impacts of Disaster to SMEs in Malaysia. *Procedia Engineering*, *212(14)*, 1131-1138.

Avison, D., Lau, F., Myers, M., and Nielsen, P.A. (1999) Action research. *Communications of the ACM*, 42(1), 94–97.

Azma, F., Mostafapour, M. Ali, & Rezaei, H. (2012). The application of information technology and its relationship with organizational intelligence. *Procedia Technology*, *1(1)*, 94–97.

Bag, S., Gupta, S., Kumar, A., & Sivarajah, U. (2021). An integrated artificial intelligence framework for knowledge creation and B2B marketing rational decision making for improving firm performance. *Industrial Marketing Management*, *92(1)*, 178-189.

Baines, T., Lightfoot, H., Peppard, J., Johnson, M., Tiwari, A., Shehab, E., & Swink, M. (2009). Towards an operations strategy for product-centric servitization. *International Journal of Operations & Production Management*, *29*(5), 494-519.

Balaji, M. S., & Roy, S. K. (2017). Value co-creation with Internet of things technology in the retail industry. *Journal of Marketing Management*, *33*(1-2), 7-31.

Bandyopadhyay, L. K., Chaulya, S. K., & Mishra, P. K. (2010). *Wireless communication in underground mines*. US: Springer.

Bandyopadhyay, D., & Sen, J. (2011). Internet of Things: Applications and Challenges in Technology and Standardization. *Wireless Personal Communications*, *58*(1), 49–69.

BarNir, A., & Smith, K. A. (2002). Interfirm alliances in the small business: The role of socialnetworks. *Journal of Small Business Management*, *40*(3), 219-232.

Baskerville, R. L. (1999). Investigating information systems with action research. *Communications of The Association for Information Systems*, *2*(1), 2-32.

Bassi, A., & Horn, G. (2008). Internet of Things in 2020: A Roadmap for the Future. *European Commission: Information Society and Media*, *22*, 97-114.

Bassett, B. R. (2009). Computer-based analysis of qualitative data: NVIVO. *Encyclopedia of Case Study Research.* Thousand Oaks: Sage Publications.

Bauer, J. M. (2017). Measuring Emerging ICT Trends. *Processings of the 15th World Telecommunication/ICT Indicators Symposium (WTIS-17)*, Tunisia, 14-16. Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/events/wtis2017/Plenary6_Bauer.pdf.

Bauer, W., & Horváth, P. (2014). Industrie 4.0-Volkswirtschaftliches Potenzial für Deutschland. *Controlling*, *27*(8-9), 515-517.

Baumback, C. M. (1988). *How to organize and operate a small business*. New Jersey: Prentice Hall.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13*(4), 544-559.

Bayo-Moriones, A., Billón, M., & Lera-López, F. (2013). Perceived performance effects of ICT in manufacturing SMEs. *Industrial Management & Data Systems*, *113*(1), 117-135.

Bazeley, P. (2007). *Qualitative data analysis with NVivo* (2nd ed.). Thousand Oaks, CA: Sage

BDO. (2018). *Food and drink report*. Retrieved from http://www.bdo.co.uk/getmedia/e29fd8c2-4ff7-4c9f-a047-4b307aeebe70/BDO-Food-and-Drink-Report-2018.aspx.

Beesley, L. G., & Cooper, C. (2008). Defining knowledge management (KM) activities: towards consensus. *Journal of Knowledge Management*, *12*(3), 48-62.

Behera, B. C., Mishra, R. R., & Thatoi, H. (2021). Recent biotechnological tools for diagnosis of corona virus disease: A review. *Biotechnology Progress*, *37*(1), 30-78.

Beier, G., Niehoff, S., Ziems, T., & Xue, B. (2017). Sustainability aspects of a digitalized industry–A comparative study from China and Germany. *International Journal of Precision Engineering and Manufacturing-Green Technology*, *4*(2), 227-234.

Bekara, C. (2014). Security issues and challenges for the IoT-based smart grid. *Procedia Computer Science*, *34(8)*, 532-537.

Bell, E., Bryman, A., & Harley, B. (2018). *Business Research Methods*. Oxford: Oxford University Press.

Belso-Martinez, J. A. (2010). Outsourcing decisions, product innovation and the spatial dimension: evidence from the Spanish footwear industry. *Urban Studies*, *47*(14), 3057-3077.

Benbasat, I., Goldstein, D. K., & Mead, M. (1987). The case research strategy in studies of information systems. *MIS Quarterly*, 11(3), 369-386.

Benyaapikul, P. (2021). Thailand's Path to Economic Recovery and Advancement: Diagnostic Study on the Middle Income Trap and Prospects for Post-Covid Economic Growth. *Thammasat Review of Economic and Social Policy*, *7*(2), 34-79.

Berdykhanova, D., Dehghantanha, A., & Hariraj, K. (2010, June). Trust challenges and issues of e-government: E-tax prospective. In *2010 International Symposium on Information Technology* (Vol. 2, pp. 1015-1019). IEEE.

Bhattacharyya, S., & Bhattacharyya, K. (2004). If you build it they will come: creating a field for project based approach in learning science through qualitative inquiry and technology integration. *Proceedings of QualIT2004: The Way Forward. Griffith University. Brisbane, Australia*.

Bhattarai, K., Mallick, S. K., & Yang, B. (2021). Are global spillovers complementary or competitive? Need for international policy coordination. *Journal of International Money and Finance, 110(1)*, 102-291.

Bi, Z. (2017). Embracing Internet of Things (IoT) and big data for industrial informatics. *Enterprise Information Systems, 11*(7), 949-951.

Bi, Z., Da Xu, L., & Wang, C. (2014). Internet of things for enterprise systems of modern manufacturing. *IEEE Transactions on Industrial Informatics*, *10*(2), 1537-1546.

Biliyaminu, U., Hamdan, H., Lengyel, L., & Farkas, K. (2018). Evaluation of IoT Device Management Tools. *Proceeding of the Third International Conference on Advances in Computation, Communications and Services, Spain,* 22-26. Retreived from http://real.mtak.hu/85014.

BizVibe. (2013). *All the Key Facts You Need to Know about UK's Manufacturing Sector* . Retrieved from https://www.bizvibe.com/blog/all-the-key-facts-you-need-to-know-about-uks-manufacturing-sector/.

Bogers, M., Hadar, R., & Bilberg, A. (2016). Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological Forecasting and Social Change*, *102(1)*, 225-239.

Böhm, E., Eggert, A., & Thiesbrummel, C. (2017). Service transition: A viable option formanufacturing companies with deteriorating financial performance? *Industrial MarketingManagement*, *60(1)*, 101-111.

Bolland, J. (2018). *5 issues UK manufacturers continue to face in 2018*. Retrieved from https://jbcole.co.uk/5-issues-uk-manufacturers-continue-to-face-in-2018/.

Bond, J. (2017). *PwC and MAPI release survey on state of IoT in manufacturing.* Retrieved from https://www.supplychain247.com/article/pwc_and_mapi_release_survey_on_state_of_iot_in_manufacturing/PwC.

Boos, D., Guenter, H., Grote, G., & Kinder, K. (2013). Controllable accountabilities: The Internet of Things and its challenges for organisations. *Behaviour & Information Technology*, *32*(5), 449-467.

Borgia, E. (2014). The Internet of Things vision: Key features, applications and open issues. *Computer Communications, 54(1),* 1-31.

Borkar, P. S., Chanana, P. U., Atwal, S. K., Londe, T. G., & Dalal, Y. D.(2020). The Replacement of HMI (Human-Machine Interface) in Industry Using Single Interface Through

IoT. In *Examining the Impact of Deep Learning and IoT on Multi-Industry Applications* (pp. 195-208). IGI Global.

Botta, A., De Donato, W., Persico, V., & Pescapé, A. (2016). Integration of cloud computing and internet of things: a survey. *Future Generation Computer Systems, 56(1)*, 684-700.

Bowersox, D. J., Closs, D. J., & Stank, T. P. (2000). Ten mega-trends that will revolutionize supply chain logistics. *Journal of Business Logistics*, *21*(2), 2-15.

Boyes, H., Hallaq, B., Cunningham, J., & Watson, T. (2018). The industrial internet of things (IIoT): An analysis framework. *Computers in Industry*, *101(1)*, 1-12.

Boyne, G. A., Gould-Williams, J. S., Law, J., & Walker, R. M. (2005). Explaining the adoptionof innovation: An empirical analysis of public management reform. *Environment and PlanningC: Government and Policy*, *23*(3), 419-435.

BPM. (2021). Retrieved from https://www.cpfworldwide.com/en/about/vision.

Bureau of Labor Statistics. (2009). *Consumer price data*. Retrieved from https://www.bls.gov/data/.

Burns, T., & Stalker, G. M. (1961). The management of innovation. London. *Tavistock Publishing. Cited in Hurley, RF and Hult, GTM (1998). Innovation, Market Orientation, and Organisational Learning: An Integration and Empirical Examination. Journal ofMarketing*, *62(1)*, 42-54.

Bourgeois, D., Reinhart, C., & Macdonald, I. (2006). Adding advanced behavioural models in whole building energy simulation: A study on the total energy impact of manual and automated lighting control. *Energy and Buildings*, *38*(7), 814-823.

Bradley, T., Thibodeau, P., & Ng, V. (2014). The Internet of Things threats and challenges. *Network World Asia*, *11*(1), 16-18.

Brender, N., & Markov, I. (2013). Risk perception and risk management in cloud computing: Results from a case study of Swiss companies. *International Journal of Information Management*, *33*(5), 726-733.

Brown, M., Pope, N., & Voges, K. (2003). Buying or browsing? An exploration of shopping orientations and online purchase intention. *European Journal of Marketing*, *37*(11/12), 1666-1684.

Brumec, S. (2006). Predicting the intention to use Internet–A comparative study. *Journal of Information and Organizational Sciences*, *30*(1), 13-28.

Bruque, S. and Moyano, J. (2007). Organisational determinants of information technology adoption and implementation in SMEs: The case of family and cooperative firms. *Technovation, 27*(5), 241-253.

Bsquares (2017). *Annual Iiot Maturity Survey News*. Retrieved from https://www.oedigital.com/bsquares-2017-annual-iiot-maturity-survey.

Buckley, P. J., & Strange, R. (2015). The governance of the global factory: Location and control of world economic activity. *Academy of Management Perspectives*, *29*(2), 237-249.

Bughin, J., Chui, M., & Manyika, J. (2015). An executive's guide to the Internet of Things. *McKinsey Quarterly*, *4(1)*, 92-101.

Bullón, J., González Arrieta, A., Hernández Encinas, A., & Queiruga Dios, A. (2017). Manufacturing processes in the textile industry. *Expert Systems for Fabrics Production*, 6(4), 15-23.

Bures, M., Klima, M., Rechtberger, V., Ahmed, B. S., Hindy, H., & Bellekens, X. (2021, March). Review of Specific Features and Challenges in the Current Internet of Things Systems Impacting Their Security and Reliability. In *World Conference on Information Systems and Technologies* (pp. 546-556). Cham: Springer.

Burke, K. (2005). The impact of firm size on Internet use in small businesses. *Electronic Markets*, *15*(2), 79-93.

Burkett, M., & Steutermann, S. (2014). How digital business disrupts the supply chain. *The Wall Street Journal*. Retrieved from https://deloitte.wsj.com/cio/2018/09/26/digital-technologies-drive-supply-chain-innovation/.

Business Sweden (2015). *Opportunities in Thailand's manufacturing sector.* Retrieved from https://www.business-sweden.se/contentassets/e87919e751fd4247842bd6bd6fcb22c6/opportunies-in-thailands-manufacturing-sector.pdf.

Business Sweden (2017). *United Kingdom – manufacturing the future*. Retrieved from https://www.business-sweden.se/contentassets/35701a7da4c24845be69f8d4bd8ca369/manufacturing-the-future.pdf.

Caglayan, O. (2019). *Where does the UK market stand in global pharma?* Retrieved from https://pharmafield.co.uk/in_depth/where-does-the-uk-market-stand-in-global-pharma/.

Caldeira, M. M., & Ward, J. M. (2003). Using resource-based theory to interpret the successful adoption and use of information systems and technology in manufacturing small and medium-sized enterprises. *European Journal of Information Systems*, *12*(2), 127-141.

Calori, R., Johnson, G., & Sarnin, P. (1994). CEOs' cognitive maps and the scope of the organization. *Strategic Management Journal*, *15*(6), 437-457.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., & Walker, K (2020). Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, 25)8), 652-661.

Campbell-Kelly, M., & Garcia-Swartz, D. D. (2013). The history of the internet: the missing narratives. *Journal of Information Technology*, *28*(1), 18-33.

Cano-Kollmann, M., Hannigan, T. J., & Mudambi, R. (2018). Global innovation networks–organizations and people. *Journal of International Management*, *24*(2), 87-92.

Carcary, M., Doherty, E., Conway, G., & McLaughlin, S. (2014). Cloud computing adoption readiness and benefit realization in Irish SMEs—an exploratory study. *Information Systems Management*, *31*(4), 313-327.

Cardona, M., Kretschmer, T., & Strobel, T. (2013). ICT and productivity: conclusions from the empirical literature. *Information Economics and Policy*, *25*(3), 109-125.

Cardoza, G., & Fornes, G. (2011). The internationalisation of SMEs from China: the case of Ningxia Hui autonomous region. *Asia Pacific Journal of Management*, *28*(4), 737-759.

Caron, X., Bosua, R., Maynard, S. B., & Ahmad, A. (2016). The Internet of Things (IoT) and its impact on individual privacy: An Australian perspective. *Computer Law & Security Review*, *32*(1), 4-15.

Carter, L., & Belanger, F. (2004). The influence of perceived characteristics of innovating on e-government adoption. *Electronic Journal of E-government*, *2*(1), 11-20.

Casals, F. E. (2011). The SME co-operation framework: A multi-method secondary research approach to SME collaboration. In *2010 International Conference on E-business, Management and Economics IPEDR*, *3*(1), 118-124.

Cassell, C., Symon, G (2004). *Essential Guide to Qualitative Methods in Organizational Research*. London: Sage.

Cassiman, B., & Valentini, G. (2016). Open innovation: Are inbound and outbound knowledge flows really complementary?. *Strategic Management Journal*, *37*(6), 1034-1046.

Central Intelligent Agency (CIA). (2019). *EUROPE: UNITED KINGDOM*. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/uk.html.

Cepeda, G., & Martin, D. (2005). A review of case studies publishing in Management Decision 2003-2004: Guides and criteria for achieving quality in qualitative research. *Management Decision*, *43*(6), 851-876.

Céspedes-Lorente, J. J., Magán-Díaz, A., & Martínez-Ros, E. (2019). Information technologies and downsizing: Examining their impact on economic performance. *Information & Management*, *56*(4), 526-535.

Chae, M., Kim, J., Kim, H., & Ryu, H. (2002). Information quality for mobile internet services: A theoretical model with empirical validation. *Electronic Markets*, *12*(1), 38-46.

Chan, F. T., & Chong, A. Y. L. (2013). Determinants of Mobile Supply Chain Management System Diffusion: A Structural Equation Analysis of Manufacturing Firms. *International Journal of Production Research*, *51*(4), 1196–1213.

Chang, C. (2021). Applying Lean and MES toward Smart Manufacturing-Application of a Thai Automotive Company. *Journal of Lean Systems*, *6*(4), 117-141.

Changraksa, S., Yogyorn, D., Boonyayothin, V., & Sujirarat, D. (2018). Discovering the influencing factors of safety culture in the stae-owned enterprise in Thailand. *International Journal on Occupational Health & Safety, Fire & Environment Allied Science*, *1*(1), 1-16.

Chantima, P., Polpinit, P., & Khunboa, C. (2016). A sensor node prototype for real-time rice whiteness measurement. In *2016 13th International Joint Conference on Computer Science and Software Engineering* (pp. 1-6). IEEE.

Chao, S. L., & Lin, Y. L. (2017). Gate automation system evaluation: a case of a container number recognition system in port terminals. *Maritime Business Review*, *2*(1), 21-35.

Chau, P. Y., & Tam, K. Y. (1997). Factors affecting the adoption of open systems: an exploratory study. *MIS Quarterly*, 21(1), 1-24.

Chehri, A., El Ouahmani, T., & Hakem, N. (2019). Mining and IoT-based vehicle ad-hoc network: industry opportunities and innovation. *Internet of Things*, 14(1), 100-117.

Chehri, A., Farjow, W., Mouftah, H. T., & Fernando, X. (2011). Design of wireless sensor network for mine safety monitoring. In *2011 24th Canadian Conference on Electrical and Computer Engineering (CCECE)* (pp. 001532-001535). IEEE.

Chehri, A., Fortier, P., & Tardif, P. M. (2007,). Security monitoring using wireless sensor networks. In *Fifth Annual Conference on Communication Networks and Services Research (CNSR'07)* (pp. 13-17). IEEE.

Chemical Industries Association (CIA). (2015). *UK Chemical and Pharmaceutical Industry Facts and Figures*. Retrieved from https://www.cia.org.uk/Portals/0/Documents/Publications/20150217%20CIA%20facts%20and%20figures%202015.pdf?ver=2017-01-09-143806-033.

Chen, C. (2013). Perceived risk, usage frequency of mobile banking services. *Managing Service Quality*, *23*(5), 410-436.

Chen, Y., Zhang, H., & Zhang, Y. (2010). Research on the development of internet of things industry in China. *Science and Technology Management Research, 10(4*), 103-106.

Chen, P. Y., & Hitt, L. M. (2002). Measuring switching costs and the determinants of customer retention in Internet-enabled businesses: A study of the online brokerage industry. *Information Systems Research*, *13*(3), 255-274.

Chen, Z., & Xing, M. (2015). *Upgrading of textile manufacturing based on Industry 4.0*. Shenzhen: Atlantis Press.

Chen, Y., Wang, Y., Nevo, S., Benitez-Amado, J., & Kou, G. (2015). IT capabilities and product innovation performance: The roles of corporate entrepreneurship and competitive intensity. *Information & Management*, *52*(6), 643-657.

Chen, Z., Xia, F., Huang, T., Bu, F., & Wang, H. (2013). A localization method for the Internet of Things. *The Journal of Supercomputing*, *63*(3), 657-674.

Chen, S., Xu, H., Liu, D., Hu, B., & Wang, H. (2014). A vision of IoT: Applications, challenges, and opportunities with china perspective. *IEEE Internet of Things Journal*, *1*(4), 349-359.

Chen, Q. and Zhang, S.J. (2015). "Developing an RFID-based man-tool safety management system on a construction site." International Conference on Construction and Real Estate Management, Lulea, Sweden, 238–247.

Cheng, J., Chen, W., Tao, F., & Lin, C. L. (2018). Industrial IoT in 5G environment towards smart manufacturing. *Journal of Industrial Information Integration*, *10(1)*, 10-19.

Chepkemoi, J. (2017). *The Largest Exports of the United Kingdom*. Retrieved from https://www.worldatlas.com/articles/the-largest-exports-of-the-united-kingdom.html.

Cherenack, K., & van Pieterson, L. (2012). Smart textiles: Challenges and opportunities. *Journal of Applied Physics*, *112*(9), 091301.

Chetty, S. (1996). The case study method for research in small-and medium-sized firms. *International Small Business Journal*, *15*(1), 73-85.

Chiang, Y., & Lee, D. (2017). Smart manufacturing with the internet of makers. *Journal of the Chinese Institute of Engineers*, *40*(7), 585-592.

Chiyangwa, T. B., & Alexander, P. M. (2016). Rapidly co-evolving technology adoption and diffusion models. *Telematics and Informatics, 33*(1), 56–76.

Christensen, J., & Huang, G. (2018). *Harnessing the power of the Internet of Things*. Retrieved from http://uu.diva-portal.org/smash/get/diva2:1219591/FULLTEXT01.pdf.

Cho, I. and Kim, Y-G. (2002). Critical factors for assimilation of object-oriented programming languages. *Journal of Management Information Systems, 18(*3), 125–156.

Chong, A. Y. L., & Chan, F. T. (2012). Structural equation modeling for multi-stage analysis on Radio Frequency Identification (RFID) diffusion in the health care industry. *Expert Systems with Applications*, *39*(10), 8645-8654.

Chong, A. Y. L., Liu, M. J., Luo, J., & Keng-Boon, O. (2015). Predicting RFID adoption in healthcare supply chain from the perspectives of users. *International Journal of Production Economics*, *159(1),* 66-75.

Chu, T. H., & Chen, Y. Y. (2016). With good we become good: Understanding e-learning adoption by theory of planned behavior and group influences. *Computers & Education*, *92(1)*, 37-52.

Chong, A., Ooi, K., Lin, B., & Raman, M. (2009). Factors affecting the adoption level of c-commerce: An empirical study. *Journal of Computer Information Systems, 50*(2), 13–22.

Chwelos, P., Benbasat, I., & Dexter, A. S. (2001). Empirical test of an EDI adoption model. *Information Systems Research*, *12*(3), 304-321.

Cisco (2015). *The internet of things: reduce security risks with automated policies*. Retrieved from https://www.cisco.com/c/dam/en_us/solutions/trends/iot/docs/security-risks.pdf.

