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# Successive generation introduction time for high technological products: an analysis based on different multi-attribute utility functions

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## Abstract

Highly competitive markets have forced many organizations to come up with generational products. The relevance, appropriateness, added functionality, and sustainability are some of the potential reasons behind the launch of a new generation over the previous generation. The launch time of the new generation is dependent on the performance of the existing generation in the market which can be measured based on the attributes viz. the adoption behavior of the customer and indicator of adoption rate. The introduction of a new generation greatly affects the market of the existing generation of the product and huge capital is ought to be invested in feature enhancement in the latest generation as compared to the existing version. Consequently, the investment made in production and marketing activities should be economical which significantly influences the launch time. Based on these attributes, the focus is on determining the launch time of the successive generation of the product. In this paper, three conflicting and contrasting attributes: customer adoption behavior, adoption rate indicator, and cost are proposed. The aim is to study and understand the impact of the trade-off for these attributes on the launch time of successive generations of the product. To examine the tradeoff between these attributes, multi-attribute utility theory has been used. The proposed decision approach is based on three different weighted combinations of the utility function in multi-attribute utility theory. Additionally, three different forms of utility functions viz, the weighted arithmetic, geometric and harmonic forms have been used in understanding their superiority over one another. For validation purposes, the case in which an organization launches successive generations of a durable product for which demand is characterized by an innovation diffusion process has been assessed.

**Keywords** Cost function · Innovation diffusion process · Customer adoption behavior · Speedy launch indicator · Weighted arithmetic, geometric and harmonic mean

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## 1 Introduction

Promotion procedure (articulation of the market objective, market position, and advertising blend) should be arranged and designed before the introduction of the product in the marketplace (Anand & Bansal, 2016; Calantone et al., 1994; Song & Parry, 1997). The dynamic consumer behavior has forced marketers to innovate, which has become the survival vehicle for many organizations (Wang et al., 2021). Moreover, the companies who spend more on innovative products obtain higher sales revenue and have better likelihoods to capture the global market. Today companies are recognized for their distinguishing strategies and frequent launch of innovative products. Successful introductions contribute substantially to prolonged economic achievements and are successful policies to broaden primary demand. The classical internal–external diffusion model as given by Bass (1969), was based on a certain set of assumptions wherein the focus was to model the adoption pattern for the growth of new products especially consumer durables.

Speedy and drastic technological shifts have prompted rapid development and frequent introduction of sequential generations of a product accompanied by the latest technology. Several examples can be quoted for generational products to name a few Microsoft Windows, Microsoft Office, Apple iPhone, Android versions, and many more (Aggrawal et al., 2014; Jiang & Jain, 2012). The introduction of a new product initiates a diffusion process among the potential purchasers with time. The diffusion process is regulated by the behavior of potential consumers besides many other factors such as price, quality, promotional offerings, and after-sale services (Byambaa et al., 2015). The diffusion process intends to represent the growth of the adoption process. Norton & Bass (1987) proposed a diffusion model of adoption and substitution for generational products. The model dealt with the dynamic sales behavior of a high technology product with successive generations by making a clear distinction of substitution models being a function of market share. The model considers demand as a function of time, thereby establishing a relationship between decision variables and market size. The model is a natural extension of the work of Bass (1969) and Fisher & Pry (1971) and is proficient in projecting the adoption of the future sale of the generational product quite satisfactorily (Johnson & Bhatia, 1997).

Despite having progress made by Speece & MacLachlan (1995), Mahajan & Muller (1996), Kim et al. (2000), Danaher et al. (2001), Jiang (2010), and many more; in modeling the inter-generational sales behavior, the field is still the focus of many researchers to investigate and model varied aspects like cross-generation repeat purchases, the distinction between switcher and substitutes, and the distinction among the sales and the actual adopters of the product. When products are launched in a generational manner, successive generations have substitution and switching effects on the earlier generations. This calls for the consideration of decision-makers to determine the introduction time of successive generations of a product in a manner that the existing generation has performed well in terms of revenue generation and its performance in the marketplace.

In literature, several arguments have been presented for the introduction time ‘now or never’ and ‘now or maturity.’ In particular, the focus of the work revolves around the interface between three attributes that directly or indirectly impact the introduction time, which can be:

- Diffusion process that explains the propagation in the marketplace.
- The production and promotional cost of the product.
- The pace of adoption in the marketplace.

These factors have a straightforward implication on the launch time. Early and late introduction both have their own merits and demerits, making it a significant aspect for decision-makers to decide the time to introduce the innovative version of the product. As the introduction time of the generation product is being influenced by several attributes, the utility theory which describes all the outcomes in terms of utility can be used as an assistance tool. For the decision-making process, Multi-Attribute Utility Theory has been applied here, which can simultaneously consider the three attributes viz the adoption behavior of the customer, the expenditure incurred in production and promotion of the product, and indicator of adoption rate. Given the conflicting attribute, MAUT helps in deciding the time to introduce the successive version by making use of utility functions that can adapt to the different perspectives according to the aspiration level and lead to a consistent solution. Keeney & Raifa (1976); Neumann & Morgenstern (1947), and Zirger & Maidique (1990) were the early contributors that have initially verified the utility theory and its related axioms. Different functional forms of utility functions exist, here all three functional forms have been formulated and analyzed. The three kinds of Multi Attribute Utility Function (MAUF) are the weighted arithmetic utility function (WAUF), weighted geometric utility function (WGUF), and weighted harmonic utility function (WHUF).

The organization of the paper is as follows: after the brief introduction, an in-depth exploration of the literature has been done. Section 3 presents the methodology used for the determination of the launch time for the sequential generations of the product. The decision-making tool that has been used on the considered attributes and their assessment criteria have been discussed alongside. In Sect. 4, a discussion on the considered data and the numerical illustration has been presented followed by a discussion in Sect. 5 which highlights the academic as well as the practical implication of the work. The conclusion has been supplemented in Sect. 6 and lastly the list of references.

