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**Production Planning & Control: Special Issue  
Guest Editorial**

**Redistributed Manufacturing – Challenges for Operations Management**

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## Redistributed Manufacturing – Challenges for Operations Management

Recent advances in small-scale local production technologies and materials sciences, combined with the power of digital design and analysis methods, have generated new opportunities for product innovators to experiment with rapid prototyping and commercialisation of highly customised products that serve existing markets or create new niches. These developments involve modest investments in local production equipment and infrastructure with low ‘break even’ points and engineer-to-order/make-to-order production runs. This represents a transformation of manufacturing and will challenge traditional operations management thinking in fundamental ways.

A number of concepts help to represent this emerging phenomenon, which include (but are not limited to) ‘factory-in-a-box’, ‘micro-factory’, ‘digital manufacturing/fabrication’ and ‘makerspace’ forms of production. At the heart of this manufacturing revolution are innovations in production technology such as additive manufacturing, bioprinting and portable continuous manufacturing units (chemical/pharma applications). These approaches are characterised by similar fundamental principles and characteristics in terms of a physical supply chain shift away from large-scale centralised manufacture towards small-scale decentralised manufacture and geographically unconstrained supply chains. The ability to relocate production nearer to consumers offers a more iterative design engagement process with end users/beneficiaries for more precise, responsive outputs that exactly meet personalised consumer requirements, in contrast to the conventional mass manufacturing ‘push’ of products and minimal customisation. This phenomenon has been recently characterised by the term ‘Redistributed Manufacturing’ (RDM), which can be considered an emerging, disruptive innovation in many sectors, offering new possibilities for a wide-ranging ecosystem of organisations, including: (I) *Original Equipment Manufacturers* of RDM-enabling production technologies that offer new opportunities for small-scale (distributed diverse customer base) production and extended variety/scope (product-service systems, unique geometric shapes or unique specialised combinations of materials); (II) *users* of RDM equipment to create new products, services and business model – both new SME innovators and incumbents; (III) *inputs/raw materials suppliers*; and (IV) *suppliers of complementary technologies* (hard and soft) covering the design, modelling and performance simulation of objects to be produced.

RDM must be considered in the context of wider converging *trends*. These include *technological* developments, such as ‘Industry 4.0’ and the digitalisation of the end-to-end manufacturing supply chain, which will allow data to hone production, distribution and other processes to reduce inefficiencies and simultaneously customise products/artefacts to the particular circumstances of their use. Such a combination could be argued as a continuation of the ‘mass customisation’ and ‘servitisation’ discourses and trends of recent years that have enabled the realisation of business model innovations. In addition, there is increasing *political* enthusiasm for local production and supply chain resilience via the exploitation of high value-added production models especially for mature economies, where globalisation offers little attraction. Furthermore, changing *social* attitudes towards environmental concerns are driving manufacturers to reduce use of resources and the negative environmental impact of production activities. The World Economic Forum’s Meta-Council on Emerging Technologies highlighted distributed manufacturing as one of 10 emerging technologies for 2015. This trend is exemplified by an initiative emerging from the UK’s 2017 Life Sciences Industrial Strategy and the output from the Advanced Therapies Taskforce which has attracted an investment of £30m in three new advanced therapy treatment centres. Another

related development includes a more recent £10m Series A investment in a bio printing spin-out company from Oxford University which ultimately aims to produce tissue for organ repair or replacement. Whilst these technologies are still transitioning towards laboratory prototypes, RDM products of this nature have the potential to revolutionise our way of life.

This special issue is concerned with exploring key issues affecting the adoption and implementation of RDM, in the context of related business and digital transformations. A number of fundamental questions and themes are explored through our collection of papers from leading authors in production, operations and systems. These include: Does RDM represent a paradigm shift in manufacturing policy, strategy and operations? Will incumbents or new entrants be the primary adopters? To what extent will RDM disrupt existing operations? What is the readiness for RDM acceptance and adoption in terms of investment in new skills and infrastructure and integration with other complementary technologies? What will the impact be on regions and communities, and could it be used as a mechanism for industrial regeneration? Finally, in terms of benefits, do the economics of RDM offer a compelling value proposition?

We argue that further research in this area is much-needed. In this edition, the following eight papers provide valuable contributions exploring key issues affecting the implementation of RDM:

- Roscoe and Blome examine the emergence of redistributed manufacturing through an ambidexterity lens, proposing a complementary approach for firms seeking to achieve the benefits associated with both centralised and distributed manufacturing operations.
- Tziantopoulos *et al.* similarly propose, from a supply chain lens, that the notion of a hybrid production method should be explored further in the context of adopting Additive Manufacturing technologies. Their framework provides a useful basis for future research and analysis of Additive Manufacturing supply chains to objectively measure impact and benefits.
- Ratnayake provides a more technical analysis of Additive Manufacturing technologies and their potential to support a redistributed manufacturing strategy to address obsolescence issues in the offshore petroleum industry - an ideal context for testing the concept and extending it to other challenging environments. This paper offers clear pointers around technology qualification, testing and evaluation, as well as commercial concerns around the adoption of redistributed manufacturing operating models.
- Hennelly *et al.* investigate the emerging local manufacturing phenomenon of makerspaces and critically assess the scalability of such activity into a wider range of industrial applications. Their study develops and tests a typology of makerspaces and offers insights across five key implementation characteristics and constraints that inform factors affecting market adoption.
- Bessière *et al.* take a broader perspective compared to other papers in this special issue, exploring the high-level opportunity and challenges of realising redistributed manufacturing in the consumer goods industry. Their article explores the debates around levels of customisation/open innovation, mass versus local production and transitioning towards new business models. Their work provides a roadmap for the

consumer goods industry and offers policy- and operations-level sign posts for future developments.

- Zaki *et al.* also analyse consumer goods manufacturing but focus more on the emerging interrelationships between big data and manufacturing. Examining 24 industry cases, they broadly highlight some of the barriers affecting adoption of redistributed manufacturing and the potential realisation of mass customisation. They argue that the case for adoption will be selective, based on the operations strategy associated with consumer products/segments, and will depend on the future leveraging of big data devices and analytics.
- Tsimiklis and Makatsoris examine the potential of redistributed manufacturing in terms of the reshoring of manufacturing, leveraging a local supply network to deliver a more responsive and higher quality offering to customers. Their approach illustrates how food manufacturers can model and inform the business case for supply chain reconfiguration and new product development.
- Veldhuis *et al.* also provide another perspective on food manufacturing, offering an in-depth examination of two industry cases, and also interestingly taking into consideration environmental impacts on water and energy consumption. As echoed by Zaki *et al.* this paper helps critically analyse the often-assumed benefits of redistributed manufacturing against a robust evidence base to better identify suitable products for local distributed production.

Given the early stage of maturity of RDM, with the opportunities and threats it poses, this portfolio of papers represents a context rich exploration of how organisations are approaching and attempting to harness this potentially disruptive new technology, derive value from it and develop new operating models to ensure a focus on applications that deliver the most benefit.

We are grateful to all the authors who submitted contributions to this special issue and to our expert reviewers that provided valuable feedback to the authors.