Cisco (2014). *Mining firm quadruples production, with Internet of Everything*. Retrieved from https://www.cisco.com/ assets/global/BE/tomorrow-starts-here/pdf/ c36-730784-01_dundee_precious_metals_cs_v3a_en_be.pdf.

Collis, J. and Hussey, R. (2009), Business research: *A practical guide for undergraduate and postgraduate students*. 3rd ed. Basingstoke: Palgrave Macmillan.

Coltman, T., Devinney, T. M., Latukefu, A., & Midgley, D. F. (2001). E-business: revolution, evolution, or hype? *California Management Review*, *44*(1), 57-86.

Columbus, L. (2017). *How IoT, big data analytics and cloud continue to be high priorities for developers.* Retrieved from https://www.cloudcomputing-news.net/news/2016/jun/27/internet-of-things-machine-learning-robotics-are-high-priorities-for-developers-in-2016/.

Constantinescu, C., Popescu, D., Muresan, P. C., & Stana, S. I. (2016). Exoskeleton-centered process optimization in advanced factory environments. *Procedia CIRP*, *41(1)*, 740-745.

Conway, J. (2016). The Industrial Internet of Things: an evolution to a smart manufacturing enterprise. *Schneider Electric*. Retrieved from http://www.mhi.org/media/members/15373/131111777451441650.pdf.

Cooper, D. and Schindler, P. (2003). *Business Research Methods (8th Edn*), International Edition, London: McGraw Hill.

Coppa, M., & Sriramesh, K. (2013). Corporate social responsibility among SMEs in Italy. *Public Relations Review*, *39*(1), 30-39.

Corbin, J. M., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, *13*(1), 3-21.

Costa, F., do Sameiro Carvalho, M., Fernandes, J. M., Alves, A. C., & Silva, P. (2017). Improving visibility using RFID–the case of a company in the automotive sector. *Procedia Manufacturing*, *13(1)*, 1261-1268.

Coughlan, T., Brown, M., Mortier, R., Houghton, R. J., Goulden, M., & Lawson, G. (2012, November). Exploring Acceptance and Consequences of the Internet of Things in the Home. In *2012 IEEE International Conference on Green Computing and Communications* (pp. 148-155). IEEE.

Coyne, I. T. (1997). Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries?. *Journal of Advanced Nursing*, *26*(3), 623-630.

CPAC. (2021). Retrieved from https://web.cpac.co.th/en/home.

Creswell, J.W. (2009). *Research design: qualitative, quantitative and mixed method approaches*, 3rd ed. Thousand Oaks, CA: Sage.

Cugno, M., Castagnoli, R., & Büchi, G. (2021). Openness to Industry 4.0 and performance: The impact of barriers and incentives. *Technological Forecasting and Social Change*, *168(1)*, 120-756.

Curkovic, S., & Sroufe, R. (2011). Using ISO 14001 to promote a sustainable supply chain strategy. *Business Strategy and the Environment*, *20*(2), 71-93.

Cyert, R. M., & March, J. G. (1963). A behavioral theory of the firm. *Englewood Cliffs, NJ*, *2*(4), 169-187.

Da Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on Industrial Informatics*, *10*(4), 2233-2243.

Dai, Q., Zhong, R., Huang, G. Q., Qu, T., Zhang, T., & Luo, T. Y. (2012). Radio frequency identification-enabled real-time manufacturing execution system: a case study in an automotive part manufacturer. *International Journal of Computer Integrated Manufacturing*, *25*(1), 51-65.

Dalitso, K., & Peter, Q. (2000). *The policy environment for promoting small and medium-sized enterprises in Ghana and Malawi*. Manchester: Institute for Development Policy and Management.

Dannreuther, C. (2007). EU SME policy: On the edge of governance. *CESifo Forum*, 8(2), 7-13.

Darvas, Z., & Wolff, G. B. (2016). *An anatomy of inclusive growth in Europe. Bruegel Blueprint Series 26, October 2016*. Retrieved from http://bruegel.org/wp-content/uploads/2016/10/BP-26-26_10_16-final-web.pdf.

Dasgupta, S., Dierckxsens, M., & Verick, S. (2021). The Impact of the COVID-19 Crisis on Middle-income Countries. *The Indian Economic Journal*, *69*(3), 534-552.

Dassisti, M., Panetto, H., Lezoche, M., Merla, P., Semeraro, C., Giovannini, A., & Chimienti, M. (2017). Industry 4.0 paradigm: The viewpoint of the small and medium enterprises. *Proceeding of the 7th International Conference on Information Society and Technology, Kopaonik, 1, 50-54.*

Daylami, N., Ryan, T., Olfman, L., & Shayo, C. (2005). System Sciences. In HICSS ‘05, *Proceedings of the 38th Annual Hawaii International Conference*, *Island of Hawaii*, 3-6.

de Moura, R. L., Ceotto, L. D. L. F., & Gonzalez, A. (2017). Industrial IoT and Advanced Analytics Framework: an approach for the Mining Industry. *Proceeding of the International Conference on Computational Science and Computational Intelligence, USA,* 1308-1314.

Deandres, N. (2014). *Leveraging applicable business models for iot enabled service solutions in the downstream automotive supply chain* (Master's thesis). Retrieved from DiVA. (diva2:839243).

Deeter-Schmelz, D. R., Goebel, D. J., & Kennedy, K. N. (2008). What are the characteristics of an effective sales manager? An exploratory study comparing salesperson and sales manager perspectives. *Journal of Personal Selling & Sales Management*, *28*(1), 7-20.

De Giovanni, P., & Cariola, A. (2021). Process innovation through industry 4.0 technologies, lean practices and green supply chains. *Research in Transportation Economics, 90(1),* 800-869.

de Guinea, A. O., Kelley, H., & Hunter, M. G. (2005). Information systems effectiveness in small businesses: extending a Singaporean model in Canada. *Journal of Global Information Management*, *13*(3), 55-79.

de Panizza, A., Lindmark, S., & Rotter, P. (2010). *RFID: Prospects for Europe: Item-level tagging and public transportation.* Luxembourg: Publications Office of the European Union.

Depietro, R., Wiarda, E., & Fleischer, M. (1990). The context for change: Organization, technology and environment. *The Processes of Technological Innovation*, *3(4*), 151-175.

Dedrick, J., & West, J. (2004, January). An exploratory study into open source platform adoption. *Proceeding of the 37th Annual Hawaii International Conference on System Sciences, 2004. Hawaii,* 10-20.

Deloitte. (2016). *2016 Global Manufacturing Competitiveness Index*. Retrieved from https://www2.deloitte.com/uk/en/pages/manufacturing/articles/global-manufacturing-competitiveness-index.html.

Department for Business, Energy and Industrial Strategy. (BEIS) (2017). *Industrial Strategy: building a Britain fit for the future*. Retrieved from https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future.

Department for Business, Energy & Industrial Strategy (BEIS). (2018). *Business population estmates for the UK and regions.* Retrieve from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746599/OFFICIAL_SENSITIVE_-_BPE_2018_-_statistical_release_FINAL_FINAL.pdf.

Department for Environment Food & Rural Affair (Defra). (2018a). *Farming Statistics Provisional crop areas, yields and livestock populations At June 2018 - United Kingdom*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/747210/structure-jun2018prov-UK-11oct18.pdf.

Department for Environment, Food & Rural Affairs (Defra). (2018b). *Food Statistics in your pocket 2017 - Global and UK supply*. Retrieved from https://www.gov.uk/government/publications/food-statistics-pocketbook-2017/food-statistics-in-your-pocket-2017-global-and-uk-supply#trends-in-uk-food-production-and-final-output-at-market-prices.

Dereli, D. D. (2015). Innovation Management in Global Competition and Competitive Advantage. *Procedia - Social and Behavioral Sciences, 195,* 1365–1370.

Devin, B. (2019). Five emerging tech trends to watch in 2019. Retrieved from https://www.finextra.com/newsarticle/33231/five-emerging-tech-trends-to-watch-in-2019.

Dlodlo, N., Foko, T., Mvelase, P., & Mathaba, S. (2012). The State of Affairs in Internet of Things Research. *Electronic Journal of Information Systems Evaluation*, *15*(3), 244-259.

Divers, B. D. (2016). IIoT and cloud for SMEs: Four key considerations. *Plant engineering*. Retreived from https://www.plantengineering.com/iiot-industrie-4-0/.

Dong, X., Chang, Y., Wang, Y., & Yan, J. (2017). v. *Information Technology & People*, *30*(1), 117-138.

Dremel, C., Wulf, J., Herterich, M. M., Waizmann, J. C., & Brenner, W. (2017). How AUDI AG Established Big Data Analytics in Its Digital Transformation. *MIS Quarterly Executive*, *16*(2), 81-100.

Dragt, B. J., Craig, I. K., & Camisani-Calzolari, F. R. (2004). Modeling of an autonomous underground mine vehicle. *IFAC Proceedings Volumes*, *37*(15), 457-462.

Duff, E. S., Roberts, J. M., & Corke, P. I. (2003, October). Automation of an underground mining vehicle using reactive navigation and opportunistic localization. In *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003)(Cat. No. 03CH37453)* (Vol. 4, pp. 3775-3780). IEEE.

Durst, S., & Runar Edvardsson, I. (2012). Knowledge management in SMEs: a literature review. *Journal of Knowledge Management*, *16*(6), 879-903.

Dutton, W. (2014). Putting things to work: social and policy challenges for the Internet of things. *Info*, *16*(3), 1-21.

Dutton, W. H., Law, G., Groselj, D., Hangler, F., Vidan, G., Cheng, L., & Wang, B. (2014). Mobile Communication Today and Tomorrow. *A Quello Policy Research Paper, Quello Center, Michigan State University.*

Dwyer, B. (2015). How credit card processing works: understanding payment processing, 9–24. Retrieved from https://www.cardfellow.com/blog/how-credit-card-processing-works/.

Edquist, H., & Henrekson, M. (2017). Do R&D and ICT affect total factor productivity growth differently? *Telecommunications Policy, 41*(2), 106–119.

Easterby-Smith, M., Lyles, M. A., & Tsang, E. W. (2008). Inter-organizational knowledge transfer: Current themes and future prospects. *Journal of Management Studies*, *45*(4), 677-690.

EEF. (2018). *Manufacturing outlook*. Retrieved from http://www.nass.org.uk/Publications/Publication4431/EEF-Manufacturing-Outlook-Q2-2018.pdf.

El Kalak, I., & Hudson, R. (2016). The effect of size on the failure probabilities of SMEs: An empirical study on the US market using discrete hazard model. *International Review of Financial Analysis, 43(6),* 135-145.

Eisenhardt, K. M. (1989). Agency theory: An assessment and review. *Academy of Management Review*, *14*(1), 57-74.

Elenko, E., Underwood, L., & Zohar, D. (2015). Defining digital medicine. *Nature Biotechnology*, *33*(5), 456.

Ericsson. (2015). *Every. Thing. Connected. A study of the adoption of 'Internet of Things' among Danish companies*. Retreived from https://digital.di.dk/SiteCollectionDocuments/Analyser/IoT_Report_onlineversion.pdf.

Ergen, E., Akinci, B., & Sacks, R. (2007). Tracking and locating components in a precast storage yard utilizing radio frequency identification technology and GPS. *Automation in Construction*, *16*(3), 354-367.

Escursell, S., Llorach-Massana, P., & Roncero, M. B. (2021). Sustainability in e-commerce packaging: A review. *Journal of Cleaner Production*, *280(1)*, 124-314.

EUbusiness. (2018). *United Kingdom: country overview*. Retrieved from https://www.eubusiness.com/europe/uk.

European Commission. (2016). *The new user guide to the SME definition*. Retrieved from https://ec.europa.eu/docsroom/documents/15582/attachments/1/translations.

European Commission. (2017). *Industry 4.0 in Aeronautics: IoT applications*. Retrieved from https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Aeronautics%20-%20IoT%20Applications%20v1.pdf.

European Union (EU). (2017). *United Kingdom overview*. Retrieved from https://europa.eu/european-union/about-eu/countries/member-countries/unitedkingdom_en.

Evans, C., & Lewis, J. (2018). *Analysing semi-structured interviews using thematic analysis: Exploring voluntary civic participation among adults* (pp. 1-6). London: SAGE.

Evol, S., & Communication, V. (1999). Evolution: Diffusion of Innovations. *International Encyclopedia of the Social & Behavioral Sciences*.

Fagerberg, J., & Srholec, M. (2017). Global dynamics, capabilities and the crisis. In *Foundations of Economic Change* (pp. 83-106). Cham: Springer.

Fan, T., Tao, F., Deng, S., & Li, S. (2015). Impact of RFID technology on supply chain decisions with inventory inaccuracies. *International Journal of Production Economics*, *159(12)*, 117-125.

Fang, S., Xu, L., Zhu, Y., Liu, Y., Liu, Z., Pei. & Zhang, H. (2015). An integrated information system for snowmelt flood early-warning based on internet of things. *Information Systems Frontiers*, *17*(2), 321-335.

Fernández-Caramés, T. M., & Fraga-Lamas, P. (2018). Towards the Internet of smart clothing: A review on IoT wearables and garments for creating intelligent connected e-textiles. *Electronics*, *7*(12), 405-420.

Ferreiro, J., & Serrano, F. (2021). The COVID Health Crisis and the Fiscal and Monetary Policies in the Euro Area. *International Journal of Political Economy*, *50*(3), 212-225.

Ferreira, P. S., Shamsuzzoha, A. H. M., Toscano, C., & Cunha, P. (2012). Framework for performance measurement and management in a collaborative business environment. *International Journal of Productivity and Performance Management*, *61*(6), 672–690.

Ferretti, M., & Schiavone, F. (2016). Internet of Things and business processes redesign in seaports: The case of Hamburg. *Business Process Management Journal*, *22*(2), 271-284.

Fichman, R. G. (2004). Going beyond the dominant paradigm for information technology innovation research: Emerging concepts and methods. *Journal of The Association for Information Systems*, *5*(8), 314-355.

Fichtinger, J., Ries, J. M., Grosse, E. H., & Baker, P. (2015). Assessing the environmental impact of integrated inventory and warehouse management. *International Journal of Production Economics*, *170(14)*, 717-729.

Fink, K., & Ploder, C. (2009). Balanced system for knowledge process management in SMEs. *Journal of Enterprise Information Management*, *22*(1/2), 36-50.

Finnegan, C. (2015). *Manufacturing in the UK: An overview*. Retrieved from https://www.designcouncil.org.uk/news-opinion/manufacturing-uk-overview.

Fitzgerald, B., & Howcroft, D. (1998). Towards dissolution of the IS research debate: from polarization to polarity. *Journal of Information Technology*, *13*(4), 313-326.

Flavián, C., Guinalíu, M., & Gurrea, R. (2006). The role played by perceived usability, satisfaction and consumer trust on website loyalty. *Information & Management*, *43*(1), 1-14.

Fleisch, E., Weinberger, M., & Wortmann, F. (2015). Business models and the internet of things. In *Interoperability and Open-Source Solutions for the Internet of Things* (pp. 6-10). Cham: Springer.

Floyd, D., & McManus, J. (2005). The role of SMEs in improving the competitive position of the European Union. *European Business Review*, *17*(2), 144-150.

Flyvbjerg, B. (2001). *Making social science matter: Why social inquiry fails and how it can succeed again*. Cambridge: Cambridge University Press.

Focacci, C. N., & Kirov, V. (2021). Regional entrepreneurial ecosystems: Technological transformation, digitalisation and the longer term—The automotive and ICT sectors in the UK and Bulgaria. *Local Economy*, *36*(1), 56-74.

Focus Economic. (2018). *The World's Top 10 Largest Economies*. Retrieved from https://www.focus-economics.com/blog/the-largest-economies-in-the-world.

Food and Drink Federation (FDF). (2015). *Economic contribution and growth opportunitie*s. Retrieved from https://www.fdf.org.uk/publicgeneral/FDF-GT-Exec-Summary.pdf.

Food and Drink Federation (FDF). (2019). *Representing the UK's biggest manufacturing sector*. Retrieved from https://www.fdf.org.uk/statsataglance.aspx.

Foong, S. Y. (1999) Effect of end user personal and systems attributes on computer based information systems success in Malaysian SMEs. *Journal of Small Business Management, 37*(3), 81–87.

Frambach, R. T., Barkema, H. G., Nooteboom, B., &Wedel, M. (1998). Adoption of a service innovation in the business market: an empir- ical test of supply-side variables. *Journal of Business Research, 41*(2), 161–174.

Frambach, R. and Schillewaert, N. (2002). Organizational innovation adoption: a multi-level framework of determinants and opportunities for future research. *Journal of Business Research, 55*(2), 163-176.

Franceschini, L., & Midali, A. (2020). Industrial IoT: a cost-benefit analysis of predictive maintenance service. *Review of General Psychology*, *17*(3), 243-254.

Fraser, D. (1999). QSR NUD*IST Vivo: Reference guide. Melbourne: Qualitative Solutions and Research.

Frazier, G. L. (1983). On the measurement of interfirm power in channels of distribution. *Journal of Marketing Research*, *20*(2), 158-166.

Frazzon, E. M., Hartmann, J., Makuschewitz, T., & Scholz-Reiter, B. (2013). Towards socio-cyber-physical systems in production networks. *Procedia Cirp*, *7*, 49-54.

Frow, P., & Payne, A. (2011). A stakeholder perspective of the value proposition concept. *European Journal of Marketing*, *45*(1/2), 223-240.

Fujitsu (2010). Cloud computing Tried and tested. *Retrieved from http://www.fujitsu.com/downloads/EU/uk/pdf/research/cloud-tried-tested.pdf*

Fuller, A., Fan, Z., Day, C., & Barlow, C. (2020). Digital twin: Enabling technologies, challenges and open research. *IEEE Access*, *8*, 108952-108971.

Gale, R. C., Wu, J., Erhardt, T., Bounthavong, M., Reardon, C. M., Damschroder, L. J., & Midboe, A. M. (2019). Comparison of rapid vs in-depth qualitative analytic methods from a process evaluation of academic detailing in the Veterans Health Administration. *Implementation Science, 14*(1), 1-12.

Gangwar, H., Date, H., & Ramaswamy, R. (2015). Understanding determinants of cloud computing adoption using an integrated TAM-TOE model. *Journal of Enterprise Information Management, 28*(1), 107–130.

Ganschar, O., Gerlach, S., Hämmerle, M., Krause, T., & Schlund, S. (2013). *Produktionsarbeit der Zukunft-Industrie 4.0* (Vol. 150). D. Spath (Ed.). Stuttgart: Fraunhofer Verlag.

Gao, L., & Bai, X. (2014). A unified perspective on the factors influencing consumer acceptance of internet of things technology. *Asia Pacific Journal of Marketing and Logistics, 26*(2), 211-231

Gardetti, M. A., & Torres, A. L. (Eds.). (2017). *Sustainability in fashion and textiles: values, design, production and consumption (1st ed.)*. London: Routledge.

Gartner, I. (2015). *Gartner's 2015 hype cycle for emerging technologies identifies the computing innovations that organizations should monitor*. Retrieved from http://www.gartner. com/newsroom/id/3114217.

Garcia, Z. (2019). *Thailand's Investment Outlook for 2019.* Retrieved from https://www.aseanbriefing.com/news/2019/02/07/thailands-investment-outlook-for-2019.html.

Gasiorek, M., Serwicka, I., & Smith, A. (2018). Which manufacturing sectors are most vulnerable to Brexit. *The World Economy, 42*(1), 21-56.

Gasson, S. (2004). Rigor in grounded theory research: An interpretive perspective on generating theory from qualitative field studies. In *The Handbook of Information Systems Research* (pp. 79-102). USA: IGI Global.

Gautam, A., & Pan, X. (2016). The changing model of big pharma: impact of key trends. *Drug Discovery Today*, *21*(3), 379-384.

Gefen, D., Karahanna, E., & Straub, D. W. (2003). Trust and TAM in online shopping: an integrated model. *MIS Quarterly*, *27*(1), 51-90.

Geletkanycz, M. A., Boyd, B. K., & Finkelstein, S. (2001). The strategic value of CEO external directorate networks: Implications for CEO compensation. *Strategic Management Journal*, *22*(9), 889-898.

Ghauri, P., N. and Gronhaug, K., (2010). Research Methods in Business Studies: A Practical Guide (4^{th} ed.). Halrow: FT-Pearson.

Ghobakhloo, M., Arias-Aranda, D., & Benitez-Amado, J. (2011). Adoption of e-commerce applications in SMEs. *Industrial Management & Data Systems*, *111*(8), 1238-1269.

Ghobadian, A., & Gallear, D. (1997). TQM and organization size. *International Journal of Operations & Production Management*, *17*(2), 121-163.

Ghobakhloo, M., & Hong Tang, S. (2013). The role of owner/manager in adoption of electronic commerce in small businesses: The case of developing countries. *Journal of Small Business and Enterprise Development*, *20*(4), 754-787.

Gilchrist, A. (2016). *Industry 4.0: The Industrial Internet of Things*. Thailand: Apress.