## 2 Literature review

In recent years, the researchers have worked extensively on the concept of understanding the dynamics behind the product that are introduced in a generational manner. Starting from the pioneering work of Norton & Bass (1987) to date there are several studies in which the rational has been mathematically examined. Researchers like Meade (1985), Gamerman & Migon (1991), have opposed the assumption of the constant-coefficient which was in the work by Norton & Bass (1987), and instead found that parameters of the diffusion process change over time for a single innovation of a product. Islam & Meade (1997) observed that under the assumption of constant coefficients the shape of the cumulative adoption curves will be the same for all generations, and subsequently, the timing of peak adoptions always occurs at an equal interval after the introduction of each generation. But for technological innovations, the product which has a higher expected profit with lower investment for a consumer diffused much faster in comparison to the other products and it occurs mostly for later technological generations rather than the earlier technologies (Mansfield, 1961). Bayus (1992) said that the coefficient of innovation and imitation may be negatively correlated. Thus, for technological generations of a product, it is quite natural that the adoption behavior of consumers will not remain constant across generations.

Mazumdar et al. (1996) proposed a framework for the optimum time to introduce the new generation that can have subsidized the sales of the old generation. Danaher et al. (2001) worked on the same concept of generational product diffusion and advertising mix. Versluis (2002) showed the supremacy over the Norton & Bass model (1987) by making use of the framework as given by Marchetti (1977) in terms of a better fit to the data. Ofek & Sarvary (2003) studied the dynamic competition in markets for the introduction of technologically advanced next-generation products. Sohn & Ahn (2003) used the Norton & Bass (1987) model to demonstrate a cost–benefit examination of launching a new generational version for information technology. The work by Huang & Tzeng (2008), contributed toward the development of a novel concept for making the predictions of product lifetime of multiple generation products using fuzzy piecewise regression analysis.

Researchers like Wilson & Norton (1989) determined the optimal time for the product line extension. Arslan et al. (2009) gave the mathematical framework for two product generations to determine the introduction time and extended the analysis for a duopoly environment. Jiang (2010) has proposed an extended multi-generational diffusion model that exclusively distinguishes between switchers and substitutes overpowering the Norton & Bass (1987) model that explicitly claims the existence of substitution and skippers but did not distinguish the two. Kapur et al. (2010) proposed a multigenerational diffusion model to study the marketing dynamics of the Indian Television Market (both Black & White and Color Television). They considered the effect of repeat-adoption-substitution diffusion in their model. Kuo & Huang (2012) developed a generic model wherein two different scenarios for dynamic pricing have been investigated the optimal pricing decisions and the related revenue of the retailer and compared them with the general models. Ismagilova et al. (2020) described a meta-analysis of the factors affecting eWOM providing behavior and Jeyaraj & Dwivedi (2020) provided a meta-analysis in information systems research.

Recently, Aggrawal et al. (2015) have also given an approach to meticulously examine the number of products sold and the number of products in use for two generations. In the work by McKie et al. (2018) the rationale behind the consumer preference and selection between different product generation and market conditions have been examined. In today’s time, many studies are now being channelized using artificial intelligence for decision making; like the recent study by Dwivedi et al. (2021) and Duan et al. (2019), explicitly talked about artificial intelligence for decision making.

Several researchers have used varied approaches for the determination of launch time. The present study is built on the stream of work wherein the aim is to determine the launch time for the advanced generation of the product. The paper is related to several literature streams but is novel in respect to consideration of three conflicting attributes namely the adoption behavior (Yang et al., 2021) of the customer, indicator of adoption rate, and the expenditure on the production and promotion of the product for determination of launch time. The focus here is to determine the launch time of the generation product based on these three attributes by examining the trade-off between these attributes. The proposed decision approach is built on three distinctive weighted combinations of utility functions in Multi-Attribute Utility Theory (MAUT). Additionally, three different forms of utility functions viz, the weighted arithmetic, geometric and harmonic forms have been used in understanding their superiority over one another. Therefore, this paper is designed to answer the following research questions:

- RQ1: How to compute the optimal launch time based on the adoption behavior of the customer, indicator of adoption rate, and the expenditure on the production and promotion of the product?
- RQ2: How to prioritize the different forms of utility functions viz, the weighted arithmetic, geometric and harmonic forms?

## 3 Research methodology

The rise in product alternatives has vividly expanded the number of options available to buyers in which time to enter the marketplace is a significant decision for the firms. The emphasis is given to the determination of the launch time of the multiple generations of the product using Multi-Attribute Utility Theory for making the tradeoff between three differing attributes. The diffusion process is the first parameter that explains the propagation of innovation in the marketplace with its four key elements namely (Rogers, 1962): an innovation (that is being launched into the market), the social system (Zhou et al. (2021), the marketplace which is being influenced with new offerings), the channel of communication (the mode through which the knowledge is being propagated) and lastly the time (which is the length of time taken for message propagation).

Among the rudiments, the way the knowledge is transmitted among the social system forms the core of diffusion theory (Bass, 1969; Mahajan & Muller, 1996; Mahajan et al., 1990; Norton & Bass, 1987). The general perspective about the concept, process, and dynamics of diffusion can be understood with the help of innovation diffusion theory. Considerable tools and models, both quantitative and qualitative, have been established to simplify the adoption decision of new technology and the calculation of diffusion rate. The main impetus underlying the contributions of modeling methods is a new product growth model suggested by Bass (1969) and Bass et al. (1994).

The second parameter examined in this paper is product development & promotional cost. Due to intense competitive market conditions, continual development turns into the existing strategy for organizations, numerous market makers present advancements frequently by adding new variations into the fundamental item. The business does have a high rate of risk and high cost associated with the planning and development of the new product. Therefore, the importance of considering the cost parameter in the present study is unquestionable.