Glaser, B. G. (1965). The constant comparative method of qualitative analysis. *Social Problems*, *12*(4), 436-445.

Glowniak, J. (1998). History, structure, and function of the Internet. *Seminars in Nuclear Medicine*, *28*(2), 135–144.

Gluhak, A., Krco, S., Nati, M., Pfisterer, D., Mitton, N., & Razafindralambo, T. (2011). A survey on facilities for experimental Internet of things research. *IEEE Communications Magazine, 49(*11), 58-67.

GMP. (n.d.). Retrieved from https://www.fda.moph.go.th/sites/food/SitePages/GMP.aspx.

Goldsmith, R. E., Freiden, J. B., & Eastman, J. K. (1995). The generality/specificity issue in consumer innovativeness research. *Technovation*, *15*(10), 601-612.

Goode, S., & Stevens, K. (2000). An analysis of the business characteristics of adopters and non-adopters of World Wide Web technology. *Information Technology and Management*, *1*(1), 129-154.

Gong, B. (2012) R.A. Greenwood, Organizational memory, downsizing, and information technology: technology: a theoretical inquiry. *International Journal Management. 29*(3), 99–109.

Gonzales, E., Hommes, M., & Mirmulstein, M. L. (2014). *MSME country indicators 2014. Towards a better understanding of micro, small, and medium enterprises*. Retrieved from https://www.smefinanceforum.org/sites/default/files/analysis%20note.pdf.

Görçün, Ö. F. (2018). The Rise of Smart Factories in the Fourth Industrial Revolution and Its Impacts on the Textile Industry. *International Journal of Materials, Mechanics and Manufacturing*, *6*(2), 136-141.

Gounaris, S., & Koritos, C. (2008). Investigating the drivers of internet banking adoption decision: a comparison of three alternative frameworks. *International Journal of Bank Marketing*, *26(*5), 282–304

Gowtham, D., Haribalaji, S., Kavinprabu, S. M., & Karuppuswamy, P. (2017). Review on smart manufacturing based on IoT : an Industrial application, *International Research Journal of Engineering and Technology*, *4*(11), 920–923.

Graham, M., & Haarstad, H. 4 Transparency and Development: Ethical Consumption through Web 2.0 and the Internet of Things. *Information Technologies & International Development, 7*(1), 1-8.

Grauer, M. (2001). International Encyclopedia of the Social & Behavioral Sciences. *International Encyclopedia of the Social & Behavioral Sciences*, 7473–7476.

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations. *The Milbank Quarterly*, *82*(4), 581-629.

Grigorescu, S., Vatau, S., & Dobra, A. (2010). Dedicated robot-robot cooperation, Chapter 55. In *DAAAM International Scientific Book 2010* (pp. 633-644). Austria: DAAAM International.

Grossman, M. (2004). The role of trust and collaboration in the internet-enabled supply chain. *Journal of American Academy of Business*, *5*(1/2), 391–396.

Grover, V., & Goslar, M. D. (1993). The initiation, adoption, and implementation of telecommunications technologies in US organizations. *Journal of Management Information Systems*, *10*(1), 141-164.

Guizzo, E. (2008). Three engineers, hundreds of robots, one warehouse. *IEEE Spectrum*, *45*(7), 26-34.

GSMA. (2018). *How Mobile IoT is Changing the Industrial Landscape*. Retrieve from https://www.gsma.com/iot/industrial-iot-feasibility-study-mobile-iot/.

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645-1660.

Guelich, U. (2018). *GEM Thailand Report 2017/18*. Retrieved from https://www.gemconsortium.org/report/50189.

Guion, L. (2002). *Triangulation: Establishing the validity of qualitative studies*. Retrieved from http://edis. ifas. edu.

Gulati, R. (1999). Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal*, *20*(5), 397-420.

Gupta, P., Seetharaman, A., & Raj, J. R. (2013). The usage and adoption of cloud computing by small and medium businesses. *International Journal of Information Management*, *33*(5), 861-874.

Ha, S., & Stoel, L. (2009). Consumer e-shopping acceptance: Antecedents in a technology acceptance model. *Journal of Business Research*, *62*(5), 565-571.

Hall, C. (2007). When the dragon awakes: Internationalisation of SMEs in China and implications for Europe. *CESifo Forum, 8*(2), 29-34.

Haddud, A., DeSouza, A., Khare, A., & Lee, H. (2017). Examining potential benefits and challenges associated with the Internet of Things integration in supply chains. *Journal of Manufacturing Technology Management, 28*(8), 1055-1085.

Hallberg, K., & BOND, J. (2000). *Revolutions in Technology for Development, World Ban*k. Retrieved from http://www.worldbank.org/html/fpd/technet/revol.html.

Han, B., Wu, Y., & Windsor, J. (2014). User' S Adoption of Free Third-Party Security Apps. *Journal of Computer Information Systems, 54*(3), 77–86.

Han, C., & Ye, H. (2018). A Novel IoT-Cloud-BIM Based Intelligent Information Management System in Building Industrialization. In *ICCREM 2018: Innovative Technology and Intelligent Construction* (pp. 72-77). Reston, VA: American Society of Civil Engineers.

Hannabuss, S. (1996). Research interviews. *New library World, 97*(5), 22-30.

Hansen, E. B., & Bøgh, S. (2021). Artificial intelligence and internet of things in small and medium-sized enterprises: A survey. *Journal of Manufacturing Systems, 58(5),* 362-372.

Hansen, D. G., Malik, A. A., & Bilberg, A. (2017). Generic Challenges and Automation Solutions in Manufacturing SMEs. In *28th International Symposium of the Danube Adrian Association for Automation & Manufacturing* (pp. 1161-1169). Vienna: DAAAM International.

Hapsari, R. A., Hartono, B., & Listiyani, Y. (2021). Dispute Settlement Analysis and Refused Claims in Payment Gateway Transactions on Paypal Indonesia. *Lambung Mangkurat Law Journal*, *6*(2), 199-212.

Harvie, C., & Lee, B. C. (Eds.). (2002). *The role of SMEs in national economies in East Asia* (Vol. 2). Cheltenham: Edward Elgar.

Hart, M., & Porter, G. (2004). The impact of cognitive and other factors on the perceived usefulness of OLAP. *Journal of Computer Information Systems, 45*(1), 47-56.

Hart, P., & Saunders, C. (1997). Power and trust: critical factors in the adoption and use of electronic data interchange. *Organizational Science, 8*(1), 23–42.

Hartmann, M. H., Halecker, B., Soldatos, J., Gusmeroli, S., Malo, P., Orio, G., Vasilakos, A. V. (2016). Management of Innovation in the Industrial Internet of Things. *IEEE Transactions on Industrial Informatics, 10*(1), 1-17.

Hartmann, B., King, W. P., & Narayanan, S. (2015). *Digital manufacturing: The revolution will be virtualized*. Retrieved from https://www.mckinsey.com/business-functions/operations/our-insights/digital-manufacturing-the-revolution-will-be-virtualized#:~:text=Few%20manufacturers%20are%20responding%20to,industries%20require%20a%20digital%20transformation.

Hashem, G., & Tann, J. (2007). The adoption of ISO 9000 standards within the Egyptian context: A diffusion of innovation approach, *Total Quality Management & Business Excellence,18(*6), 631–652.

Hashem, I. A. T., Yaqoob, I., Anuar, N. B., Mokhtar, S., Gani, A., & Khan, S. U. (2015). The rise of “big data” on cloud computing: Review and open research issues. *Information Systems, 47(1)*, 98-115.

Hashmi, M.S. and Cuddy, J. (1990) Strategic initia- tives for introducing CIM technologies in Irish SMEs. In Computer Integrated Manufacturing. Proceedings of the Sixth CIM-Europe Annual Conference, Faria, L. and Van Puymbroeck, W. (eds.). Lisbon: Springer.

Hayes, K. J., Eljiz, K., Dadich, A., Fitzgerald, J., & Sloan, T. (2015). Trialability, observability and risk reduction accelerating individual innovation adoption decisions. *Journal of Health Organization and Management, 29(*2), 271-294.

Heiser, J., & Nicolett, M. (2008). Assessing the security risks of cloud computing. *Gartner Report*, *27(1)*, 29-52.

Heller, B., Kallevig, C., Mashak, A. (2014). *Snowball Sampling Technique.* Retrieved from: https://prezi.com/1sf769zwblxb/snowball-sampling-technique/.

Hepburn, N., & Wolfe, D. A. (2014). *Technology and Innovation Centres: Lessons from Germany, the UK and the USA.* Retrieved from https://munkschool.utoronto.ca/ipl/files/2015/01/Technology-and-Innovation-Centres-Haltech-Report-2014_1.1.pdf.

Hessman, T. (2014). *Can Wearable Tech Work in the Factory?.* Retrieved from http:// www.industryweek.com/ technol- ogy/ can-wearable-tech-work- factory.

Hernes, G. (2002). Emerging trends in ICT and challenges to educational planning. *Technologies for Education: Potential, Parameters and Prospects*, 20-26.

Herterich, M. M., Uebernickel, F., & Brenner, W. (2015). The impact of cyber-physical systems on industrial services in manufacturing. *Procedia Cirp*, *30(6)*, 323-328.

Hilbert, M., & López, P. (2011). The world's technological capacity to store, communicate, and compute information. S*cience*, *332*(6025), 60-65.

Hirschheim, R. (1985). Information systems epistemology: An historical perspective. *Research Methods in Information Systems*, 13-35.

Hirschman, E. C. (1980). Innovativeness, novelty seeking, and consumer creativity. *Journal of Consumer Research*, *7*(3), 283-295.

Hoepfl, M. C. (1997). *Choosing qualitative research: A primer for technology education researchers.* Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v9n1/hoepfl.html.

Holdowsky, J., Mahto, M., Raynor, M. E., & Cotteleer, M. (2015). *Inside the internet of things (IoT).* Retrieved from https://www2.deloitte.com/us/en/insights/focus/internet-of-things.html.

Honjo, Y., & Harada, N. (2006). SME policy, financial structure and firm growth: evidence from Japan. *Small Business Economics*, *27*(4-5), 289-300.

Horlacher, A., & Hess, T. (2016). What does a Chief Digital Officer do? Managerial tasks and roles of a new C-level position in the context of digital transformation. In *2016 49th Hawaii*

International Conference on System Sciences (HICSS) (pp. 5126-5135). Koloa: IEEE.

Hornsby, J. S., Kuratko, D. F., & Zahra, S. A. (2002). Middle managers' perception of the internal environment for corporate entrepreneurship: assessing a measurement scale. *Journal of Business Venturing*, *17*(3), 253-273.

Hosek, J., Masek, P., Andreev, S., Galinina, O., Ometov, A., Kropfl, F., & Koucheryavy, Y. (2017). A SyMPHOnY of integrated IoT businesses: closing the gap between availability and adoption. *IEEE Communications Magazine*, *55*(12), 156-164.

Hossain, M., & Kauranen, I. (2016). Open innovation in SMEs: a systematic literature review. *Journal of Strategy and Management*, *9*(1), 58-73.

Houyou, A. M., Huth, H. P., Kloukinas, C., Trsek, H., & Rotondi, D. (2012, September). Agile manufacturing: General challenges and an IoT@ Work perspective. In *Proceedings of 2012 IEEE 17th International Conference on Emerging Technologies & Factory Automation (ETFA 2012)* (pp. 1-7). Krakow: IEEE.

Hoyle, P. (2016). *Must try harder: An evaluation of the UK government's policy directions in STEM education*. Retrieved from https://research.acer.edu.au/research_conference/RC2016/8august/4.

Hsu, P. F., Kraemer, K. L., & Dunkle, D. (2006). Determinants of e-business use in US firms. *International Journal of Electronic Commerce*, *10*(4), 9-45.

Hsu, C. L., & Lin, J. C. C. (2016). An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives. *Computers in Human Behavior*, *62(2)*, 516-527.

Hsu, C. L., & Lu, H. P. (2004). Why do people play on-line games? An extended TAM with social influences and flow experience. *Information & Management*, *41*(7), 853-868.

Hsu, C.-L., Lu, H.-P., & Hsu, H.-H. (2007). Adoption of the mobile internet: an empirical study of multimedia message service (MMS). *Omega*, *35*(6), 715–726.

Hsu, C. W., & Yeh, C. C. (2017). Understanding the factors affecting the adoption of the Internet of Things. *Technology Analysis & Strategic Management*, *29*(9), 1089-1102.

Huang, E., & Chuang, M. H. (2007). Extending the theory of planned behaviour as a model to explain post-merger employee behaviour of IS use. *Computers in Human Behavior*, *23*(1), 240-257.

Hughes, D. J., Rowe, M., Batey, M., & Lee, A. (2012). A tale of two sites: Twitter vs. Facebook and the personality predictors of social media usage. *Computers in Human Behavior*, *28*(2), 561-569.

Huh, H. J., Kim, T. T., & Law, R. (2009). A comparison of competing theoret- ical models for understanding acceptance behavior of information systems in upscale hotels. *International Journal of Hospitality Management*, *28(*1), 121–134.

Hwang, Y. M., Kim, M. G., & Rho, J. J. (2016). Understanding Internet of Things (IoT) diffusion: Focusing on value configuration of RFID and sensors in business cases (2008–2012). *Information Development*, *32*(4), 969-985.

IBM Think Academy (2015). How it works: Internet of things. Retrieved from https://www.youtube.com/watch?v=QSIPNhOiMoE.

Ifinedo, P. (2011). An empirical analysis of factors influencing Internet/e-business technologies adoption by SMEs in Canada. *International Journal of Information Technology & Decision Making*, *10*(4), 731-766.

Ileš, D., Martinović, G., & Kozak, D. (2011). Review of potential use, benefits and risks of nanosensors and nanotechnologies in food. *Strojarstvo: časopis za teoriju i praksu u strojarstvu*, *53*(2), 127-136.

Illa, P. K., & Padhi, N. (2018). Practical Guide to Smart Factory Transition Using IoT, Big Data and Edge Analytics. *IEEE Access*, *6*, 55162–55170.

Imhanwa, S. (2017). *A study of cloud computing adoption and non-adoption within UK small and medium sized tourism firms: a multi-theory perspective* (Doctoral dissertation, University of Manchester).

In, J. (2017). Introduction of a pilot study. *Korean Journal of Anesthesiology*, *70*(6), 601.

InterNations. (2016). *The Economy of the UK: An Overview.* Retrieved from https://www.internations.org/great-britain-expats/guide/29457-economy-finance/the-economy-of-the-uk-an-overview-16160.

International Federation of Robotics (IFR). (2018). *Robot density rises globally*. Retrieved from https://ifr.org/ifr-press-releases/news/robot-density-rises-globally.

International Monetary Fund (IMF). (2017). *World Economic Outlook Update, April 2017:*

Gaining Momentum? Washington, DC: IMF.

International Monetary Fund (IMF). (2018a). *Thailand's Economic Outlook in Six Charts*. Retrieved from https://www.imf.org/en/News/Articles/2018/06/07/NA060818-Thailands-Economic-Outlook-in-Six-Charts.

International Monetary Fund (IMF). (2018b). *UK's Economic Outlook in Six Charts.* Retrieved from https://www.imf.org/en/News/Articles/2018/11/13/na111418-uk-economic-outlook-in-six-charts.

International Monetary Fund (IMF). (2018c). *UK Economy Must Get More Efficient.* Retrieved from https://www.imf.org/en/News/Articles/2018/02/08/na021418-uk-economy-must-get-more-efficient.

Islam, S. R., Kwak, D., Kabir, M. H., Hossain, M., & Kwak, K. S. (2015). The internet of things for health care: a comprehensive survey. *IEEE Access, 3*, 678-708.

Islam, A. N. (2016). E-learning system use and its outcomes: Moderating role of perceived compatibility. *Telematics and Informatics, 33*(1), 48-55.

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET, 5*(2), 14-23.

Issa, A., Lucke, D., & Bauernhansl, T. (2017). Mobilizing SMEs towards Industrie 4.0-enabled smart products. *Procedia CIRP, 63(6)*, 670-674.

ITU. (2017). IDI 2017 Rank. Retrieved from https://www.itu.int/net4/ITU-D/idi/2017/index.html.

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods, 18*(1), 3-20.

Jaafreh, A. (2018). The Effect Factors in the Adoption of Internet of Things (IoT) Technology in the SME in KSA: An Empirical Study. *International Review of Management and Business Research, 7*(1), 135–148.

Jackson, J. K. (2021). *Global economic effects of COVID-19*. Washingtong: Congressional Research Service.

Jackson, K., & Bazeley, P. (2019). *Qualitative data analysis with NVivo*. London: Sage.

Jamshidi, P., Ahmad, A., & Pahl, C. (2013). Cloud migration research: a systematic review. *IEEE Transactions on Cloud Computing*, *1*(2), 142-157.

Jedermann, R., & Lang, W. (2008). The benefits of embedded intelligence–tasks and applications for ubiquitous computing in logistics. *Proceedings of The Internet of Things* (pp. 105-122). Berlin: Springer.

Jeschke, S., Brecher, C., Meisen, T., Özdemir, D., & Eschert, T. (2017). Industrial internet of things and cyber manufacturing systems. *Proceedings of the Industrial Internet of Things* (pp. 3-19). Cham: Springer.

Jeyaraj, A., Rottman, J. W., & Lacity, M. C. (2006). A review of the predictors, linkages, and biases in IT innovation adoption research. *Journal of Information Technology*, *21*(1), 1-23.

Jiang, Z., Guo, Y., & Wang, Z. (2021). Digital twin to improve the virtual-real integration of industrial IoT. *Journal of Industrial Information Integration, 22(2),* 100-196.

Jing, Q., Vasilakos, A. V., Wan, J., Lu, J., & Qiu, D. (2014). Security of the Internet of things: Perspectives and challenges. *Wireless Networks, 20(*8), 2481-2501.

Jiping, S. (2009). Networking technology for safety supervision system in a coal mine. *Journal of China Coal Society*, *34*(11), 1546-1549.

Johnson, N., & Markey-Towler, B. (2020). *Economics of the fourth industrial revolution: Internet, artificial intelligence and blockchain*. Oxfordshire: Routledge.

Johnston, W. J., Leach, M. P., & Liu, A. H. (1999). Theory testing using case studies in business-to-business research. *Industrial Marketing Management*, *28*(3), 201-213.

Johnston, R. B., & Mak, H. C. (2000). An emerging vision of Internet-enabled supply-chain electronic commerce. *International Journal of Electronic Commerce, 4*(4), 43-59.

Jones, C., & Pimdee, P. (2017). Innovative ideas: Thailand 4.0 and the fourth industrial revolution. *Asian International Journal of Social Sciences*, *17*(1), 4-35.

Jones, P., Simmons, G., Packham, G., Beynon-Davies, P., & Pickernell, D. (2014). An exploration of the attitudes and strategic responses of sole-proprietor micro-enterprises in adopting information and communication technology. *International Small Business Journal*, 32(3), 285–306.

Jones, P., Wynn, M., Hillier, D., & Comfort, D. (2017). The sustainable development goals and information and communication technologies. *Indonesian Journal of Sustainability Accounting and Management*, *1*(1), 1-15.

Jordan, J., Lowe, J., & Taylor, P. (1998). Strategy and financial policy in UK small firms. *Journal of Business Finance & Accounting*, *25*(1-2), 1-27.

Jorgenson, D. W., & Vu, K. M. (2016). The ICT revolution, world economic growth, and policy issues. *Telecommunications Policy*, *40*(5), 383–397.

Ju, J., Kim, M. S., & Ahn, J. H. (2016). Prototyping Business Models for IoT Service. *Procedia Computer Science, 91*(1), 882-890.

Kaasinen, E. (2005). User acceptance of mobile services-value, ease of use, trust and ease of adoption. Retrieved from http://www.vtt.fi/inf/pdf/ publications/2005/P566.pdf.

Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*. Forschungsunion.

Kamble, S. S., Gunasekaran, A., Parekh, H., & Joshi, S. (2019). Modeling the internet of things adoption barriers in food retail supply chains. *Journal of Retailing and Consumer Services, 48(1),* 154-168

Kamal, M. (2006). IT innovation adoption in the government sector: identifying the critical success factors. *Journal of Enterprise Information Management, 19*(2), pp. 192-222.

Kamin, D. A. (2017). *Exploring Security, Privacy, and Reliability Strategies to Enable the Adoption of IoT* (Doctoral dissertation).

Kapoor, K. K., Dwivedi, Y. K., & Williams, M. D. (2014a). Innovation adoption attributes: A review and synthesis of research findings. *European Journal of Innovation Management, 17*(3), 327–348.

Kapoor, K. K., Dwivedi, Y. K., & Williams, M. D. (2014b). Rogers' Innovation Adoption Attributes: A Systematic Review and Synthesis of Existing Research. *Information Systems Management*, *31*(1), 74–91.

Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information technology adoption across time: A cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS*

*Quarterly, 23(*2), 183–213.

Kartsch, V., Guermandi, M., Benatti, S., Montagna, F., & Benini, L. (2019). An Energy-Efficient IoT node for HMI applications based on an ultra-low power Multicore Processor. In *2019 IEEE Sensors Applications Symposium (SAS)* (pp. 1-6). IEEE.

KCR. (n.d.). Retrieved from https://www.kcrthairice.com/17335172/%E0%B8%9B%E0%B8%A3%E0%B8%B0%E0%B8%A7%E0%B8%B1%E0%B8%95%E0%B8%B4%E0%B8%9A%E0%B8%A3%E0%B8%B4%E0%B8%A9%E0%B8%B1%E0%B8%97.

Keefer, A., & Baiget, T. (2001). How it all began: a brief history of the Internet. *Vine*, *31*(3), 90-95.

Keller, W. (2004). International technology discussion. *Journal of Economic Literature, 42*(3), 752-782.

Kerry, C., & Danson, M. (2016). Open innovation, Triple Helix and regional innovation systems: Exploring CATAPULT Centres in the UK. *Industry and Higher Education, 30*(1), 67-78.

Khan, O., Scotti, A., Leverano, A., Bonino, F., Ruggiero, G., & Dörsch, C. (2006). Rfid in automotive: a closed-loop approach. In *2006 IEEE International Technology Management Conference (ICE)* (pp. 1-8). IEEE.

Khaleel, H., Conzon, D., Kasinathan, P., Brizzi, P., Pastrone, C., Pramudianto, F., & Paralic, M.(2015). Heterogeneous applications, tools, and methodologies in the car manufacturing industrythrough an IoT approach. *IEEE Systems Journal*, *11*(3), 1412-1423.

Khurana, S., Haleem, A., Luthra, S., & Mannan, B. (2021). Evaluating critical factors to implement sustainable oriented innovation practices: An analysis of micro, small, and medium manufacturing enterprises. *Journal of Cleaner Production*, *285(1)*, 125-377.

Kim, E. (2015*). Amazon is now using a whole lot more of the robots from the company it bought for $775 million*. Retrieved from http:// www.businessinsider.com/ amazon- doubled-the-number-of-kiva- robots-2015-10.

Kim, S., & Kim, S. (2016). A multi-criteria approach toward discovering killer IoT application in Korea. *Technological Forecasting and Social Change*, *102(1)*, 143-155.

Kim, E., Nam, D. I., & Stimpert, J. L. (2004). The applicability of Porter's generic strategies in the digital age: assumptions, conjectures, and suggestions. *Journal of Management*, *30*(5), 569-

589.

King, A., & Cole, B. (2008). *United Kingdom Map - England, Scotland, Northern Ireland, Wales.* Retrieved from https://geology.com/world/united-kingdom-satellite-image.shtml.

Kim, K. J., & Shin, D. H. (2015). An acceptance model for smart watches: implications for the adoption of future wearable technology. *Internet Research*, *25*(4), 527-541.

Kiprop, V. (2019). *10 Countries With The Highest Industrial Outputs In The World*. Retrieved from https://www.worldatlas.com/articles/10-countries-with-the-highest-industrial-outputs-in-the-world.html.

Kiran, M. B., & Wynn, M. G. (2022). The Internet of Things in the Corporate Environment: Cross-Industry Perspectives and Implementation Issues. In *Handbook of Research on Digital Transformation, Industry Use Cases, and the Impact of Disruptive Technologies* (pp. 132-148). Pennsylvania: IGI Global.

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, *23*(1), 67-94.

Kleindienst, M. & Ramsauer, C. (2016). SMEs and Industry 4.0–Introducing a KPI based Procedure Model to identify Focus Areas in Manufacturing Industry. *Athens Journal of Business and Economics, 2*(2), 109-122.

Koanantakool, T. (2016). *Digital park for SMEs*. Retrieved from https://docplayer.net/27668364-Digital-park-for-smes.html.

Kohles, J. C., Bligh, M. C., & Carsten, M. K. (2013). The vision integration process: Applying Rogers' diffusion of innovations theory to leader–follower communications. *Leadership, 9*(4), 466-485.

Kopper, C. (2021). Business as Usual Under a Military Regime? Volkswagen Do Brazil and the Military Dictatorship in Brazil (1964–1980). In *Big Business and Dictatorships in Latin America* (pp. 319-344). Cham: Palgrave Macmillan.

Kortuem, G., Kawsar, F., Sundramoorthy, V., & Fitton, D. (2009). Smart objects as building blocks for the internet of things. *IEEE Internet Computing, 14*(1), 44-51.

Kotarba, M. (2017). Measuring digitalization–key metrics. *Foundations of Management*, *9*(1), 123-138.

Kothandaraman, P., & Wilson, D. T. (2001). The future of competition: value-creating networks. *Industrial Marketing Management*, *30*(4), 379-389.

Kowatsch, T., & Maass, W. (2012). Critical privacy factors of internet of things services: An empirical investigation with domain experts. *Proceedings of the Mediterranean Conference on Information Systems* (pp. 200-211). Berlin: Springer.

KPMG. (2018). *Global Manufacturing Outlook: Transforming for a digitally connected future*. Retrieved from https://assets.kpmg/content/dam/kpmg/xx/pdf/2018/06/global-manufacturing-outlook.pdf.

Kirton, M. J. (2004). *Adaption-innovation: In the context of diversity and change*. London: Routledge.

Krotov, V. (2017). The Internet of Things and new business opportunities. *Business Horizons*, *60*(6), 831-841.

Kshetri, N. (2014). Big data′ s impact on privacy, security and consumer welfare. *Telecommunications Policy*, *38*(11), 1134-1145.

Kuan, K.K.Y., and Chau, P.Y.K., (2001), A perception-based model for edi adoption in small businesses using a technology-organization-environment framework. *Information & Management*, *38*(8), 507-521.

Kulkarni, D. (2018). I*nternet of things in finnish metal industry* (Master's thesis). Retreived from https://dspace.cc.tut.fi/dpub/bitstream/handle/123456789/25810/Kulkarni.pdf?sequence=3&isAllowed=y.

Kumar, P., Udhas, P. (2011). *The Cloud Changing the Business Ecosystem*. Retrieved from http://www.kpmg.com/IN/en/IssuesAndInsights/ThoughtLeadership/The_Cloud_Changing_the_Business_Ecosystem.pdf.

Kummu, M., De Moel, H., Porkka, M., Siebert, S., Varis, O., & Ward, P. J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of the Total Environment*, *438(5)*, 477-489.

Kuo, Y. F., & Yen, S. N. (2009). Towards an understanding of the behavioral intention to use 3G mobile value-added services. *Computers in Human Behavior*, *25*(1), 103-110.

Küsters, D., Praß, N., & Gloy, Y. S. (2017). Textile Learning Factory 4.0–Preparing Germany's Textile Industry for the Digital Future. *Procedia Manufacturing*, *9(2)*, 214-221.

Kuswandi, B., & Moradi, M. (2019). Improvement of Food Packaging Based on Functional Nanomaterial. *Proceedings of the Nanotechnology: Applications in Energy, Drug and Food* (pp. 309-344). Cham: Springer.

Kuswandi, B., Wicaksono, Y., Abdullah, A., Heng, L. Y., & Ahmad, M. (2011). Smart packaging: sensors for monitoring of food quality and safety. *Sensing and Instrumentation for Food Quality and Safety*, *5*(3-4), 137-146.

Iacovou, C. L., Benbasat, I., & Dexter, A. S. (1995). Electronic data interchange and small organizations: adoption and impact of technology. *MIS Quarterly*, 19(4), 465-485.

Lakner, C., & Milanovic, B. (2016). *Response to Adam Corlett's 'Examining an Elephant: Globalisation and the Lower Middle Class of the Rich World.'*. New York: Graduate Center Paper New York.

Laskier, R. (2017). "Modernizing the mining industry with the internet of things". In *Internet of Things and Data Analytics Handbook* , Wiley, 2017, pp.521-543, Retrieved from 10.1002/9781119173601.ch32.

Lawson, S. (2016). *Enterprise IoT: A cost-cutter today, a money-maker tomorrow*. Retrieved from https://www.computerworld.com/article/3040290/enterprise-iot-a-cost-cutter-today-a-money-maker-tomorrow.html.

Lean, O. K., Zailani, S., Ramayah, T., & Fernando, Y. (2009). Factors influencing intention to use e-government services among citizens in Malaysia. *International Journal of Information Management*, *29*(6), 458–475.

Lederer, M., Knapp, J., & Schott, P. (2017). The digital future has many names—How business process management drives the digital transformation. In *2017 6th International Conference on Industrial Technology and Management (ICITM)* (pp. 22-26). Cambridge: IEEE.

Lee, J., Ardakani, H. D., Yang, S., & Bagheri, B. (2015). Industrial big data analytics and cyber-physical systems for future maintenance & service innovation. *Procedia Cirp*, *38(6)*, 3-7.

Lee, Y. H., Hsieh, Y. C., & Hsu, C. N. (2011). Adding innovation diffusion theory to the technology acceptance model: supporting employees' intentions to use e-learning systems. *Educational Technology & Society*, *14*(4), 124–137.

Lee, J., Kao, H. A., & Yang, S. (2014). Service innovation and smart analytics for industry 4.0 and big data environment. *Procedia Cirp*, *16(6)*, 3-8.

Lee, S., & Kim, K. J. (2007). Factors affecting the implementation success of Internet-based information systems. *Computers in Human Behavior*, *23(*4), 1853–1880.

Lee, J., Lapira, E., Bagheri, B., & Kao, H. A. (2013). Recent advances and trends in predictive manufacturing systems in big data environment. *Manufacturing Letters*, *1*(1), 38-41.

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons, 58*(4), 431-440.

Leech, N. L., & Onwuegbuzie, A. J. (2011). Beyond constant comparison qualitative data analysis: Using NVivo. *School Psychology Quarterly*, *26*(1), 70-71.

Leedy, P.D. and Ormrod, J.E. (2005). *Practical Research: Planning and Design* (8^{th} ed.). NJ: Pearson Merrill Prentice Hall.

Leiner, B. M., Cerf, V. G., Clark, D. D., Kahn, R. E., Kleinrock, L., Lynch, D. C., & Wolff, S. S. (1997). The past and future history of the Internet. *Communications of the ACM*, *40*(2), 102-108.

Leiting, A. K., De Cuyper, L., & Kauffmann, C. (2022). The Internet of Things and the case of Bosch: Changing business models while staying true to yourself. *Technovation, 118*(1), 1-9.

Lee, Y. K., Park, J. H., Chung, N., & Blakeney, A. (2012). A unified perspective on the factors influencing usage intention toward mobile financial services. *Journal of Business Research*, *65*(11), 1590-1599.

Leminen, S., Rajahonka, M., Westerlund, M., & Siuruainen, R. (2015). Ecosystem business models for the Internet of things. *Internet of Things Finland*, 10-13.

Lenhart, A., Purcell, K., Smith, A., & Zickuhr, K. (2010). *Social Media & Mobile Internet Use among Teens and Young Adults. Millennials.* USA: Pew Internet & American Life project.

Leo, M., Battisti, F., Carli, M., & Neri, A. (2014). A federated architecture approach for Internet of Things security. *Proceeding of the Euro Med Telco Conference (EMTC), Italy,* 1-5.

Leuth, K. (2015). How IoT infrastructure providers will win big from the IoT hype. *Retrieved from https://iot- analytics.com/iot-infrastructure-providers-iot-hype/.*

Levy, S., & Chard, D. J. (2001). Research on reading instruction for students with emotional and behavioural disorders. *International Journal of Disability, Development and Education, 48*(4), 429-444.

Levy, M. and Powell, P. (1998) SME flexibility and the role of information systems. *Journal of Small Business Economics*, 11(4), 183–196.

Li, Z., & Cheng, Y. (2014). From free to fee: Exploring the antecedents of consumer intention to switch to paid online content. *Journal of Electronic Commerce Research, 15*(4), 281-299.

Li, Y., Hou, M., Liu, H., & Liu, Y. (2012). Towards a theoretical framework of a strategic decision, supporting capability and information sharing under the context of the Internet of Things. *Information Technology Management, 13*(4), 205–216.

Li, B., & Li, Y. (2017). Internet of things drives supply chain innovation: A research framework. *International Journal of Organizational Innovation, 9*(3), 71-92.

Li, L. (2018). China's manufacturing locus in 2025: With a comparison of "Made-in-China 2025" and "Industry 4.0". *Technological Forecasting and Social Change*, *135(12),* 66-74.

Li, X., Troutt, M. D., Brandyberry, A., & Wang, T. (2011). Decision factors for the adoption and continued use of online direct sales channels among SMEs. *Journal of the Association for Information Systems*, *12*(1), 4-5.

Li, S., Tryfonas, T., & Li, H. (2016). The Internet of Things: a security point of view. *Internet Research*, *26*(2), 337-359.

Li, Y., Yang, F., & Guo, H. (2020). A gas well inspection automation system based on IoT perception technology. *Proceedings of the IOP Conference Series: Earth and Environmental Science* (Vol. 514, No. 2, p. 022076). Bristol: IOP Publishing.

Li, T. H., Yuan, Y. B., & Zhang, M. Y. (2012). BIM and RFID assisted life cycle management of prefabricated buildings. *Journal of Engineering Management*, *26*(3), 28-32.

Lightfoot, W., & Taylor, M. (2018). *An outlook for the UK economy – brighter than some would think.* Retrieved from https://policyexchange.org.uk/an-outlook-for-the-uk-economy-brighter-than-some-would-think/.

Lian, J. W., Yen, D. C., & Wang, Y. T. (2014). An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. *International Journal of Information Management, 34*(1), 28-36.

Liang, T. P., You, J. J., & Liu, C.C. (2010). A resource-based perspective on information technology and firm performance: a meta analysis. *Industrial Management & Data Systems, 110*(8), 1138–1158.

Liao, Z., & Cheung, M. T. (2002). Internet-based e-banking and consumer attitudes: an empirical study. *Information & Management*, *39*(4), 283-295.

Lightfoot, H. W., Baines, T., & Smart, P. (2011). Examining the information and communication technologies enabling servitized manufacture. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, *225*(10), 1964–1968.

Lippert, S. K., & Forman, H. (2005). Utilization of information technology: Examining cognitive and experiential factors of post-adoption behavior. *IEEE Transactions on Engineering Management*, *52*(3), 363-381.

Lin, H. F. (2011). An empirical investigation of mobile banking adoption: The effect of innovation attributes and knowledge-based trust. *International Journal of Information Management*, *31*(3), 252-260.

Lin, T. C. (2013). CEOs and Presidents. *UCDL Rev.*, *47*, 13-51.

Lin, A., and Chen, N. C. (2012). Cloud computing as an innovation: Perception, attitude, and adoption. *International Journal of Information Management, 3*2(6), 533–540.

Lin, D., Lee, C. K. M., & Lin, K. (2016). Research on effect factors evaluation of internet of things (IOT) adoption in Chinese agricultural supply chain. In *2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)* (pp. 612-615). Malaysia: IEEE.

Lin, J., Shen, Z., Zhang, A., & Chai, Y. (2018). Blockchain and IoT based food traceability for smart agriculture. In *Proceedings of the 3rd International Conference on Crowd Science and Engineering* (pp. 1-6). New York: Association for Computing Machinery.

Lin, X., Zhou, Y. W., Xie, W., Zhong, Y., & Cao, B. (2020). Pricing and Product-bundling Strategies for E-commerce Platforms with Competition. *European Journal of Operational Research, 283*(3), 1026-1039.

Lincoln, Y. S. (2002). *On the nature of qualitative evidence.* Presented at the annual meeting of the Association for the Study of Higher Education, Sacramento, CA.

Lincoln, Y. S., & Guba, E. G. (1990). Judging the quality of case study reports. *International Journal of Qualitative Studies in Education*, *3*(1), 53-59.

Liu, Z., Zhang, A., & Li, S. (2013). Vehicle anti-theft tracking system based on Internet of things. In *Proceedings of 2013 IEEE International Conference on Vehicular Electronics and Safety* (pp. 48-52). IEEE.

Longzhe, S. G. X. Z. J. (2005). Development of Safety Information Management System at Noncoal Mines. *Industrial Safety and Dust Control*, *5*, 52-52.

Lopez-Gracia, J., & Aybar-Arias, C. (2000). An empirical approach to the financial behaviour of small and medium sized companies. *Small Business Economics*, *14*(1), 55-63.

Love, P. E. D., & Irani, Z. (2004). An exploratory study of information technology evaluation and benefits management practices of SMEs in the construction industry. *Information & Management, 42*(1), 227–242.

Low, C., Chen, Y., & Wu, M. (2011). Understanding the determinants of cloud computing adoption. *Industrial Management & Data Systems, 111*(7), 1006-1023.

Lu, Y., Papagiannidis, S., & Alamanos, E. (2018). Internet of Things: A systematic review of the business literature from the user and organisational perspectives. *Technological Forecasting and Social Change, 136(12)*, 285-297.

Lu, H. P., & Yu-Jen Su, P. (2009). Factors affecting purchase intention on mobile shopping web sites. *Internet Research*, *19*(4), 442-458.

Lu, Y., Zhou, T., & Wang, B. (2009). Exploring Chinese users' acceptance of instant messaging using the theory of planned behavior, the technology acceptance model, and the flow theory. *Computers in Human Behavior, 25*(1), 29-39.

Lueth, K., Glienke, D. (2017). Guide to IoT innovation (SME focus). *Retrieved from https://iot-analytics.com/wp/wp-content/uploads/2017/09/Guide-to-IoT-Innovation-SME-Focus-September-2017-vf.pdf*.

Lund, D., MacGillivray, C., Turner, V. and Morales, M. (2014). Worldwide and Regional Internet of Things (IoT) 2014-2020 Forecast: A Virtuous Circle of Proven Value and A Demand. *International Data Corporation*. Retrieved from https://studylib.net/doc/13054228/worldwide-and-regional-internet-of-things--iot--2014%E2%80%932020.

Lyytinen, K., & Damsgaard, J. (2011). Inter-organizational information systems adoption–a configuration analysis approach. *European Journal of Information Systems*, *20*(5), 496-509.

M'Chirgui, Z., & Chanel, O. (2006). New product adoption and use: The case of the Moneo electronic purse. In *2006 IEEE International Conference on Management of Innovation and*

Technology (Vol. 2, pp. 637-641). Taiwan: IEEE.

MacGregor, R. C., & Vrazalic, L. (2005). A basic model of electronic commerce adoption barriers: A study of regional small businesses in Sweden and Australia. *Journal of Small Business and Enterprise Development*, *12*(4), 510-527.

MacGregor, R., & Vrazalic, L. (2007). Small business clusters and their role in prioritising barriers to e-commerce adoption: a study of two approaches to cluster development. *International Journal of Electronic Marketing and Retailing*, *1*(3), 236-259.

Macpherson, A., Jones, O., Zhang, M., and Wilson, A. (2003). Re-conceptualising learning spaces: developing capabilities in a high-tech small firm. *Journal of Workplace Learning, 15*(6), 259-270.

Magazzino, C., Porrini, D., Fusco, G., & Schneider, N. (2021). Investigating the link among ICT, electricity consumption, air pollution, and economic growth in EU countries. *Energy Sources, Part B: Economics, Planning, and Policy*, *16*(11-12), 976-998.

Mahdavian, A., Shojaei, A., Mccormick, S., Papandreou, T., Eluru, N., & Oloufa, A. A. (2021). Drivers and barriers to implementation of connected, automated, shared, and electric vehicles: an agenda for future research. *IEEE Access*, *9*, 22195-22213.

Maheswari, C., Priyanka, E. B., Thangavel, S., Vignesh, S. R., & Poongodi, C. (2020). Multiple regression analysis for the prediction of extraction efficiency in mining industry with industrial IoT. *Production Engineering*, *14*(4), 457-471.

Mahalik, N., & Kim, K. (2016). The role of information technology developments in food supply chain integration and monitoring. In *Innovation and Future Trends in Food Manufacturing and Supply Chain Technologies* (pp. 21-37). Sawston: Woodhead Publishing.

Mahmoodzadeh, Z., Wu, K. Y., Droguett, E. L., & Mosleh, A. (2020). Condition-Based Maintenance with Reinforcement Learning for Dry Gas Pipeline Subject to Internal Corrosion. *Sensors*, *20*(19), 2-26.

Mahmoud, H. H. H., Amer, A. A., & Ismail, T. (2021). 6G: A comprehensive survey on technologies, applications, challenges, and research problems. *Transactions on Emerging Telecommunications Technologies, 32*(4), 33-42.

Mahmoud, R., Yousuf, T., Aloul, F., & Zualkernan, I. (2015). Internet of things (IoT) security: Current status, challenges and prospective measures. *Proceeding of the 10th International Conference for Internet Technology and Secured Transactions*, 336-341.

Majidi, N., Kasavan, C., & Harindranath, G. (2021). In support of return and reintegration? A roadmap for a responsible use of technology. In *Research Handbook on International Migration and Digital Technology*. Cheltenham: Edward Elgar Publishing.