The third attribute considered in the present proposal is the adoption rate indicator. Unlike the old-style market, the present scenario includes more adopter participation. The count of people engaged in buying process generally relies on the features of the item and its appeal in the marketplace (Bansal et al., 2021a; Kapur et al., 2004; Aggarwal et al., 2014). Especially, the new form of the item can draw in an expanding number of adopters in the beginning stage in the meantime dynamically more individuals know it and they use it. When the number of adopters touches the pinnacle level, at that point it will begin declining as the product loses its market value. Appropriately, it is practical to consider that the adoption rate significantly contributes toward the determination of product launch time. We obtained a high correlation between the adoption rate indicator and the optimal launch time of the new generation.

Researchers have suggested that the success of the product depends on grabbing the right chance of market penetration, the behavior of potential adopters, and in what way and based on what criterion the launch time has been determined. Thereby making it the need of the hour to balance the necessity to innovate and the complexity associated with the launch of the generational product. For this purpose, the MAUT technique (Bansal et al. (2021b) has been used in which three significant strategies are taken into consideration as adoption pattern, the cost of the production and promotion, and adoption rate indicator.

Following is the list of notations.

$N(t)$: the total count of individuals who have adopted the product by $'t'$.

$m$: the total poetential market size.

$f(t)$: probability distribution function representing adopter's behavior.
$F(t)$: cumulative distribution function for the adoption pattern.
$p$ and $q$: innovation and imitation coefficients.
$U$: Overall Multi Attribute Utility Function.
$U_i(x_i)$: Utility function of $i^{th}$ attribute.
$x_i$: the value of $i^{th}$ the attribute.
$w_i$: relative importance of the weights for the utilities of attributes.

### 3.1 Modeling adopter's behavior

In the twentieth century, F. M. Bass proposed a growth model for the planning of buying patterns of new products, and a behavior rationale has been presented. Since its publication, many researchers have considered the Bass model (1969) as the base of their work (Mahajan et al., 1990, 1993; Sultan et al., 1990). The Bass model comprises a system that is utilized for the experimental speculation and the basic principle portrays that the likelihood for an individual adoption at the time '$t$' given that people have not yet adopted as a linear function of existing adopters:

$$\frac{\mathrm{d}N(t)}{\mathrm{d}t} = \left(p + \frac{q}{m}N(t)\right)(m - N(t)) \tag{1}$$

Making use of the preliminary condition $N(0) = 0$, the solution of this model is given as:

$$N(t) = m\left(\frac{1 - e^{-(p+q)t}}{1 + \frac{q}{p}e^{-(p+q)t}}\right) \tag{2}$$

Equation (2) can be rewritten by using the alternative form of the Bass Model (1969) given by Kapur et al. (2004):

$$N(t) = m\left(\frac{1 - e^{-bt}}{1 + \beta e^{-bt}}\right) \tag{3}$$

For describing the special property of adopters' behavior, the first derivative of the cumulative number of adopters has been selected that can be given as:

$$N'(t) = m\frac{\left(\frac{(p+q)^2}{p}\right)e^{-(p+q)t}}{\left(1 + \left(\frac{q}{p}\right)e^{-(p+q)t}\right)^2} \tag{4}$$

Equation (4) can help in determining the time for highest sales at $(T*)$ with maximum value as:

$$S(T*) = m\frac{(p+q)^2}{4q}$$

and the time as:

$$T *= \frac{1}{(p+q)} \ln \left(\frac{q}{p}\right) \tag{5}$$

## 3.2 Determination of optimal launch time

Assume that $x_1, x_2, x_3, \ldots, x_k, k \geq 2$, are attributes related to the decision. The overall utility $(x_1, x_2, x_3, \ldots, x_k)$ can be computed in the following manner:

- *Direct assessment:* Here, the overall utility is assessed in the combined form $U(x_1, x_2, x_3, \ldots, x_k)$ using all the attributes under consideration.
- *Decomposed assessment:* Using the individual utilities of all the attributes $U_i(x_i)$, computed $U(x_1, x_2, x_3, \ldots, x_k)$ by combining the $U_i(x_i)$ of all attributes in different manners.

For decision making three representations of MAUT viz. WAUF, WGUF, and WHUF have been used and are explained below.

i. Weighted arithmetic utility function (WAUF)

For the consequence set of attributes that has values $x_1, x_2, x_3, \ldots, x_k$, $k \geq 2$, its overall WAUF is computed as

$$\begin{aligned} & U(x_1, x_2, x_3, \ldots x_k) = w_1 U_1(x_1) + w_2 U_2(x_2) + \ldots + w_k U_k(x_k) \\ & = \sum_{i=1}^{k} w_i U_i(x_i),\ 0 \leq U_i(x_i) \leq 1, \\ & \sum_{i=1}^{k} w_i = 1, 0\ \leq w_i \leq 1 \end{aligned} \tag{6}$$

The WAUF form is probably the best known and most widely used. The total score for the multi-attribute function is computed by multiplying the utility function for each attribute by importance assigned to the attribute and then summing these products over all the attributes.

ii. Weighted Geometric Utility Function (WGUF)

In WGUF the attributes are connected in product form. The weights become exponents associated with each attribute value. For a consequence set of attributes that has values $x_1, x_2, x_3, \ldots x_k, k \geq 2$, its overall weighted geometric utility representation can be given as:

$$\begin{aligned} & U(x_1, x_2, x_3, \ldots x_k) = U_1(x_1)^{w_1} \cdot U_2(x_2)^{w_2} \cdots U_k(x_k)^{w_k} \\ & = \prod_{1}^{k} U_i(x_i)^{w_i}, \quad 0 \leq U_i(x_i) \leq 1, \\ & \sum_{i=1}^{k} w_i = 1,\ 0 \leq w_i \leq 1. \end{aligned} \tag{7}$$

iii. Weighted Harmonic Utility Function (WHUF)