Majhi, D., Rao, M., Sahoo, S., Dash, S. P., & Mohapatra, D. P. (2020). Modified Grey Wolf Optimization (GWO) based Accident Deterrence in Internet of Things (IoT) enabled Mining Industry. In *2020 International Conference on Computer Science, Engineering and Applications (ICCSEA)* (pp. 1-4). Thailand: IEEE.

Make UK. (2017a). *Sector Bulletin : Automotive Manufacturing*. Retrieved from https://www.makeuk.org/Insights/Reports/2019/03/08/Industry-Sector-Bulletins.

Make UK. (2017b). *Sector Bulletin : Aerospace Manufacturing*. Retrieved from https://www.makeuk.org/Insights/Reports/2019/03/08/Industry-Sector-Bulletins.

Make UK. (2017c). *Sector Bulletin : Food & Drink Manufacturing*. Retrieved from https://www.makeuk.org/Insights/Reports/2019/03/08/Industry-Sector-Bulletins.

Make UK. (2017d). *Sector Bulletin : Pharmaceutical* . Retrieved from https://www.makeuk.org/Insights/Reports/2019/03/08/Industry-Sector-Bulletins.

Malterud, K. (2001). Qualitative research: standards, challenges, and guidelines. *The Lancet*, *358*(9280), 483-488.

Mamun, A. A. (2018). Diffusion of innovation among Malaysian manufacturing SMEs. *European Journal of Innovation Management*, *21*(1), 113-141.

Manglani, H., Hodge, G. L., & Oxenham, W. (2019). Application of the Internet of Things in the textile industry. *Textile Progress*, *51*(3), 225-297.

Manyika, J. (2012). *Manufacturing the future: The next era of global growth and innovation*. Retrieved from https://www.mckinsey.com/business-functions/operations/our-insights/the-future-of-manufacturing.

Manyika, J. (2015). *The Internet of Things: Mapping the value beyond the hype*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Technology%20Media%20and%20Telecommunications/High%20Tech/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/Unlocking_the_potential_of_the_Internet_of_Things_Executive_summary.pdf.

Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J., & Aharon, D. (2015).

Unlocking the Potential of the Internet of Things. Retrieved from https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/the-internet-of-things-the-value-of-digitizing-the-physical-world.

Manyika, J., & Roxburgh, C. (2011). *The great transformer: The impact of the Internet on economic growth and prosperity*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/High%20Tech/Our%20Insights/The%20great%20transformer/MGI_Impact_of_Internet_on_economic_growth.ashx.

Mao, E., & Palvia, P. (2006). Testing an extended model of IT acceptance in the Chinese cultural context. *SIGMIS Database, 37(*2/3), 20–32.

Mapfaira, H., Mutingi, M., Lefatshe, K., & Mashaba, T. (2014). Lean manufacturing adoption and implementation barriers in Botswana manufacturing companies. *Proceeding of the International Conference on Advances in Marine, Industrial and Mechanical Engineering,* Johannesburg, 21(2), 814-821.

Marcucci, G., Antomarioni, S., Ciarapica, F. E., & Bevilacqua, M. (2021). The impact of Operations and IT-related Industry 4.0 key technologies on organizational resilience. *Production Planning & Control*, 38(1), 1-15.

Marcus, J. (2016). *Airbus uses IoT to fuel 'Factory of the Future'*. Retrieved from https://www.intelligent-aerospace.com/articles/2016/04/airbus-uses-iot-to-fuel-factory-of-the-future.html.

Markman, J. (2016). *New Age Analytics: Transforming the Internet through Machine Learning, IoT, and Trust Modeling*. India: Apple Academic Press.

Martin, C. J. (1989). Information management in the smaller business: the role of the top manager. *International Journal of Information Management*, *9*(3), 187-197.

Marshak, M., Wickson, F., Herrero, A., & Wynberg, R. (2021). Losing practices, relationships and agency: ecological deskilling as a consequence of the uptake of modern seed varieties among South African Smallholders. *Agroecology and Sustainable Food Systems*, *45*(8), 1189-1212.

Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., & Ghalsasi, A. (2011). Cloud computing—The business perspective. *Decision Support Systems*, *51*(1), 176-189.

Mason, J. (2002). *Qualitative Research*. London: *Sage Publications*.

Masters, K. (2018). *Amazon News Roundup: Amazon Dominates UK Retail Scene And The 'Tax Case Of The Millennium'*. Retrieved from https://www.forbes.com/sites/kirimasters/2018/04/17/70-of-us-comparison-shop-on-our-phones-while-in-the-store-and-other-amazon-news/#7cdb7435258a.

Matei, A., & Savulescu, C. (2012). Empirical analysis of ICT, economic growth and competitiveness in the EU, The International Conference on ICT Management (ICTM 2012), Wroclow, Poland.

Matias, J. B., & Hernandez, A. A. (2021). Cloud computing adoption intention by MSMEs in the Philippines. *Global Business Review*, *22*(3), 612-633.

Mathieson, K. (1991). Predicting user intentions: comparing the technology acceptance model with the theory of planned behavior. *Information Systems Research*, *2*(3), 173-191.

Matlay, H. (1999). Employee relations in small firms: A micro-business perspective. *Employee Relations*, *21*(3), 285-295.

Matsas, M., Pintzos, G., Kapnia, A., & Mourtzis, D. (2017). An integrated collaborative platform for managing product-service across their life cycle. *Procedia CIRP*, *59(6)*, 220-226.

Matta, V., Koonce, D., & Jeyaraj, A. (2012). Initiation, experimentation, implementation of innovations: The case for radio frequency identification systems. *International Journal of Information Management*, *32*(2), 164-174.

Maylor, H. and Blackmon, K. (2005). *Researching Business and Management*. Houndmills: Palgrave-MacMillan.

McAfee, A., & Brynjolfsson, E. (2017). *Machine, platform, crowd: Harnessing our digital future*. New York: WW Norton & Company.

McCargo, D. (2017). Thailand in 2016. *University of California Press Journals*, *57*(1), 150-156.

Merchantsavvy. (2018). *UK SME Data, Stats & Charts*. Retrieved from https://www.merchantsavvy.co.uk/uk-sme-data-stats-charts/.

McGivern Y.(2006). *The Practice of Market and Social Research: an Introduction*. 2nd ed. Harlow: Financial Times Prentice Hall.

McKenzie, J. (2001). How teacher learn technology best. *From Now On: The Educational Technology Journal*, 10(6). Retrieved from http://www.fno.org/mar01/howlearn.html.

McMullen, H., Griffiths, C., Leber, W., & Greenhalgh, T. (2015). Explaining high and low performers in complex intervention trials: A new model based on diffusion of innovations theory. *Trials*, *16(*1), 1-16.

Meattini, R., Benatti, S., Scarcia, U., De Gregorio, D., Benini, L., & Melchiorri, C. (2018). An sEMG-based human–robot interface for robotic hands using machine learning and synergies. *IEEE Transactions on Components, Packaging and Manufacturing Technology*, *8*(7),1149-1158.

Medaglia, C. M., & Serbanati, A. (2010). An overview of privacy and security issues in the internet of things. In *The Internet of Things* (pp. 389-395). New York: Springer.

Melville, Kraemer, & Gurbaxani. (2017). Review: Information Technology and Organizational Performance: An Integrative Model of IT Business Value. *MIS Quarterly*, *28*(2), 283.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management*, *16*(4), 441-454.

Miao, Y., Zhou, M., & Ghoneim, A. (2020). Blockchain and AI-Based Natural Gas Industrial IoT System: Architecture and Design Issues. *IEEE Network*, *34*(5), 84-90.

Michaelas, N., Chittenden, F., & Poutziouris, P. (1999). Financial policy and capital structure choice in UK SMEs: Empirical evidence from company panel data. *Small Business Economics*, *12*(2), 113-130.

Mikalef, P., & Pateli, A. (2017). Information technology-enabled dynamic capabilities and their indirect effect on competitive performance: Findings from PLS-SEM and fsQCA. *Journal of Business Research*, *70(12)*, 1–16.

Miles, M.B. & Huberman, A.M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook* (2nd Edition), Sage, California.

Mingers, J. (2003). The paucity of multimethod research: a review of the information systems literature. *Information Systems Journal*, *13*(3), 233-249.

Mingers, J., & Brocklesby, J. (1997). Multimethodology: Towards a framework for mixing methodologies. *Omega*, *25*(5), 489-509.

Mirchandani, D. A., & Motwani, J. (2001). Understanding small business electronic commerce adoption: An empirical analysis. *Journal of Computer Information Systems*, *41*(3), 70-73.

Miroudot, S., & Cadestin, C. (2017). *Services in global value chains: From inputs to value-creating activities* (No. 197). Paris: OECD Publishing.

Moeuf, A., Lamouri, S., Pellerin, R., Eburdy, R., & Tamayo, S. (2017). Industry 4.0 and the SME: a technology-focused review of the empirical literature. In *7th International Conference on Industrial Engineering and Systems Management.* Germany: IESM.

Molaei, F., Rahimi, E., Siavoshi, H., Afrouz, S. G., & Tenorio, V. (2020). A comprehensive review on internet of things (IoT) and its implications in the mining industry. *American Journal of Engineering and Applied Sciences*, *13*(3), 499-515.

Monostori, L. (2014). Cyber-physical production systems: Roots, expectations and R&D challenges. *Procedia Cirp*, *17(6)*, 9-13.

Mooney, K. G. (2001). Challenges faced by the pharmaceutical industry: training graduates for employment in pharmaceutical R&D. *European Journal of Pharmaceutical Sciences*, *12*(4), 353-359.

Moore, G. C., & Benbasat, I. (1991). Development of an instru- ment to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2(*3), 192– 222.

Mora-Monge, C. A., Azadegan, A., & Teich, J. (2010). Effective benchmarking of innovation adoptions: A theoretical framework for e-procurement technologies. *An International Journal*, *17*(4), 5-31.

Moser, A., & Korstjens, I. (2018). Series: Practical guidance to qualitative research. Part 3: Sampling, data collection and analysis. *European Journal of General Practice*, *24*(1), 9-18.

Moskowitz, S. L. (2017). The Small and Medium-Sized Enterprise (SME). *Cybercrime and Business*, 45-68. Oxford: Butterworth-Heinemann.

Mourtzis, D., Vlachou, E., & Milas, N. (2016). Industrial Big Data as a result of IoT adoption in manufacturing. *Procedia Cirp, 55(6),* 290-295.

Mulligan, C., Karnouskos, S., Boyle, D., Höller, J., & Tsiatsis, V. (2018). Origins and IoT Landscape. *In Internet of Things* (pp. 9–30). Amsterdam: Elsevier.

Muparuri, L., & Gumbo, V. (2021). Leaning of Public Examination Assessment Processes: The Role Of ICT. *Africa Growth Agenda*, *18*(3), 14-17.

Munger, K. (2020). All the news that's fit to click: The economics of clickbait media. *Political Communication*, *37*(3), 376-397.

Murrey, J. (2011). *Cloud network architecture and ICT*. Retrieved from https://itknowledgeexchange.techtarget.com/modern-network-architecture/cloud-network-architecture-and-ict/.

Murray, A., Papa, A., Cuozzo, B., & Russo, G. (2016). Evaluating the innovation of the Internet of Things: Empirical evidence from the intellectual capital assessment. *Business Process Management Journal*, *22*(2), 341-356.

Müller, J. M., Buliga, O., & Voigt, K. I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, *132(12)*, 2-17.

Müller, J. M., Buliga, O., & Voigt, K. I. (2021). The role of absorptive capacity and innovation strategy in the design of industry 4.0 business Models-A comparison between SMEs and large enterprises. *European Management Journal*, *39*(3), 333-343.

Müller, J. M., Maier, L., Veile, J., & Voigt, K. I. (2017). Cooperation strategies among SMEs for implementing industry 4.0. In *proceedings of the Hamburg International Conference of Logistics (HICL)* (pp. 301-318). Berlin: Epubli.

Mustonen-Ollila, E., & Lyytinen, K. (2003). Why organizations adopt information system process innovations: A longitudinal study using diffusion of innovation theory. *Information Systems Journal*, *13*(3), 275–297.

Myers, M. D. (1997). Qualitative Research in Information Systems. *MIS Quarterly*, 21(2), 241-242.

Naderifar, M., Goli, H., & Ghaljaie, F. (2017). Snowball sampling: A purposeful method of sampling in qualitative research. *Strides in Development of Medical Education*, *14*(3), 1-4.

Nag, R., Hambrick, D. C., & Chen, M. J. (2007). What is strategic management, really? Inductive derivation of a consensus definition of the field. *Strategic Management Journal*, *28*(9),935-955.

National Manufacturing Competitiveness Levels (NMCL). (2016). *Sectors*. Retrieved from https://www.nmcl.co.uk/sectors/#Other.

Ndubisi, N., & Kahraman, C. (2005). Malaysian women entrepreneurs: understanding the ICT usage behaviors and drivers. *Journal of Enterprise Information Management*, *18*(6), 721-739.

Neisse, R., Fovino, I. N., Baldini, G., Stavroulaki, V., Vlacheas, P., & Giaffreda, R. (2014, September). A model-based security toolkit for the internet of things. In *2014 Ninth International Conference on Availability, Reliability and Security* (pp. 78-87). Seoul: IEEE.

Newfoodmagazine. (2018). *APRIL™ Robotics Weighing Station*. Retrieved from https://www.newfoodmagazine.com/wp-content/uploads/Online-OAL_Brochure_A4_screen-3.pdf.

Ng, V. (2014). Drivers and obstacles to IoT adoption in Asia Pacific. *Netw. World Asia*, *11*(3), 12-14.

Ng, I. C., & Wakenshaw, S. Y. (2017). The Internet-of-Things: Review and research directions. *International Journal of Research in Marketing*, *34*(1), 3-21.

Nguyen., T.H. (2009). Information technology adoption in SMEs: an integrated framework. *International Journal of Entrepreneurial Behaviour & Research*, *15*(2), 162-186.

Nguyen, T. N., Zeadally, S., & Vuduthala, A. (2021). Cyber-physical cloud manufacturing systems with digital-twins. Fort Wayne: IEEE.

Nickels, L. (2015). AM and Aerospace: an ideal combination. *Metal Powder Report*, *70*(6), 300-303.

Niebel, T. (2018). ICT and economic growth – Comparing developing, emerging and developed countries. *World Development*, *104(4)*, 197–211.

Niederman, F., Ferratt, T. W., & Trauth, E. M. (2016). On the Co-Evolution of Information Technology and Information Systems Personnel. *ACM SIGMIS Database*, *47*(1), 29–50.

Nikbin, D., & Abushakra, A. (2019). *Knowledge Management in Organizations* (Vol. 1027). Springer International Publishing. Retrieved from https://doi.org/10.1007/978-3-030-21451-7.

Nkwe, N. (2012). Role of SMEs in Botswana. *American International Journal of Contemporary Research*, *2*(8), 29–37.

Noe, R. A., Hollenbeck, J. R., Gerhart, B., & Wright, P. M. (2017). *Human Resource Management: Gaining a Competitive Advantage*. New York: McGraw-Hill Education.

Nordea. (2019). *The economic context of the United Kingdom*. Retrieved from https://www.nordeatrade.com/en/explore-new-market/united-kingdom/economical-context?&accepter_cookies=oui.

Notani, V., & Jain, P. (2021). Surviving International Competition: Analysis of Measures Employed by Local Companies. *International Journal of Management (IJM)*, *12*(6), 232-239.

Nowak, A. (2018). *What is the Future of the Global Economy?* Retrieved from http://www.wz.uw.edu.pl/portaleFiles/6133-wydawnictwo-/new_structrural_2018/Alojzy_Z._Nowak.pdf.

Nylander, S., Wallberg, A., & Hansson, P. (2017). Challenges for SMEs entering the IoT world: success is about so much more than technology. In *Proceedings of the Seventh International Conference on the Internet of Things* (p. 16). Kista: ACM.

Nysveen, H., & Pedersen, P. E. (2014). Consumer adoption of RFID-enabled services. Applying an extended UTAUT model. *Information Systems Frontiers*, *18*(2), 293–314.

Oates, B. J. (2005). *Researching Information Systems and Computing*. New York: Sage.

O'Callaghan, R., Kaufmann, P. J., & Konsynski, B. R. (1992). Adoption correlates and share effects of electronic data interchange systems in marketing channels. *Journal of Marketing*, *56*(2), 45-56.

Odumeru, J. A. (2012). Diffusion of online recruiting technology in Nigeria. *Online Journal of Social Sciences Research*, *1*(4), 104–114.

O'Donoghue, T. (2018). Planning your qualitative research thesis and project: An introduction to interpretivist research in education and the social sciences. London: Routledge.

OECD. (1998). *Use of Information and Communication Technologies at Work*. Retrieved from https://www150.statcan.gc.ca/n1/pub/75-001-x/00501/5724-eng.html#Ref_OECD_1998.

OECD. (2005). *OECD SME and Entrepreneurship Outlook 2005*. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=3123.

Office for National Statistics (ONS). (2019a). *EMP13: Employment by industry*. Retrieved from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employmentbyindustryemp13.

Office for National Statistics (ONS). (2019b). *UK trade: December 2018.*
Retrieved from

https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/bulletins/uktrade/decemb er2018.

Office for National Statistics (ONS). (2019c). *JOBS05: Workforce jobs by region and industry.* Retrieved from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeety pes/datasets/workforcejobsbyregionandindustryjobs05.

Office for National Statistics (ONS). (2019d). *Manufacturing sector performance, UK: 2008 to 2018*. Retrieved from https://www.ons.gov.uk/businessindustryandtrade/manufacturingandproductionindustry/articles/ manufacturingsectorperformanceuk/2008to2018.

Office for National Statistics (ONS). (2019e). *UK Business Register and Employment Survey Statistical bulletins*. Retrieved from https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeety pes/bulletins/businessregisterandemploymentsurveybresprovisionalresults/provisionalresults2017 revisedresults2016#public-and-private-sector-estimates.

Office for National Statistics (ONS). (2019f). *UK trade: January 2019*. Retrieved from https://www.ons.gov.uk/economy/nationalaccounts/balanceofpayments/bulletins/uktrade/january 2019.

Ogbonna, E. and Harris, L. C. (2005) The adoption and use of information technology: A longitudinal study of a mature family firm. *New Technology, Work and Employment, 20*(1), 2-18.

Ok, J. S., Kwon, S. D., Heo, C. E., & Suh, Y. K. (2021). A survey of industrial internet of things platforms for establishing centralized Data-Acquisition middleware: categorization, experiment, and challenges. *Scientific Programming*.

Okusa, S., & Anma, S. (1980). Slope failures and tailings dam damage in the 1978 Izu-Ohshima-Kinkai earthquake. *Engineering Geology, 16*(3-4), 195-224.

Oliveira, A., Filipe, V., & Amorim, E. V. (2021). Data Integration in Shop Floor for Industry 4.0. In *International Symposium on Distributed Computing and Artificial Intelligence* (pp. 190-193). Cham: Springer.

Oliveira, T., & Martins, M. F. (2008, July). A Comparison of Web Site Adoption in Small and Large Portuguese Firms. In *ICE-B* (pp. 370-377).

Oliveira, T., & Martins, M. F. (2011). Literature Review of Information Technology Adoption Models at Firm Level. *Electronic Journal Information Systems Evaluation*, *14*(1), 110–121.

Oliveira, T., Thomas, M., & Espadanal, M. (2014). Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information and Management*, *51*(5), 497–510.

Omar, W. M. S. W., Doh, J. H., Panuwatwanich, K., & Miller, D. (2014). Assessment of the embodied carbon in precast concrete wall panels using a hybrid life cycle assessment approach in Malaysia. *Sustainable Cities and Society*, *10*, 101-111.

O'Neill, D., & Organ, S. (2016). A literature review of the evolution of British prefabricated low-rise housing. *Structural Survey*, *34*(2), 191-214.

Ong, J. W., Poong, Y. S., & Ng, T. H. (2008). 3G services adoption among university students: Diffusion of innovation theory. *Communications of the IBIMA*, *3*(16), 114-121.

Onu, P., & Mbohwa, C. (2021). Industry 4.0 opportunities in manufacturing SMEs: Sustainability outlook. *Materials Today: Proceedings, 44(1)*, 1925-1930.

Orlikowski, W. J., & Baroudi, J. J. (1991). Studying information technology in organizations: Research approaches and assumptions. *Information Systems Research*, *2*(1), 1-28.

OSIsoft. (2015). *Challenges, Opportunities and Strategies for Integrating IIoT Sensors with Industrial Data Ecosystems* [white paper]. Retrieved from https://www.osisoft.com/White-Papers/Challenges,-Opportunities-and-Strategies-for-Integrating-IIoT-Sensors-with-Industrial-Data-Ecosystems/.

Ossai-Igwe, E. L. (2012). Is Small and Medium Enterprise (SME) an Entrepreneurship? *International Journal of Academic Research in Business and Social Sciences*, *2*(1), 341–352.

Oxford Business Group (OBG) (2017). *Thailand's manufacturing sector to move further up the value chain.* Retrieved from https://oxfordbusinessgroup.com/overview/upwards-march-raft-well-performing-industries-manufacturing-sector-set-move-further-value-chain.