In WHUF the inverses of each attribute are connected by the importance weight assigned to the attribute. For a consequence set of attributes that has values $x_1, x_2, x_3, \ldots x_k, k \geq 2$, its overall WHUF is computed as

$$\begin{aligned} \frac{1}{U(x_1, x_2, \ldots, x_k)} &= w_1 \frac{1}{U_1(x_1)} + w_2 \frac{1}{U_2(x_2)} + w_3 \frac{1}{U_3(x_3)} + \cdots w_k \frac{1}{U_k(x_k)} \\ &= \sum_{i=1}^{k} w_i \frac{1}{U_i\left(x_i\right)}, \quad 0 \leq U_i\left(x_i\right) \leq 1, \\ &\sum_{i=1}^{k} w_i = 1, \; 0 \leq w_i \leq 1. \end{aligned} \tag{8}$$

The method of the utilization of the MAUT approach is explained wherein the utility functions are evaluated using the following procedure:

i. Assessment of attributes.
ii. Formulation of the single utility function for all attributes.
iii. Estimation of scaling constants.
iv. Optimization of MAUF

### 3.2.1 Assessment of attributes

The attributes considered should be the most important ones and should be relevant to the final decision. They should be fundamentally independent among which appropriate tradeoffs may later be made. The attribute should be selected in a meaningful and practical way for effective decision-making since product launches act as a critical driver for firms' performance. Most importantly, to sustain the fierce competition, the firms need to innovate which means that the new product development is possibly the main process in the present market scenario. Still, the introduction time is measured over time and that sometimes becomes too difficult. To overcome this challenging situation, understanding the customer adoption pattern for the current product in the market can be an alternative option. In the current proposal, the emphasis is laid on the customer's adoption indicator. Consequently, the intent of the customer's adoption pattern can be expressed as:

$$\text{Maximize}\, A_1 = \frac{N(t)}{m} \tag{9}$$

where the customer's adoption indicator $A_1$ represents the first alternative.

Yet, the introduction is particularly the costlier action during the new product development. Concerning the strategy of generational product, early or delayed entry impact the firm's profit as well as the position of the firm. Thus, the second attribute is the total cost of production and promotion for the first generation of the product over the total investment that is available. Also, to note an organization always wish to invest less and reap more profit, hence the second attribute can be given as:

$$\text{Minimize}\, A_2 = \frac{C(t)}{C_B} \tag{10}$$

where $A_2$ represents the second attribute and the cost structure as given by Aggrawal et al. (2014) has been utilized.

$$C(T) = C_1N(T) + C_2(m - N(T)) + C_3T$$

where $C_1$ denotes the expenditure incurred on the production of the previous generational product before the launch of its succeeding version ($t \leq T$); $C_2$ represents the expenditure incurred on the production of the previous generational product after the launch of its succeeding version ($i.e \quad t > T$) and $C_3$ is the advertisement cost per unit time.

More specifically, each generation release began attracting a greater number of adopters initially and reach its peak value with time. This will lead to market saturation and declining interest of the customer and necessitates the upcoming of a new generation. Consequently, it is rational to presume adoption rate indicator to be the function of hazard rate $h(t)$ acts as an indicative parameter for deciding the launch of a new generation of the product, given as follows (Kapur et al., 2004):

$$h(t) = \frac{f(t)}{1 - F(t)}$$

For the analysis purpose, it has been assumed that $F(t) = \frac{1-e^{-bt}}{1+\beta e^{-bt}}$ and $f(t) = \frac{d}{dt}(F(t))$.

The third attribute $A_3$, representing the adoption rate indicator which is based on the rate at which adoption $h(t)$ occurs in a certain time interval $\left[t_1, t_2\right]$, is defined as the probability that an adoption occurring in the interval $\left[t_1, t_2\right]$, given that adoption has not occurred before $t_1$, which can be formulated as:

$$\text{Maximize}\, A_3 = \frac{h(t)}{h_{\max}} \tag{11}$$

where $h_{\max}$ being the maximum value of $h(t)$ that will be '1', as this quantity represents the probability. The hazard function reflects the picture of adoption changes over the product's life. The product adoption pattern and the rate that persuade the adoption are important aspects to understand the future adoption of successive generational products. Equations (9), (10), and (11) will be used for analysis purposes.

### 3.2.2 Formulation of utility functions for all attributes

In this subsection, the emphasis is on assigning values to utility functions. Each utility function corresponding to different attributes will be designed to signify the management's satisfaction level. These values can be determined on the extreme points for which considering the worst and best values for customer adoption behavior and indicator of adoption rate as $u\left(A^{\mathrm{W}}\right) = 0$ and $u\left(A^{\mathrm{B}}\right) = 1$ where $A^{\mathrm{W}}$ and $A^{\mathrm{B}}$ to represent the worst and best utility point. Similarly, for the formulation of cost-utility function, $u\left(C^{\mathrm{W}}\right) = 0$ and $u\left(C^{\mathrm{B}}\right) = 1$ corresponds to lowest and highest budget consumption. To establish the functional form of utility functions either an additive or exponential form can be used which is:

$$u(x_i) = b \cdot x_i + a \; or \; u(x_i) = b \cdot e^{k \cdot x_i} + a \tag{12}$$

where $a$, $b$ and $k$ are constant parameters that secure the normalization of utilities between 0 and 1, i.e., $u(x_i) \in [0, 1]$.