Pachayappan, M., Rajesh, N., & Saravanan, G. (2016). Smart logistics for pharmaceutical industry based on Internet of Things (IoT). In *International Conference on Advances in Computational Intelligence and Communication (CIC 2016)* (pp. 31-36). Puducherry: CIC.

Paiola, M., Agostini, L., Grandinetti, R., & Nosella, A. (2022). The process of business model innovation driven by IoT: Exploring the case of incumbent SMEs. *Industrial Marketing Management*, *103*(1), 30-46.

Pan, Y., Nam, T., Ogara, S., & Lee, S. (2013). Adoption model of mobile-enabled systems in supply chain. *Industrial Management & Data Systems*, *113*(2), 171-189.

Pandit, V., & Poojari, A. (2014). A study on amazon prime air for feasibility and profitability: A graphical data analysis. *IOSR Journal of Business and Management*, *16*(11), 6-11.

Papakostas, N., O'Connor, J., & Byrne, G. (2016). Internet of things technologies in manufacturing: Application areas, challenges and outlook. In *2016 International Conference on Information Society (i-Society)* (pp. 126-131). Dublin: IEEE.

Papert, M., & Pflaum, A. (2017). Development of an ecosystem model for the realization of internet of things (IoT) services in supply chain management. *Electronic Markets*, *27*(2), 175-189.

Parker, G. G., & Anderson Jr, E. G. (2002). From buyer to integrator: The transformation of the supply-chain manager in the vertically disintegrating firm. *Production and Operations Management*, *11*(1), 75-91.

Patra, S., & Krishna, V. (2015). Globalization of R&D and open innovation: linkages of foreign R&D centers in India. *Journal of Open Innovation: Technology, Market, and Complexity*, *1*(1), 2-24.

Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods*. New York: SAGE.

Parent, M. (2019). Unbiasing information technology decisions. *Organizational Dynamics*. Retrieved from https://doi.org/10.1016/j.orgdyn.2019.02.001.

Pariona, A. (2017). *The Economy Of The United Kingdom*. Retrieved from https://www.worldatlas.com/articles/the-economy-of-the-united-kingdom.html.

Parisot, A.H. (1997). Distance education as a catalyst for changing teaching in the community college: Implications for institutional policy. *New Directions for Community Colleges*, 99, 5-13.

Paritala, P. K., Manchikatla, S., & Yarlagadda, P. K. (2017). Digital Manufacturing-Applications Past, Current, and Future Trends. *Procedia Engineering*, *174(5)*, 982-991.

Park, E., Baek, S., Ohm, J., & Chang, H. J. (2014). Determinants of player acceptance of mobile social network games: An application of extended technology acceptance model. *Telematics and Informatics*, *31*(1), 3-15.

Park, E., & Kim, K. J. (2014). An integrated adoption model of mobile cloud services:

exploration of key determinants and extension of technology acceptance model. *Telematics and Informatics, 31*(3), 376-385.

Parker, C. M., & Castleman, T. (2009). Small firm e-business adoption: A critical analysis of theory. *Journal of Enterprise Information Management*, *22*(1–2), 167–182.

Parker, C., Scott, S., & Geddes, A. (2019). *Snowball sampling*. London: SAGE. Park,

E., Cho, Y., Han, J., & Kwon, S. J. (2017). Comprehensive Approaches to User Acceptance of Internet of Things in a Smart Home Environment. *IEEE Internet of Things Journal*, *4*(6), 2342–2350.

Parsons, J. K., Messer, K., Palazzi, K., Stroup, S. P., & Chang, D. (2014). Diffusion of surgical innovations, patient safety, and minimally invasive radical prostatectomy. *JAMA Surgery*, *149*(8), 845-851.

Parteka, A., & Wolszczak-Derlacz, J. (2015). Integrated sectors-diversified earnings: the (missing) impact of offshoring on wages and wage convergence in the EU27. *The Journal of Economic Inequality*, *13*(3), 325-350.

Pashaeypoor, S., Ashktorab, T., Rassouli, M., & Alavi-Majd, H. (2016). Predicting the adoptionof evidence-based practice using "Rogers diffusion of innovation model." *Contemporary Nurse, 52(*1), 85–94.

Patel, K. K., & Patel, S. M. (2016). Internet of things-IOT: definition, characteristics, architecture, enabling technologies, application & future challenges. *International Journal of Engineering Science and Computing, 6*(5), 6122-6131.

Patil, S. (2020). *How IoT Transforms the Way to a More Sustainable Textile Manufacturing, Clariontech.com*. Retrieved from https://www. clariontech.com/blog/how-iot-transforms-the-way-to-a-moresustainable-textile-manufacturing.

Pavic, S., Koh, S., Simpson, M. and Padmore, J. (2007). 'Could e-business create a competitive advantage in UK SMEs?', *Benchmarking*: *An International Journal, 14*(3), 320-351.

Pearson, J. M., & Grandon, E. E. (2005). An empirical study of factors that influence e-commerce adoption/ non-adoption in small and medium-sized businesses. *Journal of Internet Commerce, 4(*4), 1–21.

Peik, B. (2020). *A New Three-Dimensional Rockfall Trajectory Simulator for Open-Pit Mines* (Doctoral dissertation).

Pelto, J. (1973). *The Snowmobile Revolution: Technology and Social Change in the Arctic*. Cummings, Menlo Park, CA.

Peņicina, L., & Kirikova, M. (2013). *Perspectives in Business Informatics Research*. *Perspectives in Business Informatics Research 2013* (Vol. 158). Springer International Publishing. Retrieved from https://doi.org/10.1007/978-3-642-40823-6.

Penjor, S., & Zander, P. (2016). Predicting Virtual Learning Environment Adoption: A Case Study. *Turkish Online Journal of Educational Technology, 15*(1), 69-81.

Persaud, A. (2001). The Knowledge Gap. *Foreign affairs*, *80*(2), 107-117.

Pettinger, T. (2017). *Relative decline in UK manufacturing*. Retrieved from https://www.economicshelp.org/blog/7617/economics/economic-growth-during-great-moderation/.

Pickernell, D., Senyard, J., Jones, P., Packham, G., & Ramsey, E. (2013). New and young firms: entrepreneurship policy and the role of government–evidence from the Federation of Small Businesses survey. *Journal of Small Business and Enterprise Development*, *20*(2), 358-382.

Pines, L. (2016). *What Are Thailand's Top Commodity Exports & Imports? The Top 10 Revealed*. Retrieved from https://commodity.com/thailand/.

Popa, A., Hnatiuc, M., Paun, M., Geman, O., Hemanth, D. J., Dorcea, D., & Ghita, S. (2019). An intelligent IoT-based food quality monitoring approach using low-cost sensors. *Symmetry*, *11*(3), 374.

Porter, M. E. (2001). Strategy and the Internet. *Harvard Business Review*, *79*(3), 62–78.

Porter, M. E., & Heppelmann, J. E. (2015). How smart, connected products are transforming companies. *Harvard Business Review, 93*(10), 96-114.

Pundir, Y., Sharma, N., & Singh, Y. (2016). Internet of things (IoT): challenges and future directions. *International Journal of Advanced Research in Computer and Communication Engineering, 5*(3), 960-964.

PunyaSavatsut, C. (2011). SMEs access to finance in Thailand. *Small and Medium Enterprises (SMEs) Access to Finance in Selected East Asian Economies*, 14, 193-230.

Puranikmath, A. V., & Babu, K. M. (2020). Application of Internet of Things in Smart Textile and Apparel Manufacturing. *World Journal of Textile Engineering and Technology,* 6(1), 39-51.

Prahalad, C. K. (2012). Bottom of the Pyramid as a Source of Breakthrough Innovations. *Journal of Product Innovation Management*, *29*(1), 6-12.

Pratt, M., Sarmiento, O. L., Montes, F., Ogilvie, D., Marcus, B. H., Perez, L. G., & Wells, J. C. (2012). The implications of megatrends in information and communication technology and transportation for changes in global physical activity. *The Lancet*, *380*(9838), 282–293.

Premkumar, P. (2003). Meta-analysis of research on information technology implementation in small business. *Journal of Organizational Computing and Electronic Commerce*, *13*(2), 91–121

Premkumar, G., Ramamurthy, K., & Nilakanta, S. (1994). Implementation of electronic data interchange: an innovation diffusion perspective. *Journal of Management Information Systems*, *11*(2), 157-186.

Prescott, M.B. & Conger, S.A. (1995) Information technology innovations: a classification by IT locus of impact and research approach. *The Data Base for Advances in Information Systems, 26* (3), 20–41.

Priyanka, E. B., Maheswari, C., Ponnibala, M., & Thangavel, S. (2019). SCADA based remote monitoring and control of pressure & flow in fluid transport system using IMC-PID controller. *Advances in Systems Science and Applications*, *19*(3), 140-162.

PWC. (2015). *The Internet of Things: what it means for US manufacturing. Retrieved from http://www.themanufacturinginstitute.org/~/media/659A17245F6F4375BCCE889079427CB6/Data_Driven_Manufacturing_Whitepaper.pdf.*

Pye, A. (2014). The internet of things: connecting the unconnected. *Engineering & Technology*, *9*(11), 64-64.

Qin, Y., Sheng, Q. Z., Falkner, N. J., Dustdar, S., Wang, H., & Vasilakos, A. V. (2016). When things matter: A survey on data-centric internet of things. *Journal of Network and Computer Applications*, *64(6)*, 137-153.

Qiu, X., Luo, H., Xu, G., Zhong, R., & Huang, G. Q. (2015). Physical assets and service sharing for IoT-enabled Supply Hub in Industrial Park (SHIP). *International Journal of Production Economics*, *159(1)*, 4-15.

Quinlan, C., Babin, B., Carr, J., & Griffin, M. (2019). *Business Research Methods*. Kentucky: South Western Cengage.

Qureshil, S., Kamal, M., & Wolcott, P. (2011). Information Technology Interventions for Growth and Competitiveness in Micro-Enterprises. *International Journal of Enterprise Information Systems*, *5*(2), 71–95.

Rahmati, M., Yazdizadeh, H., & Yazdizadeh, A. (2017). Leakage detection in a gas pipeline using artificial neural networks based on wireless sensor network and Internet of Things. In *2017IEEE 15th International Conference on Industrial Informatics (INDIN)* (pp. 659-664). IEEE.

Ramdani, B., & Kawalek, P. (2007). SMEs & IS Innovations Adoption: a review & assessment of previous research. *Academia. Revista Latinoamericana de Administración*, 39, 47-70.

Ramdani, B., Kawalek, P., & Lorenzo, O. (2009). Predicting SMEs' adoption of enterprise systems. *Journal of Enterprise Information Management, 22*)1/2), 10–24

Ramundo, L., Taisch, M., & Terzi, S. (2016). State of the art of technology in the food sector value chain towards the IoT. In *2016 IEEE 2nd International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)* (pp. 1-6). Bologna : IEEE.

Rashid, Y., Rashid, A., Warraich, M. A., Sabir, S. S., & Waseem, A. (2019). Case study method: A step-by-step guide for business researchers. *International Journal of Qualitative Methods, 18*(1), 1-9.

Rattanawiboonsom, V. (2021). A study on the success factors for knowledge management in supply chains of electronics industry. *Management Science Letters*, *11*(8), 2195-2202.

Raymond, L., & Uwizeyemungu, S. (2007). A profile of ERP adoption in manufacturing SMEs. *Journal of Enterprise Information Management*, *20*(4), 487-502.

Razzaq, A., An, H., & Delpachitra, S. (2021). Does technology gap increase FDI spillovers on productivity growth? Evidence from Chinese outward FDI in Belt and Road host countries. *Technological Forecasting and Social Change*, *172(1),* 50-121.

Reaidy, P. J., Gunasekaran, A., & Spalanzani, A. (2015). Bottom-up approach based on Internet of Things for order fulfillment in a collaborative warehousing environment. *International Journal of Production Economics*, *159(1)*, 29-40.

Rehman, A. U., Mahmood, M. S., & Mustafa, G. (2021). A Comparative Analysis on Handling Big Data Using Cloud Services. *Lahore Garrison University Research Journal of Computer Science and Information Technology*, *5*(4), 78-86.

Researchethics. (n.d.). Retrieved from https://www.swansea.ac.uk/law/research/researchethics/.

Reilly, M. (2019). *Ultimate guide to digital underwriting.* Retrieved from https://insuranceblog.accenture.com/ultimate-guide-to-digital-underwriting.

Resnick. N. (2018). *The Advantages of Manufacturing in China and the Benefits It Brings to your Business.* Retrieved from https://www.sourcify.com/advantages-manufacturing-china-benefits-brings-business/.

Reuters. (2011). *Tesco to outpace growth at global rivals*. Retrieved from https://www.reuters.com/article/tesco-igd/tesco-to-outpace-growth-at-global-rivals-study-idUSLDE71F1LR20110217.

Reuters (2015). *Thailand's outdated tech sector casts cloud over economy.* Retrieved from https://www.reuters.com/article/us-thailand-economy-electronics/thailands-outdated-tech-sector-casts-cloud-over-economy-idUSKBN0ME2S620150318.

Rhodes, C. (2018a). *Manufacturing: statistics and policy*. Retrieved from https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN01942.

Rhodes, C. (2018b). *Manufacturing: international comparisons*. Retrieved from https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN05809.

Richards, L. (1999). *Using Nvivo in Qualitative Research Melbourne*. Australia: Sage.

Richards, L. (2002). Qualitative computing--a methods revolution?. *International Journal of Social Research Methodology*, *5*(3), 263-276.

Riege, A. M. (2003). Validity and reliability tests in case study research: a literature review with "hands-on" applications for each research phase. *Qualitative Market Research: An International Journal*, *6*(2), 75-86.

Riemenschneider, C. K., & McKinney, V. R. (2002). Assessing belief differences in small business adopters and non-adopters of web-based e-commerce. *Journal of Computer Information Systems*, *42(*2), 101–107.

Rijsdijk, S. A., Hultink, E. J., & Diamantopoulos, A. (2007). Product intelligence: its conceptualization, measurement and impact on consumer satisfaction. *Journal of the Academy of Marketing Science*, *35*(3), 340-356.

Riley, G. (2018). *State of the UK Economy*. Retrieved from https://www.tutor2u.net/economics/reference/state-of-the-uk-economy-may-2018.

Rico, M., Benito, G., Salgueiro, A. R., Díez-Herrero, A., & Pereira, H. G. (2008). Reported tailings dam failures: a review of the European incidents in the worldwide context. *Journal of Hazardous Materials*, *152*(2), 846-852.

Rio, T. (2008). *Mine of the Future.* Retrieved from http://www.riotinto.com/australia/pilbara/mine-of-thefuture-9603.aspx.

Rivard, S., Raymond, L. and Verreault, D. (2006). Resource-based view and competitive strategy: an integrated model of the contribution of information technology to firm performance. *The Journal of Strategic Information Systems*, *15*(1), 29-50.

Roberts, K. A., & Wilson, R. W. (2002). ICT and the Research Process: Issues Around the Compatibility of Technology with Qualitative Data Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *3*(2). Retrieved from https://doi.org/10.17169/fqs-3.2.862.

Robey, D., Boudreau, M.-C. and Rose, G. M. (2000). Information technology and organizational learning: a review and assessment of research. *Accounting, Management and Information Technologies, 10*(2), 125-155.

Robinson, L. (2009). A summary of diffusion of innovations. *Enabling change*, *5*(10), 2-10.

Robson, C. (2002). *Real World Research*. 2nd ed., Oxford: Blackwell.

Rogers, E. M. (1958). Categorizing the adopters of agricultural practices. *Rural Sociology*, *86*(2), 1-9.

Rogers, E. M., & Beal, G. M. (1957). The Importance of Personal influence in the Adoption of Technological Changes. *Social Forces*. *36*(4), 329-335.

Rogers, E. M. (1962). *Diffusion of Innovations.* First edition. New York: Free Press.

Rogers, E. M. (1983). *Diffusion of Innovations.* Third edition. New York: Free Press.

Rogers, E.M. (1995). *Diffusion of Innovations.* Fourth edition. New York: Free Press.

Rogers, E.M. (2003). *Diffusion of Innovations.* Fifth edition. New York: Free Press.

Rogers E. M, Shoemaker and Floyd F. (1971). *Communication of Innovations*. New York: Free Press.

Rogers, E. M. (2001). *Evolution: Diffusion of Innovations*. *International Encyclopedia of the Social & Behavioral Sciences: Second Edition* (Second Ed., Vol. 7). Amsterdam: Elsevier.

Roja, P., & Srihari, D. (2018). IoT based smart helmet for air quality used for the mining industry. *International Journal of Scientific Research in Science*, *4*(8), 514-521.

Rondan-Cataluña, F. J., Arenas-Gaitán, J., & Ramírez-Correa, P. E. (2015). A comparison of the different versions of popular technology acceptance models a non-linear perspective. *Kybernetes*, *44*(5), 788–805.

Rosas, J. A. D., Brito, V., Brito Palma, L., & Barata, J. (2017). Approach to Adapt a Legacy Manufacturing System Into the IoT Paradigm. *International Journal of Interactive Mobile Technologies*, *11*(5), 91-104.

Rosen, E. (2002). *The anatomy of buzz: How to create word of mouth marketing*. New York: Crown Business.

Rose, S., Clark, M., Samouel, P., & Hair, N. (2012). Online customer experience in e-retailing: an empirical model of antecedents and outcomes. *Journal of Retailing*, *88*(2), 308-322.

Rossiter, D. G. (2018). Past, present & future of information technology in pedometrics. *Geoderma*, *324(16)*, 131–137.

Roulston, K., & Choi, M. (2018). Qualitative interviews. *The SAGE handbook of Qualitative Data Collection*, 233-249.

Rouse, A., & Dick, M. (1994). The use of NUDIST, a computerized analytical tool, to support qualitative information systems research. *Information Technology & People*, *7*(3), 50-62.

Rowlands, B. (2003). Employing interpretive research to build theory of information systems practice. *Australasian Journal of Information Systems*, *10*(2), 3-22.

Royal Thai Government. (2016). *"Transforming Nations through Creativity and Innovation."* Retrieved from http://www.thaigov.go.th/index.php/en/governmenten1/item/106096-106096.

Russell, A. L. (2012). Histories of Networking vs. the History of the Internet. In *SIGCIS Workshop* (Vol. 7). Denmark: SIGCIS.

Rust, R. T., & Lemon, K. N. (2001). E-service and the consumer. *International Journal of Electronic Commerce*, *5*(3), 85-101.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. *Boston Consulting Group*, *9*(1), 54-89.

Ryan, B., & Gross, N. C. (1943). The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology*, *8*(1), 15-24.

Sadeghi, A. R., Wachsmann, C., & Waidner, M. (2015, June). Security and privacy challenges in industrial internet of things. In *2015 52nd ACM/EDAC/IEEE Design Automation Conference (DAC)* (pp. 1-6). San Francisco: IEEE.

Sadiku, M. N., Wang, Y., Cui, S., & Musa, S. M. (2017). Industrial Internet of Things. *International Journal of Advances in Scientific Research and Engineering*, *3*(11), 1–5.

Saedi, A., & Iahad, N. A. (2013). An Integrated Theoretical Framework for Cloud Computing Adoption by Small and Medium-Sized Enterprises. In *PACIS* (p. 48). Jeju Island: Aisel.

Safari, F., Safari, N., & Hasanzadeh, A. (2015). The adoption of software-as-a-service 177 (SaaS): Ranking the determinants. *Journal of Enterprise Information Management*, *28(*3),400-422.

Sahin, I., & Rogers, F. (2006). Detailed Review of Rogers' Diffusion of Innovations Theory and Educational Technology-Related Studies Based on Rogers' Theory. *Turkish Online Journal of Educational Technology*, *5*(2), 1303–6521.

Sahraoui, S., & Bilami, A. (2015). Efficient HIP-based approach to ensure lightweight end-to-end security in the internet of things. *Computer Networks*, *91(16)*, 26-45.

Saint, A. (2014). Internet of things brave new world [Communications Manufacturing]. *Engineering & Technology*, *9*(9), 80-83.

Saldaña, J. (2009). *The Coding Manual for Qualitative Researchers (1st ed.).* Thousand Oaks, CA: Sage.

Sale, J. E., Lohfeld, L. H., & Brazil, K. (2002). Revisiting the quantitative-qualitative debate: Implications for mixed-methods research. *Quality and Quantity*, *36*(1), 43-53.

Saleem, J., Adebisi, B., Ande, R., & Hammoudeh, M. (2017). A state of the art survey-Impact of cyber attacks on SME's. In *Proceedings of the International Conference on Future Networks and Distributed Systems* (p. 52). Cambridge: Association for Computing Machinery.

Sambasivan, M., Patrick Wemyss, G., & Che Rose, R. (2010). User acceptance of a G2B system:A case of electronic procurement system in Malaysia. *Internet Research*, *20*(2), 169-187.

Sanchez, L., Muñoz, L., Galache, J. A., Sotres, P., Santana, J. R., Gutierrez, V. & Pfisterer, D. (2014). SmartSantander: IoT experimentation over a smart city testbed. *Computer Networks, 61*(1), 217-238.