### 3.2.3 Estimation of scaling constants

The estimation of weights parameters corresponding to three attributes be represented by $w_{A1}, w_{A2}$ and $w_{A3}$ which indicate the importance given to each attribute. Basically, in the literature, the researchers (Anand et al., 2014) have talked about the existence of two common methods for assessment of weights viz. deterministic and probabilistic approaches. As in the present work, only three attributes are considered, probabilistic scaling technique has been used wherein $w_{A1} + w_{A2} + w_{A3} = 1$.

### 3.2.4 Optimization structure of multi-attribute utility function (MAUF)

Considering the recently assessed utility functions and scaling constants, picking the MAUF form is significant. MAUF is a blend of utilities of various attributes alongside their importance. The MAUF is the objective that needs to be maximized. We have examined three functional forms of MAUF. The generally applied design of MAUF is an additive linear form of utility with their weights and two other nonlinear types of MAUF which have been examined above given in Eqs. (6), (7), and (8).

Weighted arithmetic utility function (WAUF) can be given as:

$$U\left(A_1, A_2, A_3\right) = w_{A_1} \times u\left(A_1\right) + w_{A_2} \times u\left(A_2\right) + w_{A_3} \times u\left(A_3\right) \tag{13}$$

Weighted geometric utility function (WGUF) can be given as:

$$U\left(A_1, A_2, A_3\right) = u\left(A_1\right)^{w_{A1}} \times u\left(A_2\right)^{w_{A2}} \times u\left(A_3\right)^{w_{A3}} \tag{14}$$

Weighted harmonic utility function (WHUF) can be given as:

$$U\left(A_1, A_2, A_3\right) = w_{A_1} \times \frac{1}{u\left(A_1\right)} + w_{A_2} \times \frac{1}{u\left(A_2\right)} + w_{A_3} \times \frac{1}{u\left(A_3\right)} \tag{15}$$

where $w_{A_1} + w_{A_2} + w_{A_3} = 1$ and they represent the associated importance corresponding to all three different attributes. The $u(A_1)$, $u(A_2)$, and $u(A_3)$ utility function for customer's adoption behavior, cost of production and promotion, and the adoption rate. From the general perspective, for customer's adoption behavior and the adoption rate needs to be maximized whereas the cost of production and promotion needs to be minimized. To align the different notions, convert minimization cost-utility by multiplying "–" the sign before the cost-utility form. By maximizing MAUF's, the optimum time to release $T*$ will be obtained.

## 4 Case study

With the help of the sale data from the first release of the DRAM data set (Victor & Ausubel, 2001), a choice model for computing the launch time of the successive generation is presented here.

## 4.1 The data set

The data consists of six generations (Victor & Ausubel, 2001), 4 K, 16 K, 64 K, 256 K,1 M, and 4 M of DRAM collected from 1974 to 1997. Here, only first-generation has been used and based on which the introduction time for the next generation of the product has been determined making use of MAUT. Table 1 contains the parameter estimation for the first generation of the product.

## 4.2 Formulation of the utility function for all attributes

Using the managerial experiences, the single utility function for each attribute is computed by the method suggested in Sect. 3.2.2. Assuming the management scenarios in our application example are as follows:

- From the managerial perspective, the risk-neutral attitude for each attribute has been demonstrated.
- For the customer adoption behavior criterion, the administration has confirmed that at least 70% of the population must have adopted (as higher the adoption level the more desirable it becomes); its highest expected value is 100%. The highest value is attained when the maximum sale of the product is reached (see Fig. 1). The lowest customer adoption is $A_1^{\mathrm{W}} = 0.7$ and the highest customer adoption for the base product are considered as $A_1^{\mathrm{B}} = 1$
- Accordingly, the production and promotion cost aspirations are on the lower front that is the managers always wish to minimize the investment being done in the product and promotional cost. But at the same time, a handful amount is always spent which cannot be decreased below a certain limit and increased on the higher front. Thus, the lowest budget consumption requirement is $A_2^{\mathrm{B}} = 0.2$ and the highest budget consumption is $A_2^{\mathrm{B}} = 0.6$.
- Additionally, the lowest adoption rate indicator is $A_3^{\mathrm{W}} = 0.2$ while the highest adoption rate indicator for the product is $A_3^{\mathrm{B}} = 0.5$.

The linear form of the utility function is chosen, based on management's risk-neutral attitude toward these three attributes, and its simple structure is obtained using Eq. (12) parameters *a* and *b* are determined. The functional form can be given as follows:

Customer adoption behavior attribute single utility function

$$u(A_1) = \frac{10}{3}A_1 - \frac{7}{3};$$

Production and promotional cost attribute single utility function

**Table 1** Parameter estimation of data set

| Parameters | |
|---|---|
| $m$ | 341.05 |
| $b$ | 0.980 |
| $\beta$ | 55.53 |

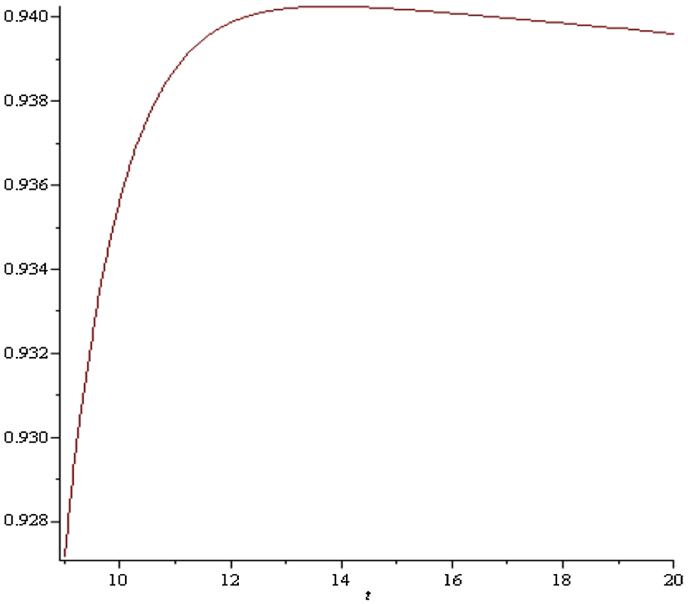

**Fig. 1** Utility graph for arithmetic functional form

$$u(A_2) = \frac{10}{4}A_2 - \frac{1}{2};$$

Adoption rate indicator attribute single utility function

$$u(A_3) = \frac{10}{3}A_3 - \frac{2}{3};$$

Based on organization cost evaluations, we assume that $c_1 = 150,\ c_2 = 180,\ c_3 = 50$ and the amount of budget ($C_b$) for DRAM is 500000 units of currency. The weight parameter considered here are subjectively used $w_{A_1} = 0.3$; $w_{A_2} = 0.5$; and $w_{A_3} = 0.2$. Lastly, using the assessed single utility functions and the weight parameters, the three different functional forms of MAUF are evaluated using Maple package software., obtained results are supplied in Table 2. Figures 1, 2, and 3 shows the MAUF for all three structures.

According to the results obtained, the maximum utility and introduction time is achieved for WAUF. Suggesting that the second generation of the product should be introduced in the 14th week for the successful growth of the first-generation product in the marketplace. Also, the result obtained shows the supremacy of the WAUF over the other two functional forms WGUF and WHUF.

**Table 2** Utility assessment result

| MAUF structure | Optimal release time | Utility value |
|---|---|---|
| WAUF | 13.78 | 0.940 |
| WGUF | 12.12 | 0.594 |
| WHUF | 10.81 | 0.408 |

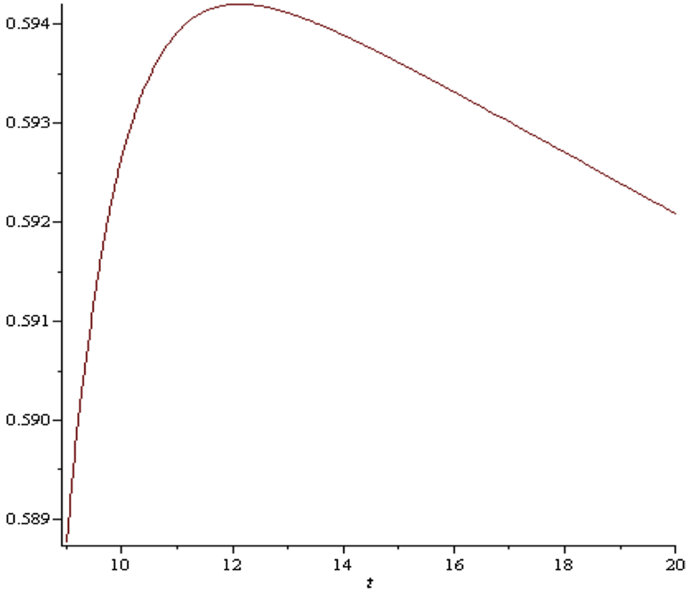

**Fig. 2** Utility graph for geometric functional form

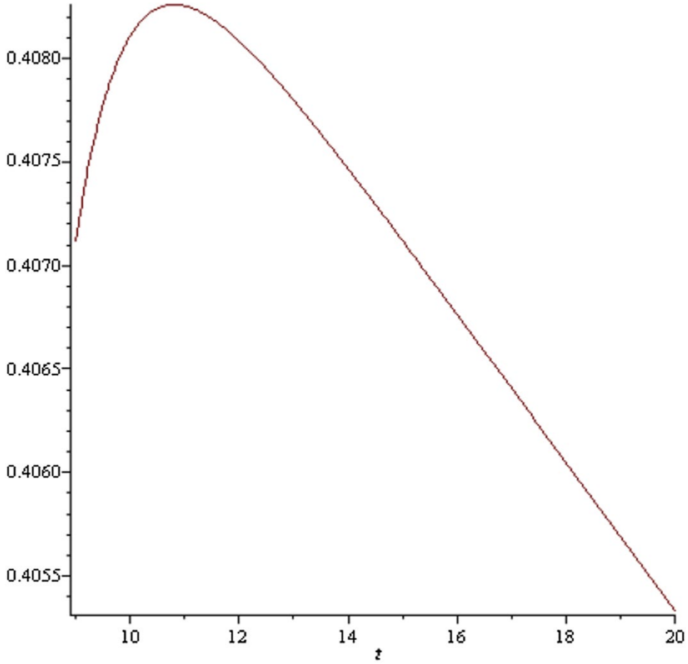

**Fig. 3** Utility graph for harmonic functional form

## 5 Discussion

### 5.1 Research contribution

The dynamic nature of the market is continuously increasing pressure on decision-makers to come up with newer products. It becomes quite imperative for decision-makers to launch the product in such a way that its existing generation has catered to a substantial market share. The work contributes to well-known innovation diffusion process-based decision model for examining the strategic decision which an organization can take for deciding the launch time for its newer generational product. The approach presented here is based on using three conflicting attributes and help in guiding the decision-maker in determining the launch time of successive generation based on customer adoption behavior, adoption rate indicator, and cost perspective.

### 5.2 Implications for practice

For survival in the marketplace, it has become quite imperative for decision-makers to introduce advanced products which can fulfill customers' expectations at the same time generate greater profits for the company. In the competitive world, the managerial concern includes explaining how generational products go up against one another. There are two types of competition that one generation faces that is the competition from the existing generation of the same product and with other competitors offering a similar product. Several generations compete in terms of catering to many adopters and at the same time impact each other's performance in the market. It is significant for any firm to concentrate on optimum launch time for generation product(s). The choice related to early or late introduction depends on understanding the determinants of customer expectations.

Early entry impacts the prior existing generation and eventually, the presence of both will cannibalize the sales, whereas too late entry will lead to trailing down the market opportunity that can result from the competitor's presence in the market. Thus, the tradeoff which should be performed in the decision model is significant and selection criteria form the base in decision making. The optimization model talked about in this article considers that the second version of the product will be presented in the market based on three conflicting attributes which are of utmost importance to any organization. The market presence and advertising play a significant role in generating revenue for any organization and knowing the optimal introduction time can help in managing the same effectively and efficiently.

### 5.3 Limitations and future research directions

The idea has been validated on consumer durable products. It would be interesting to know how the methodology works on another category of products. Further, the parameters and the functional form of utility function have been studied in the crisp environment that can be extended to include the uncertainly that commonly exists in the marketplace.

## 6 Conclusion

The strategy behind the launching of any new generation has always been a million-dollar question for almost every organization. For most of these organizations minimizing cost or maximizing adoption, of their product has been the basic tradeoff they have dealt with. From an administrator's perspective, it is basic to comprehend the ideal span between the introduction of different versions of the product that can address both the expenses incurred and market adoption limitations. The fundamental thought behind the launch of the progressive product is to catch the advantages of advances made by the association's innovative work division as far as creating new highlights, upgrading the product configuration, delivering innovation, and so on. In this manner, to get the serious edge it is basic to realize the ideal time for the launch of the generational product. In this investigation, we discover three ascribes as customer's adoption behavior, adoption rate indicator, and cost which affect the timing of introduction of the new generation. For compromises between these ascribes, MAUT has been used.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

## References

Agarwal, M., Aggrawal, D., Anand, A., & Singh, O. (2017). Modeling multi-generation innovation adoption based on conjoint effect of awareness process. *International Journal of Mathematical Engineering and Management Sciences, 2*(2), 74–84.

Aggrawal, D., Anand, A., Singh, O., & Kapur, P. K. (2015). Modelling successive generations for products-in-use and number of products sold in the market. *International Journal of Operational Research, 24*(2), 228–244.

Aggrawal, D., Singh, O., Anand, A., & Agarwal, M. (2014). Optimal introduction timing policy for a successive generational product. *International Journal of Technology Diffusion (IJTD), 5*(1), 1–16.

Anand, A., & Bansal, G. (2016). Predicting customer's satisfaction (dissatisfaction) using logistic regression. *International Journal of Mathematical Engineering and Management Sciences, 1*(2), 77–88.

Anand, A., Singh, O., Aggrawal, D., & Singh, J. (2014). An interactive approach to determine optimal launch time of successive generational product. *International Journal of Technology Marketing, 9*(4), 392–407.

Arslan, H., Kachani, S., & Shmatov, K. (2009). Optimal product introduction and life cycle pricing policies for multiple product generations under competition. *Journal of Revenue and Pricing Management, 8*(5), 438–451.

Bansal, G., Anand, A., & Agarwal, M. (2021b). Modeling the impact of remanufacturing process in determining demand-cost trade off using MAUT. *American Journal of Mathematical and Management Sciences, 40*(2), 120–133.

Bansal, G., Anand, A., & Aggrawal, D. (2021a). Modeling multi-generational diffusion for competitive brands: An analysis for telecommunication industries. *Journal of Management Analytics, 8*(4), 715–740.

Bass, F. M. (1969). A new-product growth model for consumer durables. *Management Science, 15*, 215–222.

Bass, F. M., Krishnan, T. V., & Jain, D. C. (1994). Why the Bass model fits without decision variables. *Marketing Science, 13*(3), 203–223.

Bayus, B. L. (1992). Have diffusion rates been accelerating over time? *Marketing Letters, 3*(3), 215–226.

Byambaa, T., Janes, C., Takaro, T., & Corbett, K. (2015). Putting health impact assessment into practice through the lenses of diffusion of innovations theory: A review. *Environment Development and Sustainability, 17*(1), 23–40.

Calantone, R. J., Di Benedetto, C. A., & Bhoovaraghavan, S. (1994). Examining the relationship between degree of innovation and new product success. *Journal of Business Research, 30*(2), 143–148.

Danaher, P. J., Hardie, B. G., & Putsis, W. P., Jr. (2001). Marketing-mix variables and the diffusion of successive generations of a technological innovation. *Journal of Marketing Research, 38*(4), 501–514.

Duan, Y., Edwards, J. S., & Dwivedi, Y. K. (2019). Artificial intelligence for decision making in the era of big data–evolution, challenges and research agenda. *International Journal of Information Management, 48*, 63–71.

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., & Williams, M. D. (2021). Artificial intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 57*, 101994.

Fisher, J. C., & Pry, R. H. (1971). A simple substitution model of technological change. *Technological Forecasting and Social Change, 3*, 75–88.

Gamerman, D., & Migon, H. S. (1991). Tractors in Spain--A dynamic reanalysis. *Journal of the Operational Research Society*, *42*(2), 119–124.

Huang, C. Y., & Tzeng, G. H. (2008). Multiple generation product life cycle predictions using a novel two-stage fuzzy piecewise regression analysis method. *Technological Forecasting and Social Change, 75*(1), 12–31.

Islam, T., & Meade, N. (1997). The diffusion of successive generations of a technology: A more general model. *Technological Forecasting and Social Change, 56*(1), 49–60.

Ismagilova, E., Rana, N. P., Slade, E. L., & Dwivedi, Y. K. (2021). A meta-analysis of the factors affecting eWOM providing behaviour. *European Journal of Marketing, 55*(4), 1067–1102.

Jeyaraj, A., & Dwivedi, Y. K. (2020). Meta-analysis in information systems research: Review and recommendations. *International Journal of Information Management, 55*, 102226.

Jiang, Z. (2010). How to give away software with successive versions. *Decision Support Systems, 49*(4), 430–441.