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179-183.

Santoro, G., Vrontis, D., Thrassou, A., & Dezi, L. (2018). The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity. *Technological Forecasting and Social Change*, *136(11)*, 347-354.

Santos, J. B. & Brito, L. A. L. (2012). Toward a subjective measurement model for firm performance. *Brazilian Administration Review, 9*(6), 95–117.

Sandelowski, M. (2000). Whatever happened to qualitative description?. *Research in Nursing & Health*, *23*(4), 334-340.

Saunders, M. L., & Lewis, P. & Thornhill, A. (2009). *Research Methods for Business Students*. England: Pearson Education Limited.

Saran, C. (2012). *Almost a third of BI projects fail to deliver on business objectives*. Retrieved from https://www.computerweekly.com/news/2240113585/Almost-a-third-of-BI-projects-fail-to-deliver-on-business-objectives.

Savoury, R. D. (2019). *Influential Determinants of Internet of Things Adoption in the US Manufacturing Sector* (Doctoral dissertation). Retrieved from https://scholarworks.waldenu.edu/dissertations/7076/.

Savulescu, C. (2015). Dynamics of ICT Development in the EU. *Procedia Economics and Finance*, 23(5), 513–520.

Schlick, J., Stephan, P., & Zühlke, D. (2012). Produktion 2020. Auf dem Weg zur 4. industriellen Revolution. *Information Management & Consulting, 27*(3), 26-34.

Schniederjans, D. G. (2017). Adoption of 3D-printing technologies in manufacturing: A survey analysis. *International Journal of Production Economics*, *183(1)*, 287–298.

Schönsleben, P., Fontana, F., & Duchi, A. (2017). What Benefits do Initiatives Such as Industry 4.0 Offer for Production Locations in High-wage Countries?. *Procedia CIRP*, *63(6)*, 179-183.

Schreier, M. (2018). Sampling and generalization. *The SAGE Handbook of Qualitative Data Collection*. London: Sage.

Schreiner, M., & Woller, G. (2003). Microenterprise development programs in the United States and in the developing world. *World Development*, *31*(9), 1567-1580.

Schwab, K. (2017). *The Global Competitiveness Report 2017-2018*. Geneva: World Economic Forum.

Schwab, K. (2019). *The Global Competitiveness Report 2018*. Geneva: World Economic Forum.

Scotland Food & Drink. (2018). *Industry performance review 2018*. Retrieved from https://foodanddrink.scot/media/1466/sfd-2018_web.pdf.

Sena Ferreira, P., Shamsuzzoha, A. H. M., Toscano, C., & Cunha, P. (2012). Framework for performance measurement and management in a collaborative business environment. *International Journal of Productivity and Performance Management*, *61*(6), 672-690.

Senyo, P. K., Effah, J., & Addae, E. (2016). Preliminary insight into cloud computing adoption in a developing country. *Journal of Enterprise Information Management, 29*(4), 505–524.

Serpanos, D., & Wolf, M. (2017). *Internet-of-Things (IoT) Systems: Architectures, Algorithms, Methodologies*. Oxford: Springer.

Seyal, A. H., Noah Abd Rahman, M., & Awg Yussof Hj Awg Mohammad, H. (2007). A quantitative analysis of factors contributing electronic data interchange adoption among Bruneian SMEs: A pilot study. *Business Process Management Journal*, *13*(5), 728-746.

Shabanpour, R., Shamshiripour, A., & Mohammadian, A. (2018). Modeling adoption timing of autonomous vehicles: innovation diffusion approach. *Transportation*, *45*(6), 1607-1621.

Shah Alam, S. (2009). Adoption of internet in Malaysian SMEs. *Journal of Small Business and Enterprise Development*, *16*(2), 240-255.

Shahzad, K., & Imran, F. (July). Surviving the covid-19 pandemic: the role of digital innovation and transformation. In *International Conference on Applied Human Factors and Ergonomics* (pp. 708-715). Cham: Springer.

Sharma, K. L. S. (2016). Information Technology–Operation Technology Convergence. *Overview of Industrial Process Automation*, 359–375. Retrieved from https://doi.org/10.1016/b978-0-12-805354-6.00020-7.

Sharma, G. (2017). Pros and cons of different sampling techniques. *International Journal of Applied Research*, 3(7), 749-752.

Sharma, A., Gupta, S., & Sharma, A. (2017). IoT in Mining: A Review. *International Journal of Electronics, Electrical and Computational System*, 6(2), 84-91.

Shamsuzzoha, A., Toscano, C., Carneiro, L. M., Kumar, V., & Helo, P. (2016). ICT-based solution approach for collaborative delivery of customised products. *Production Planning & Control*, 27(4), 280-298.

Sheffield. (2012). Learning and Teaching Services. *Retrieved from http://www.sheffield.ac.uk/lets/strategy/resources/evaluate/general/data- analysis/template-analysis.*

Shelby, Z., & Bormann, C. (2011). *6LoWPAN: The wireless embedded Internet* (Vol. 43). NJ: John Wiley & Sons.

Shen, K., Cheng, C., Li, X., & Zhang, Z. (2019). Environmental cost-benefit analysis of prefabricated public housing in Beijing. *Sustainability*, *11*(1), 207. https://doi.org/10.3390/su11010207.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, *22*(2), 63-75.

Sherry, L. (1997). The boulder valley internet project: Lessons learned. *The Technological Horizons in Education Journal, 25*(2), 68-73.

Shi, J., & Li, P. (2006, June). An initial review of policies for SMEs in the US, Japan and China. In *2006 IEEE International Conference on Management of Innovation and Technology* (Vol. 1, pp. 270-274). China: IEEE.

Shin, D. H. (2009). Determinants of customer acceptance of multi-service network: An implication for IP-based technologies. *Information & Management*, *46*(1), 16-22.

Shin, D. H. (2013). User centric cloud service model in public sectors: Policy implications of cloud services. *Government Information Quarterly*, *30*(2), 194-203.

Shin, D. H. (2015). User value design for cloud courseware system. *Behaviour & Information Technology*, *34*(5), 506-519.

Shin, D. H., & Jin Park, Y. (2017). Understanding the Internet of Things ecosystem: multi-level analysis of users, society, and ecology. *Digital Policy, Regulation and Governance*, *19*(1), 77-100.

Sia, C. L., Teo, H. H., Tan, B. C., & Wei, K. K. (2004). Effects of environmental uncertainty on organizational intention to adopt distributed work arrangements. *IEEE Transactions on Engineering Management*, *51*(3), 253-267.

Siegrist, M., Cvetkovich, G., & Roth, C. (2000). Salient value similarity, social trust, and risk/benefit perception. *Risk Analysis*, *20*(3), 353-362.

Simmons, G., Armstrong, G., & Durkin M (2011) An exploration of small business website optimization: Enablers, influencers and an assessment approach. *International Small Business Journal 29*(5), 534–561.

Sin Tan, K., Choy Chong, S., Lin, B., & Cyril Eze, U. (2009). Internet-based ICT adoption: Evidence from Malaysian SMEs. *Industrial Management & Data Systems, 109*(2), 224–244.

Singh, A., Singh, U. K., & Kumar, D. (2018). IoT in mining for sensing, monitoring and prediction of underground mines roof support. In *2018 4th International Conference on Recent Advances in Information Technology* (pp. 1-5). Dhanbad: IEEE.

Sinha, I., & Mukherjee, S. (2016). Acceptance of technology, related factors in use of off branche-banking: an Indian case study. *Journal of High Technology Management Research, 27*(1), 88–100.

Sinoscan. (2017). Best of British *Manufacturing.* Retrieved from http://sinoscan.co.uk/best-british-manufacturing/.

Sivathanu, B. (2019). Adoption of Industrial IoT (IIoT) in Auto-Component Manufacturing SMEs in India. *Information Resources Management Journal*, *32*(2), 52–75.

Skinner, E. (2018). *Current Trends in Information Technology*. Retrieved from http://www.finsmes.com/2018/06/current-trends-in-information-technology.html.

Slater III, W. F. (2002). *Internet history and growth.* Retrieved from https://www.internetsociety.org/internet/history-internet/.

Slevitch, L. (2011). Qualitative and quantitative methodologies compared: Ontological and epistemological perspectives. *Journal of Quality Assurance in Hospitality & Tourism*, *12*(1), 73-81.

Small and Medium Enterprise Development Bank of Thailand. (2019). *SMEs definition*. Retrieved from https://www.smebank.co.th/about/definition.

SMMT. (2018). *Smmt Motor industry facts 2018*. Retrieved from https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-Motor-Industry-Facts-June-2018.pdf.

Smulowitz, S., 2017. Document analysis. The international encyclopedia of communication research methods, pp.1-8.

Soldatos, J., Gusmeroli, S., Malo, P., & Di Orio, G. (2016). Internet of things applications in future manufacturing. *Digitising Industry-Internet of Things Connecting the Physical, Digital and Virtual Worlds*, 153-183.

Sommer, L. (2015). Industrial revolution-industry 4.0: Are German manufacturing SMEs the first victims of this revolution? *Journal of Industrial Engineering and Management, 8*(5), 1512-1532.

Son, J. Y., and Benbasat, I. (2007). Organizational buyers’ adoption and use of B2B electronic marketplaces: efficiency- and legitimacy-oriented perspectives. *Journal of Management Information Systems, 24*(1), 55–99.

Song, J., Koo, C., & Kim, Y. (2008). Investigating antecedents of behavioral intentions in mobile commerce. *Journal of Internet Commerce, 6*(1), 13-34.

Sony, M., Antony, J., Mc Dermott, O., & Garza-Reyes, J. A. (2021). An empirical examination of benefits, challenges, and critical success factors of industry 4.0 in manufacturing and service sector. *Technology in Society, 67(1)*, 101-754.

Sophonthummapharn, K. (2009). The adoption of techno-relationship innovations: A framework for electronic customer relationship management. *Marketing Intelligence & Planning, 27*(3), 380-412.

Spacey, J. (2016). *IT vs ICT*. Retrieved from https://simplicable.com/new/it-vs-ict.

Spanos, Y. E., & Lioukas, S. (2001). An examination into the causal logic ofrent generation: Contrasting Porter's competitive strategy framework and the resource-based per-spective. *Strategic Management Journal, 22*(10), 907-934.

Stake, R. E. (1995). *The Art of Case Study Research*. London: Sage.

Stankovic, J. A. (2014). Research directions for the internet of things. *IEEE Internet Things Journal. 1*(1), 3–9.

Stentoft, J., Jensen, K. W., Philipsen, K., & Haug, A. (2019, January). Drivers and barriers for Industry 4.0 readiness and practice: a SME perspective with empirical evidence. In *Proceedings of the 52nd Hawaii International Conference on System Sciences*.

Sturges, J. E., and Hanrahan, K. J. (2004). Comparing telephone and face-to-face qualitative interviewing: a research note. *Qualitative Research, 4*(1), 107-118.

Speier, C., & Venkatesh, V. (2002). The hidden minefields in the adoption of sales force automation technologies. *Journal of Marketing, 66*(3), 98-111.

Statista. (2019). *Distribution of cars exported from the United Kingdom (UK) from 2015 to 2017,by main export destinations*. Retrieved from https://www.statista.com/statistics/298970/destination-of-cars-exported-from-the-united-kingdom/.

Stevens, G. C., & Johnson, M. (2016). Integrating the supply chain: 25 years on. *International Journal of Physical Distribution & Logistics Management*, *46*(1), 19-42.

Stočes, M., Vaněk, J., Masner, J., & Pavlík, J. (2016). Internet of Things (IoT) in agriculture - selected aspects. *Agris on-line Papers in Economics and Informatics, 8*(1), 83–88.

Stojkoska, B. L. R., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production*, *140(1)*, 1454-1464.

Strauss, A., & Corbin, J. (1990). *Basics of Qualitative Research*. New York: Sage.

Stringer, E. T., & Genat, W. (2004). *Action Research in Health*. NJ: Merrill Prentice Hall.

Suuchi (2019). "The Growing Role of IoT in Apparel Manufacturing". Retrieved from https://www.suuchi.com/the-growing-role-of-iot-in-apparelmanufacturing.

Suleman, H. (2016). *Determinants of Key Success Criteria in Establishing and Sustaining an Internet of Things (IOT) New Technology Venture (NTV) IN SOUTH AFRICA.* Retrieved from http://wiredspace.wits.ac.za/bitstream/handle/10539/21503/HussainSuleman_1261322_2nd%20Submission%20-%20Final%20thesis.pdf?sequence=1&isAllowed=y.

Summers, L. (2017). Crises in Economic Thought, Secular Stagnation, and Future Economic Research. *NBER Macroeconomics Annual*, *31*(1), 557-577.

Sun, E., Zhang, X., & Li, Z. (2012). The internet of things (IOT) and cloud computing (CC) based tailings dam monitoring and pre-alarm system in mines. *Safety Science*, *50*(4), 811-815.

Sung, S. Y., & Choi, J. N. (2014). The roles of individual differences and innovation properties in multiple forms of innovation implementation. *Social Behavior and Personality: an International Journal*, *42*(7), 1201-1219.

Sztipanovits, J., Ying, S., Cohen, I., Corman, D., Davis, J., Khurana, H., & Stormo, L. (2013). *Strategic R&D opportunities for 21st century cyber-physical systems*. *Steering Committee for the Foundation for Innovation in Cyber-Physical Systems, National Institute of Standards and Technology (NIST)*. Retrieved from https://www.nist.gov/system/files/documents/el/12-Cyber-Physical-Systems020113_final.pdf.

Tan, J. (2016). *Improving digital infrastructure for a better-connected Thailand*. *Huawei Technologies*. Retrieved from http://tinyurl.com/jen5wl5.

Tan, M., & Teo, T. S. (1998). Factors influencing the adoption of the Internet. *International Journal of Electronic Commerce*, *2*(3), 5-18.

Tafere, G. A., Beyera, G. K., & Wami, S. D. (2019). The effect of organizational and individual factors on health and safety practices: results from a cross-sectional study among manufacturing industrial workers. *Journal of Public Health*, 28(1), 173-179.

Tao, F., Cheng, Y., Da Xu, L., Zhang, L., & Li, B. H. (2014). CCIoT-CMfg: cloud computing and internet of things-based cloud manufacturing service system. *IEEE Transactions on Industrial Informatics*, *10*(2), 1435-1442.

Tao, D., Jin, L., Wang, Y., & Li, X. (2014). Rank preserving discriminant analysis for human behavior recognition on wireless sensor networks. *IEEE Transactions on Industrial Informatics*, *10*(1), 813-823.

Taneja, S., Pryor, M. G., & Hayek, M. (2016). Leaping innovation barriers to small business longevity. *Journal of Business Strategy*, *37*(3), 44-51.

Tangpinijkul, N. (2010). Rice milling system. *Department of Agriculture, Thailand*, 1-27.

Targetjobs, (2018). *Manufacturing engineering: industry sector overview*. Retrieved from https://targetjobs.co.uk/career-sectors/engineering/advice/282461-manufacturing-engineering-industry-sector-overview.

Tarute, A., Duobiene, J., Kloviene, L., Vitkauskaite, E., & Varaniute, V. (2018). Identifying factors affecting digital transformation of SMEs. *Proceedings of the International Conference on Electronic Business*, 64, 373–381.

Tarutė, A., & Gatautis, R. (2014). ICT Impact on SMEs Performance. *Procedia - Social and Behavioral Sciences*, *110(3)*, 1218–1225.

Tashakkori, A., and Teddlie, C. (2003). *Handbook of mixed methods in the social and behavioural sciences. Research design: Qualitative, quantitative, and mixed methods approach.* Thousand Oaks, CA: Sage

Tashkandi, A. N., & Al-Jabri, I. M. (2015). Cloud computing adoption by higher education institutions in Saudi Arabia: An exploratory study. *Cluster Computing*, *18*(4), 1527–1537.

Tellis, W. M. (1997). Application of a case study methodology. *The Qualitative Report*, *3*(3), 1-19.

Teo, T. S., & Pok, S. H. (2003). Adoption of WAP-enabled mobile phones among Internet users. *Omega*, *31*(6), 483-498.

Teo, H. H., Oh, L. B., Liu, C., & Wei, K. K. (2003). An empirical study of the effects of interactivity on web user attitude. *International Journal of Human-Computer Studies*, *58*(3), 281-305.

Thailand Board of Invesment (BOI) (2018). *Here's how Thailand's manufacturing industry is shaping the future of robotics and automation.* Retrieved from https://qz.com/1442763/heres-how-thailands-manufacturing-industry-is-shaping-the-future-of-robotics-and-automation/.

The Heritage Foundation (2019). *Thailand Economic Freedom*. Retrieved from https://www.heritage.org/index/pdf/2019/countries/thailand.pdf.

The International Trade Administration (ITA). (2018). *Thailand - Market Overview.* Retrieved from https://www.export.gov/article?id=Thailand-market-overview.

The Manufacturer. (2019). *UK Manufacturing Statistics*. Retrieved from https://www.themanufacturer.com/uk-manufacturing-statistics/.

The Telegraph. (2016). *The Future of Manufacturing*. Retrieved from https://www.telegraph.co.uk/business/tips-for-the-future/future-of-manufacturing/.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, *27*(2), 237-246.

Thomas, M. O., & Rad, B. B. (2017). Reliability evaluation metrics for internet of things, car tracking system: a review. *International Journal of Computer Science and Information Technologies*, *9*(2), 1-10.

Thong, J. Y. (1999). An integrated model of information systems adoption in small businesses. *Journal of Management Information Systems*, *15*(4), 187-214.

Thornton, P. (2010). *The global manufacturing sector: current issues*. Retrieved from https://www.cimaglobal.com/Documents/Thought_leadership_docs/Global_manufacturing_report.pdf.

Tita, B. (2015). Smart glasses get new look on factory floor. *The Wall Street Journal*. Retrieved from https://www.wsj.com/articles/smart-glasses-get-new-look-on-factory-floor-1433301177.

Toma, C., & Popa, M. (2018). IoT Security Approaches in Oil & Gas Solution Industry 4.0. *Informatica Economica*, *22*(3), 46-61.

Tomic, D. (2017). *The Benefits and Challenges with Implementation of Internet of Things (IoT) in Manufacturing Industry.* Retrieved from https://kth.diva-portal.org/smash/get/diva2:1189553/FULLTEXT01.pdf.

Tornatzky, L. G., & Klein, K. J. (1982). Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, 29(1), 28-45.

Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *Processes of Technological Innovation*. Washington: Lexington books.

Tortermvasana, K. (2016). ICT pushes drive towards ‘Thailand 4.0’. *Bangkok Post*. Retrieved from http://tinyurl.com/hkbv4t7.

Trading Economics. (2019a). *United Kingdom Inflation Rate*. Retrieved from https://tradingeconomics.com/united-kingdom/inflation-cpi.

Trading Economics. (2019b). *United Kingdom Manufacturing PMI*. Received from https://tradingeconomics.com/united-kingdom/manufacturing-pmi.

Trawnih, A., Yaseen, H., Al-Adwan, A. S., Alsoud, R., & Jaber, O. A. (2021). Factors influencing social media adoption among SMEs during Covid-19 crisis. *Journal of Management Information and Decision Sciences*, *24*(6), 1-18.

Truman, G. E., Sandoe, K., & Rifkin, T. (2003). An empirical study of smart card technology. *Information & Management*, *40*(6), 591-606.

Tsang, Y. P., Choy, K. L., Wu, C. H., Ho, G. T. S., & Lam, H. Y. (2019). Blockchain-driven IoT for food traceability with an integrated consensus mechanism. *IEEE Access*, *7*, 129000-129017.

Tu, M. (2018). An exploratory study of internet of things (IoT) adoption intention in logistics and supply chain management a mixed research approach. *International Journal of Logistics Management*, *29*(1), 131–151.

Tucker, W. (2019). The eight emerging technologies you should learn to love. Retrieved from https://www.pwc.co.uk/services/consulting/technology/insights/eight-emerging-technologies- learn-to-love.html.

Turber, S., Vom Brocke, J., Gassmann, O., & Fleisch, E. (2014, May). Designing business models in the era of internet of things. *In International Conference on Design Science Research in Information Systems* (pp. 17-31). Cham: Springer.

Tushman, M., & Nadler, D. (1986). Organizing for innovation. *California Management Review*, *28*(3), 74-92.

Ueasangkomsate, P. (2015). Adoption e-commerce for export market of small and medium enterprises in Thailand. *Procedia-Social and Behavioral Sciences*, *207(42)*, 111-120.

uktradeinfo. (2019). *Aerospace Sector Report*. Retrieved from https://www.parliament.uk/documents/commons-committees/Exiting-the-European-Union/17-19/Sectoral%20Analyses/1-Sectoral-Analyses-Aerospace-Report.pdf

United Nations. (2019). *World Economic Situation and Prospects 2019*. New York: United Nations.

United Nations Department of Global Communications (DESA). (2019). *Global economic situation and prospects.* New York: United Nations.

Uniyal, S., Mangla, S. K., Sarma, P. R., Tseng, M. L., & Patil, P. (2021). ICT as “Knowledge management” for assessing sustainable consumption and production in supply chains. *Journal of Global Information Management*, *29*(1), 164-198.