Jiang, Z., & Jain, D. C. (2012). A generalized Norton-Bass model for multigeneration diffusion. *Management Science, 58*(10), 1887–1897.

Johnson, W. C., & Bhatia, K. (1997). Technological substitution in mobile communications. *Journal of Business and Industrial Marketing, 12*, 383–399.

Kapur, P. K., Bardhan, A. K., & Jha, P. C. (2004). An Alternative formulation of innovation diffusion model and its extension. In V. K. Kapoor (Ed.), *Mathematics and information theory* (pp. 17–23). New Delhi: Anamya Publication.

Kapur, P. K., Chanda, U., Tandon, A., & Anand, S. (2010, December). Innovation diffusion of successive generations of high technology products. In: *2010 2nd International Conference on Reliability, Safety and Hazard-Risk-Based Technologies and Physics-of-Failure Methods (ICRESH)* (pp. 505–510)

Keeny, R. L., & Raiffa, H. (1976). *Decision with multiple objectives*. Wiley.

Kim, N., Chang, D. R., & Shocker, A. D. (2000). Modeling intercategory and generational dynamics for a growing information technology industry. *Management Science, 46*(4), 496–512.

Kuo, C. W., & Huang, K. L. (2012). Dynamic pricing of limited inventories for multi-generation products. *European Journal of Operational Research, 217*(2), 394–403.

Mahajan, V., & Muller, E. (1996). Timing, diffusion and substitution of successive generations of technological innovations: The IBM mainframe case. *Technological Forecasting and Social Change, 51*, 109–132.

Mahajan, V., Muller, E., & Bass, F. M. (1990). New product diffusion model in marketing: A review and directions for research. *Journal of Marketing, 54*, 1–2.

Mahajan, V., Muller, E., & Bass, F. M. (1993). New-product diffusion models. *Handbooks in Operations Research and Management Science, 5*, 349–408.

Mansfield, E. (1961). Technical change and the rate of imitation. *Econometrica Journal of the Econometric Society, 29*, 741–766.

Marchetti, C. (1977). Primary energy substitution models: On the interaction between energy and society. *Technological Forecasting and Social Change, 10*(4), 345–356.

Mazumdar, T., Sivakumar, K., & Wilemon, D. (1996). Launching new products with cannibalization potential: An optimal timing framework. *Journal of Marketing Theory and Practice, 4*(4), 83–93.

McKie, E. C., Ferguson, M. E., Galbreth, M. R., & Venkataraman, S. (2018). How do consumers choose between multiple product generations and conditions? An empirical study of iPad sales on eBay. *Production and Operations Management, 27*(8), 1574–1594.

Meade, N. (1985). Forecasting using growth curves—an adaptive approach. *Journal of the Operational Research Society, 36*(12), 1103–1115.

Norton, J. A., & Bass, F. M. (1987). A diffusion theory model of adoption and substitution for successive generation of high-technology products. *Management Science, 33*(9), 1069–1086.

Ofek, E., & Sarvary, M. (2003). R&D, marketing, and the success of next-generation products. *Marketing Science, 22*(3), 355–370.

Rogers, E. M. (1962). *Diffusion of innovations*. The Press.

Singh, O., Kapur, P. K., & Anand, A. (2012). A multi attribute approach for release time and reliability trend analysis of a software. *International Journal of System Assurance and Engineering Management (IJSAEM), 3*(3), 246–254.

Singhal, S., Anand, A., & Singh, O. (2019). SDE based generalized innovation diffusion modeling. *International Journal of Mathematical Engineering and Management Sciences, 4*(3), 697–707.

Singhal, S., Anand, A., & Singh, O. (2020). Studying dynamic market size-based adoption modeling & product diffusion under stochastic environment. *Technological Forecasting and Social Change, 161*, 120285.

Sohn, S. Y., & Ahn, B. J. (2003). Multigeneration diffusion model for economic assessment of new technology. *Technological Forecasting and Social Change, 70*(3), 251–264.

Song, X. M., & Parry, M. E. (1997). A cross-national comparative study of new product development processes: Japan and the United States. *Journal of Marketing, 61*(2), 1–18.

Speece, M. W., & Maclachlan, D. L. (1995). Application of a multi-generation diffusion model to milk container technology. *Technological Forecasting and Social Change, 49*(3), 281–295.

Sultan, F., Farley, J. U., & Lehmann, D. R. (1990). A meta-analysis of applications of diffusion models. *Journal of Marketing Research, 27*(1), 70–77.

Versluis, C. (2002). DRAMs, fiber, and energy compared with three models of market penetration. *Technological Forecasting and Social Change, 69*(3), 263–286.

Victor, N. M., & Ausubel, J. (2001). DRAMs as model organisms for study of technological evolution. *Technological Forecasting and Social Change, 68*, 1–20.

Von Neumann, J., & Morgenstern, O. (1947). *Theory of games and economic behavior*, 2nd rev.

Wang, X., Wang, Y., Lin, X., & Abdullat, A. (2021). The dual concept of consumer value in social media brand community: A trust transfer perspective. *International Journal of Information Management, 59*, 102319.

Wilson, L. O., & Norton, J. A. (1989). Optimal entry timing for a product line extension. *Marketing Science, 8*(1), 1–17.

Yang, Zz., Yu, S., & Lian, F. (2021). Online shopping versus in-store shopping and its implications for urbanization in China: Based on the shopping behaviors of students relocated to a remote campus. *Environment Development and Sustainability, 23*, 2846–2866. https://doi.org/10.1007/s10668-020-00649-6

Zhou, S., Barnes, L., McCormick, H., & Cano, M. B. (2021). Social media influencers' narrative strategies to create eWOM: A theoretical contribution. *International Journal of Information Management, 59*, 102293.

Zirger, B. J., & Maidique, M. A. (1990). A model of new product development: An empirical test. *Management Science, 36*(7), 867–883.

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