US International Trade Commission. (2010). Small and medium-sized enterprises: Overview of participation in US exports. *Investigation No. 332-508*, *91*.

Utterback, J. M. (1974). Innovation in industry and the diffusion oftechnology. *Science*, *183*(4125), 620-626.

Vadlamudi, S. (2021). The economics of internet of things: An information market system. *Asian Business Review*, *11*(1), 35-40.

Vahtera, A. M. (2008). Organisational Factors Affecting IT Innovation Adoption in the Finnish Early Childhood Education. In *ECIS* (pp. 1106-1116). Galway: Aisel.

Valero, E., Adán, A., & Cerrada, C. (2015). Evolution of RFID applications in construction: A literature review. *Sensors*, *15*(7), 15988-16008.

Valmohammadi, C. (2016). Examining the perception of Iranian organizations on Internet of Things solutions and applications. *Industrial and Commercial Training*, *48*(2), 104-108.

Van Der Wijst, D. (2012). *Financial structure in small business: Theory, tests and applications* (Vol. 320). Berlin: Springer Science & Business Media.

Van de Ven, A. H., Angle, H. L., & Poole, M. S. (Eds.). (2000). *Research on the management of innovation: The Minnesota studies*. Oxford: Oxford University Press.

Van Meter, K. M. (1990). Methodological and design issues: techniques for assessing the representatives of snowball samples. *NIDA Research Monograph*, *98*(51), 31-43.

Van Slyke, C., Lou, H., Belanger, F., & Sridhar, V. (2010). The influence of culture on consumer-oriented electronic commerce adoption. *Journal of Electronic Commerce Research*, *11*(1), 310-315.

Van Wart, M., Roman, A., Wang, X. H., & Liu, C. (2017). Integrating ICT adoption issues into (e-)leadership theory. *Telematics and Informatics*, *34*(5), 527–537.

Varaniute, V., Vitkauskaite, E., & Tarute, A. (2018). Peculiarities of IoT-based business model transformations in SMEs. *Proceedings of the International Conference on Electronic Business (ICEB)* (pp. 439–446). China: Guilin.

Vashi, S., Ram, J., Modi, J., Verma, S., & Prakash, C. (2017, February). Internet of Things (IoT): A vision, architectural elements, and security issues. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)*(pp. 492-496). Palladam: IEEE.

Vella, H. (2015). *Using the Internet of Things to boost efficiency in mining operations*. Retrieved from http:// www.mining-technology.com/features/featureusing-the-internet-of-things-to-boost-efficiency-inmining-operations-4585946.

Venkatesh, V., & Davis, F. D. (1996). A model of the antecedents of perceived ease of use: Development and test. *Decision Sciences, 27*(3), 451-481.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186-204.

Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273-315.

Venkatesh, V., Thong, J. Y., & Xu, X. (2012). Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology. *MIS Quarterly, 36*(1), 157-178.

Verdouw, C., Sundmaeker, H., Tekinerdogan, B., Conzon, D., & Montanaro, T. (2019). Architecture framework of IoT-based food and farm systems: A multiple case study. *Computersand Electronics in Agriculture*, *165*, 104939.

Verl, A., Lechler, A., Wesner, S., Kirstädter, A., Schlechtendahl, J., Schubert, L., & Meier, S. (2013). An approach for a cloud-based machine tool control. *Procedia CIRP*, *7(3)*, 682-687.

Vermesan, O., & Friess, P. (Eds.). (2013). *Internet of Things: converging technologies for smart environments and integrated ecosystems*. Aalborg: River Publishers.

Vermesan, O., & Friess, P. (Eds.). (2014). Internet of things-from research and innovation to market deployment. Aalborg: River Publishers.

Vishwanath, A., & Goldhaber, G. M. (2003). An examination of the factors contributing to adoption decisions among late-diffused technology products. *New Media & Society*, *5*(4), 547-572.

Vu, K. M. (2017). ICT diffusion and production in ASEAN countries: Patterns, performance, and policy directions. *Telecommunications Policy*, *41*(10), 962–977.

Wade, M. (2009) Resource-based view of the firm [online]. Retrieved from http://www.fsc.yorku.ca/york/istheory/wiki/index.php/Resource-based_view_of_the_firm.

Wainwright, D., Green, G., Mitchell, E., & Yarrow, D. (2005). Towards a framework for benchmarking ICT practice, competence and performance in small firms. *Performance Measurement and Metrics*, *6*(1), 39-52.

Walsham, G. (1995). Interpretive case studies in IS research: nature and method. *European*

Journal of Information Systems, *4*(2), 74-81.

Walsham, G., & Han, C. K. (1993). Information systems strategy formation and implementation: the case of a central government agency. *Accounting, Management and Information Technologies*, *3*(3), 191-209.

Walsham, G. (1995). Interpretive case studies in IS research: nature and method. *European Journal of Information Systems*, *4*(2), 74-81.

Wan, J., Tang, S., Shu, Z., Li, D., Wang, S., Imran, M., & Vasilakos, A. V. (2016). Software-defined industrial internet of things in the context of industry 4.0. *IEEE Sensors Journal*, *16*(20), 7373-7380.

Wang, E. S. T. (2014). Perceived control and gender difference on the relationship between trialability and intent to play new online games. *Computers in Human Behavior, 30*(1), 315-320.

Wang, C., Daneshmand, M., Dohler, M., Mao, X., Hu, R. Q., & Wang, H. (2013). Guest Editorial-Special issue on internet of things (IoT): Architecture, protocols and services. *IEEE Sensors Journal*, *13*(10), 3505-3510.

Wang, Y., Hong, A., Li, X., & Gao, J. (2020). Marketing innovations during a global crisis: A study of China firms' response to COVID-19. *Journal of Business Research*, *116(1)*, 214-220.

Wang, H., He, W., & Wang, F. K. (2012). Enterprise cloud service architectures. *Information Technology and Management*, *13*(4), 445-454.

Wang, Y. M., & Wang, Y. C. (2016). Determinants of firms' knowledge management system implementation: An empirical study. *Computers in Human Behavior, 64(11)*, 829-842.

Wang, Z., Wang, T., Hu, H., Gong, J., Ren, X., & Xiao, Q. (2020). Blockchain-based framework for improving supply chain traceability and information sharing in precast construction. *Automation in Construction*, *111(3)*, 1-13.

Wanjari, S. S. (2020). Measuring the Turnaround in Business Performance due to WMS and MES Implementation in a Process Manufacturing Client. *European Journal of Business and Management Research*, *5*(5), 1-9.

Ward, J., & Peppard, J. (2002). *Strategic Planning for Information Systems*. NJ: John Wiley & Sons.

Warrian, B. P., & Southin, T. (2017). The Internet of Things and Printed Electronics: Case

Studies of Innovation by SME Manufacturers. *Global Journal of Management and Business Research: G Interdisciplinary*, *17*(3), 35–44.

Weber, R. H. (2010). Internet of Things – New Security and Privacy Challenges. *Computer Law & Security Review, 26*(1), 23–30.

Wedawatta, G. S. D., Ingirige, M. J. B., & Amaratunga, R. D. G. (2011). Case study as a research strategy: Investigating extreme weather resilience of construction SMEs in the UK.

Wei, C. C., Chien, C. F., & Wang, M. J. J. (2005). An AHP-based approach to ERP system selection. *International Journal of Production Economics*, *96*(1), 47-62.

Wei, J., Lowry, P. B., & Seedorf, S. (2015). The assimilation of RFID technology by Chinese companies: A technology diffusion perspective. *Information & Management*, *52*(6), 628-642.

Weigelt, C. and Sarkar, M. (2009). Learning from supply-side agents: The impact of technology solution providers' experiential diversity on clients' innovation adoption. *Academy of Management Journal, 5*2(1), 37-60.

Weinberg, B. D., Milne, G. R., Andonova, Y. G., & Hajjat, F. M. (2015). Internet of Things: Convenience vs. privacy and secrecy. *Business Horizons*, *58*(6), 615-624.

Weller, C., Kleer, R., & Piller, F. T. (2015). Economic implications of 3D printing: Market structure models in light of additive manufacturing revisited. *International Journal of Production Economics*, *164(6)*, 43-56.

Wellsandt, S., Hribernik, K., & Thoben, K. D. (2015, June). Content analysis of product usage information from embedded sensors and web 2.0 sources: A first analysis of practical examples. In *2015 IEEE International Conference on Engineering, Technology and Innovation/International Technology Management Conference (ICE/ITMC)* (pp. 1-9). Belfast: IEEE.

WEP, I. (2015). Industrial Internet of Things: Unleashing the Potential of Connected Products and Services. In *World Eco. Forum Ind*. Agenda. Geneva: World Economic Forum.

Wharton, R. F., & Brunetto, Y. (2007). Women entrepreneurs, opportunity recognition and government-sponsored business networks. *Women in Management Review*, *22*(3), 187-207.

Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. *Information Systems Frontiers*, *17*(2), 261-274.

Whitmore, A., Agarwal, A., & Da Xu, L. (2014). The Internet of Things – A Survey of Topics and Trends. *Information Systems Frontiers, 16*(1), 1–5.

Wilkins, L., Swatman, P., & Holt, D. (2011). Evolutionary Diffusion Theory. In *Global Business: Concepts, Methodologies, Tools and Applications* (pp. 1961-1977). IGI Global.

Will, M. (2008). Talking about the future within an SME? Corporate foresight and the potential contributions to sustainable development. *Management of Environmental Quality: An International Journal*, *19*(2), 234-242.

Williams, M. D., Rana, N. P., & Dwivedi, Y. K. (2015). The unified theory of acceptance and use of technology (UTAUT): a literature review. *Journal of Enterprise Information Management*, *28*(3), 443-488.

Wollschlaeger, M., Sauter, T., & Jasperneite, J. (2017). The future of industrial communication: Automation networks in the era of the internet of things and industry 4.0. *IEEE Industrial Electronics Magazine*, *11*(1), 17-27.

Wong, L. P. (2008). Data analysis in qualitative research: A brief guide to using NVivo. *Malaysian Family Physician: The Official journal of The Academy of Family Physicians of Malaysia*, *3*(1), 14.

Wong, K. S., & Kim, M. H. (2017). Privacy Protection for Data-Driven Smart Manufacturing Systems. *International Journal of Web Services Research*, *14*(3), 17-32.

Wood, C. (2017). *Barriers to Innovation Diffusion for Social Robotics Start-ups And Methods of Crossing the Chasm.* Retrieved from http://www.diva-portal.org/smash/get/diva2:1234344/FULLTEXT01.pdf.

Workman, D. (2019a). *Thailand's Top Trading Partners*. Retrieved from http://www.worldstopexports.com/thailands-top-import-partners/.

Workman, D. (2019b). *United Kingdom's Top 10 Exports.* Retrieved from http://www.worldstopexports.com/united-kingdoms-top-exports/.

Workman, D. (2019c). *United Kingdom's Top 10 Imports.* Retrieved from http://www.worldstopexports.com/united-kingdoms-top-10-imports/.

Workman, D. (2019c). Aerospace Exports by Country. Retrieved from http://www.worldstopexports.com/aerospace-exports-by-country/.

Worldatlas. (2017). *The Economy of Thailand*. Retrieved from https://www.worldatlas.com/articles/the-economy-of-thailand.html.

Worldatlas. (2018). *The Biggest Industries In Thailand*. Retrieved from https://www.worldatlas.com/articles/the-biggest-industries-in-thailand.html.

Worldatlas. (2019). *10 Countries With The Highest Industrial Outputs In The World*. Retreived from https://www.worldatlas.com/articles/10-countries-with-the-highest-industrial-outputs-in-the-world.html.

World Bank. (2018). *United Kingdom.* Retrieved from https://data.worldbank.org/country/united-kingdom.

World Bank. (2019a). *Global Economic Prospects, January 2019 : Darkening Skies*. Washington, DC: World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/31066.

World Bank. (2019b). *Gross value added at basic prices (GVA) (current US$).* Retrieved from https://data.worldbank.org/indicator/NY.GDP.FCST.CD?locations=XM-XD-1W-EU-8S&start=1960&end=2017&view=chart.

World Bank. (2020). *Manufacturing, value added (% of GDP)-Thailand.* Retrieved from https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=TH.

World Economic Forum. (2019). *Global Competitiveness Index 4.0.* Retrieved from http://reports.weforum.org/global-competitiveness-report-2018/competitiveness-rankings/.

Wright, P. (2014). Cyber-physical product manufacturing. *Manufacturing Letters*, *2*(2), 49-53.

Wu, Y., Cegielski, C. G., Hazen, B. T., & Hall, D. J. (2013). Cloud computing in support of supply chain information system infrastructure: understanding when to go to the cloud. *Journal of Supply Chain Management*, *49*(3), 25-41.

Wynn, M. (2009). Information systems strategy development and implementation in SMEs. *Management Research News, 32*(1), 78-90.

Wynn, M. G. (Ed.). (2021). *Handbook of Research on Digital Transformation, Industry Use Cases, and the Impact of Disruptive Technologies*. Pennsylvania: IGI Global.

Wynn, M., Turner, P., Abas, H., & Shen, R. (2009). Employing Knowledge Transfer to support IS implementation in SMEs. *Industry and Higher Education, 23*(2), 111-125.

Xia, M., Li, T., Zhang, Y., & de Silva, C. W. (2016). Closed-loop design evolution of engineering system using condition monitoring through internet of things and cloud computing. *Computer Networks*, *101*, 5-18.

Xiangfeng, L. (2007). SME development in China: A policy perspective on SME industrial clustering. *Asian SMEs and Globalization", ERIA Research Project Report, 5*, 37-68.

Xu, K., Qu, Y., & Yang, K. (2016). A tutorial on the internet of things: from a heterogeneous network integration perspective. *IEEE Network*, *30*(2), 102-108.

Yang, T. (2018). *ICT technologies standards and protocols for active distribution network*. *Smart Power Distribution Systems*. Tianjin: Elsevier.

Yang, H. D., & Choi, I. Y. (2001). Revisiting technology acceptance model with social influence factors. *In Proceedings of PACIS,* pp. 509–523.

Yang, H., Lay, Y., & Tsai, C. (2006). An implementation and usability evalu- ation of automatic cash-payment system for hospital. *Journal of Scientific and Industrial Research, 65(*6), 485-494.

Yang, C., Shen, W., & Wang, X. (2016, May). Applications of Internet of Things in manufacturing. In *2016 IEEE 20th International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (pp. 670-675). Nanchang: IEEE.

Yang, L., Yang, S. H., & Plotnick, L. (2013). How the internet of things technology enhances emergency response operations. *Technological Forecasting and Social Change*, *80*(9), 1854-1867.

Yeandle, M., & Wardle, M. (2019). *The Global Financial Centres Index 25*. Retrieved from https://www.longfinance.net/publications/long-finance-reports/the-global-financial-centres-index-25/.

Yi, M. Y., Jackson, J. D., Park, J. S., & Probst, J. C. (2006). Understanding information technology acceptance by individual professionals: Toward an integrative view. *Information & Management, 43(*3), 350–363.

Yin, R.K. (1993). *Applications of Case Study Research, Applied Social Research Methods Series,* 34. California: Sage.

Yin, R.K. (1994). *Case Study Research, Design and Methods* (2nd Edition). California: Sage.

Yin, R.K. (2003). *Case Study Research: Design and Methods* (3rd Edition). California: Sage.

Yin, S., & Kaynak, O. (2015). Big data for modern industry: challenges and trends [point of view]. *Proceedings of the IEEE, 103*(2), 143-146.

Yinghua, Z., Guanghua, F., Zhigang, Z., Zhian, H., Hongchen, L., & Jixing, Y. (2012). Discussion on application of IOT technology in coal mine safety supervision. *Procedia Engineering*, *43(17)*, 233-237.

Yoon, T. E., & George, J. F. (2013). Why aren't organizations adopting virtual worlds?. *Computers in Human Behavior*, *29*(3), 772-790.

Yoon, C., & Kim, S. (2007). Convenience and TAM in a ubiquitous computing environment: The case of wireless LAN. *Electronic Commerce Research and Applications, 6*(1), 102-112.

Yu, Z. H., Wei, Y. B., & Zhi, S. D. (2017). The design and application of information management system for precast concretes based on IOT. In *Proceedings of the International Conference on Future Networks and Distributed Systems* (pp. 1-4). Bristol: IOP Publishing.

Yunis, M., Tarhini, A., & Kassar, A. (2018). The role of ICT and innovation in enhancing organizational performance: The catalysing effect of corporate entrepreneurship. *Journal of Business Research*, *88(7)*, 344–356.

Zanello, G., Fu, X., Mohnen, P., & Ventresca, M. (2016). The creation and diffusion of innovation in developing countries: a systematic literature review. *Journal of Economic Surveys*, *30*(5), 884-912.

Zhao, Y., Von Delft, S., Morgan-Thomas, A., & Buck, T. (2020). The evolution of platform business models: Exploring competitive battles in the world of platforms. *Long Range Planning*, *53*(4), 101-892.

Zhang, X., Kuchinke, L., Woud, M. L., Velten, J., & Margraf, J. (2017). Survey method matters: Online/offline questionnaires and face-to-face or telephone interviews differ. *Computers in Human Behavior*, 71(1), 172-180.

Zhang, Y. & Tao, F. (2016). *Optimization of Manufacturing Systems Using the Internet of Things.* Retrieved from https://www.elsevier.com/books/optimization-of-manufacturing-systems-using-the-internet-of-things/zhang/978-0-12-809910-0.

Zhong, R. Y., Dai, Q. Y., Zhou, K., & Dai, X. B. (2008). Design and Implementation of DMES

Based on RFID. In *2008 2nd International Conference on Anti-counterfeiting, Security and Identification* (pp. 475-477). Guiyang: IEEE.

Zhong, R. Y., Dai, Q. Y., Qu, T., Hu, G. J., & Huang, G. Q. (2013). RFID-enabled real-time manufacturing execution system for mass-customization production. *Robotics and Computer-Integrated Manufacturing*, *29*(2), 283-292.

Zhou, C., Damiano, N., Whisner, B., Reyes, M. (2017). *Industrial Internet of Things (IIoT) applications in underground coal mines. Mining Engineering, 69(12), 50–56.*

ZHANG, F., & GU, W. (2010). Application of internet of thing in logistics information in coal mine. *China Mining Magazine*, *8*(19), 101-104.

Zhiqiang, Z., Varghese, A., Quan, C. W., & Ashok, P. V. (2019). Natural-Language Chat and Control HMI for Manufacturing Shopfloor. In *International Manufacturing Science and Engineering Conference* (Vol. 58745, p. V001T02A031). New York: American Society of Mechanical Engineers.

Zhong, R. Y., Huang, G. Q., Lan, S., Dai, Q. Y., Chen, X., & Zhang, T. (2015). A big data approach for logistics trajectory discovery from RFID-enabled production data. *International Journal of Production Economics*, *165(7)*, 260-272.

Zhong, R. Y., Peng, Y., Xue, F., Fang, J., Zou, W., Luo, H., & Huang, G. Q. (2017). Prefabricated construction enabled by the Internet-of-Things. *Automation in Construction*, *76(4)*,59-70.

Zhong, R. Y., Xu, X., & Wang, L. (2017). IoT-enabled smart factory visibility and traceability using laser-scanners. *Procedia Manufacturing*, *10(4)*, 1–14.

Zhu, K., Dong, S., Xu, S. X., & Kraemer, K. L. (2006). Innovation diffusion in global contexts: determinants of post-adoption digital transformation of European companies. *European Journalof Information Systems*, *15*(6), 601-616.

Zhu, K., and Kraemer, K.L., (2005), Post-adoption variations in usage and value of e-business by organizations: Cross-country evidence from the retail industry. *Information Systems Research, 16*(1), 61–84.

Zhu, K., Kraemer, K. L., & Xu, S. (2006). The process of innovation assimilation by firms in different countries: A technology diffusion perspective on e-business. *Management Science, 52*(10), 1157–1576.

Ziegler, S., Crettaz, C., & Thomas, I. (2014, May). IPv6 as a global addressing scheme and integrator for the Internet of Things and the cloud. In *2014 28th International Conference on Advanced Information Networking and Applications Workshops* (pp. 797-802). Victoria: IEEE.

Zinas, N., Kontogiannis, S., Kokkonis, G., Valsamidis, S., & Kazanidis, I. (2017). Proposed open source architecture for Long Range monitoring. The case study of cattle tracking at Pogoniani. In *Proceedings of the 21st Pan-Hellenic Conference on Informatics* (pp. 1-6). Greece: PCI.

Zohrabi, M. (2013). Mixed Method Research: Instruments, Validity, Reliability and Reporting Findings. *Theory & Practice in Language Studies*, *3*(2).

Zuehlke, D. (2010). SmartFactory—Towards a factory-of-things. *Annual Reviews in Control*, *34*(1), 129-138.

Zuppo, C. M. (2012). Defining ICT in a Boundaryless World : The Development of a Working Hierarchy. *International Journal of Managing Information Technology*, *4*(3), 13–22.