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Abstract

Through this paper, an attempt has been made to understand the impact of technological change in terms of product improvement, durability, and reliability, which are in turn affected by firm's marketing strategy under competition and its conflict with operations strategy. In order to survive in a competitive environment firms need to keep innovating. However, the continuous cycle of frequent improvement may require a flexible operations strategy, which would increase input costs. Understanding this conflict of making operations flexible, products durable, reliable and competitive, as demanded by the marketing strategy, while keeping the cost low and PLC longer, is the aim of this research work.

Keywords
Technological change, Marketing strategy, Operations strategy, Product life cycle

1. Introduction
Over the years, rapid technological advancement and cut throat competition, while leading to increased variety within the product line, has not necessarily led to increased profitability or market share (Ramdas, 2003). Additionally, this has led towards shortening product-life-cycle and wider customer demands (Bernardes & Hanna, 2009; Danneels, 2002). Therefore, product development needs to be innovative, quality oriented and low cost, as well as providing optimal value to the customers (Anderson & Joglekar, 2005). As a result, in order to achieve product competitiveness through quality, cost and optimal value, firms have started innovation of various typologies. Garcia & Calantone (2002) identify these as *Newness Factor* and observed that the most common typology for product innovativeness categorization is High/Medium/Low and Radical Breakthrough/Significant/Incremental technological change. In order to understand the impact of product innovation on an existing setup, this paper considers product innovation within the context of incremental technological change. The idea is to understand the impact in a continuum where the existing plant or the assembly line or the process are subjected to change because of innovation and hence, the flexibility of the plant needs to be looked into. Such an effort of developing a model is also stated as "Socially Optimal Cost-reducing R&D with Product Durability" (Goel, 2000). These models have been either studied through the marketing strategy perspective i.e. from the point of view of price, advertising, competition, timing between product introduction and modes of advertising such as word-of-mouth etc. (Easingwood, et al., 1983; Mahajan et al., 1990). The product advertising, cost or R&D, its impact on price and durability has been also studied through demand curves (Goel, 2007). The impact of improved product quality on durability and frequency

of replacement of one version of the product by the newer version has also been studied through durability and recyclability (Geyer et al., 2007; van Nes & Cramer, 2005). However, the improvement in the product in terms of operational parameters like reliability and durability and the required process flexibility alongside marketing parameters like advertising, price, competition, product introduction frequency, which are implications of product innovation, have not been studied together in a consolidated manner.

The current paper intend to discuss the various approaches used for product innovation. Furthermore, the paper uses the Bass Model and Product Life Cycle (PLC) analysis to discuss the product innovation and its absorption in the market. It discusses variations in the Bass Model due to parameters like advertising, competition, market size and price. The paper also attempts to identify the gaps in the areas that have not been addressed as other parameters of marketing strategy. Afterwards the impact of product innovation is studied in terms of product durability, recyclability and improvement in terms of bathtub curve, thereby identifying the unaddressed areas of operations strategy e.g. process and plant flexibility, for frequent product innovation. The overall focus of the paper is to understand the optimal mix of all these parameters to maximize the organizational profit.

2. Product Innovation – Approaches

Garvin (1984) describes quality through five different approaches, which are basically the varying perspective from philosophy, economics, marketing and operations management. He defines these approaches as,

a) The transcendent approach – which he meant as "innate excellence". He states that this innate excellence is absolutely recognizable as a mark of uncompromising standard and highest achievement, which cannot be quantitatively measured.

b) The Product-based approach – described as difference between ingredients or attribute of a product, which can provide a vertical dimension of desirability and can be quantitatively measured.

c) The user-based approach – based on the wants and needs of the user and their perceived image of the product, defined as ideal points in marketing, demand curve in economics and fitness for use in management.

d) Manufacturing based approach – concerned with engineering, R&D and manufacturing practices, it is basically confined to supply side of the production and consumption process. Sometimes also established as conformance to requirements, the approach attempts towards manufacturing efficiency as well as consumer's interest in quality. This can be concluded as to provide optimal output with most efficient resource inputs.

e) The Value Based Approach – it defines quality in terms of cost and prices. Prices reflect the affordable and acceptable prices and cost reflects the conformance to an acceptable cost. He defines the quality as affordable excellence.

Garvin (1984) also states that there is a potential conflict between the marketing strategy that uses the user-based approach and the operations strategy, which uses the manufacturing, based approach. While discussing the eight dimensions of quality he attempts towards correlating these dimensions with the marketing strategy of price and market share. This paper attempts towards analyzing the same, however it takes Product Life Cycle (PLC) concept as the basic premise to study the conflict.

The purpose of various operations management strategies (Lean manufacturing, Flexible manufacturing, just in time, agile manufacturing, focused factory, etc.) is to optimize the multiple objectives of the organizations (CONDOR, 1988). These multiple objectives are expected to be

sensitive to the market demands and economic conditions so that the product remains competitive throughout the Product Life Cycle (PLC). Hence, operations strategy in a manufacturing setup is always trying to match itself with the above discussed and to prepare itself for the investments needed for any slowdown or takeoff (Feitzinger & Lee, 1997; Golder & Tellis, 2004)). However, the operations strategy also needs to be sensitive and flexible enough to adapt to any technological change in the product, process or the inputs as the raw materials. Hayes and Wheelwright (1984) considered operations strategy with four dimensions – (a) capacity, (b) raw materials and supply chain, (c) technology and (d) process. Considering these four dimensions, the conflict is always in terms of either upgrading the existing plant or developing a new one, which can cater to these changing products, process or raw materials. However, innovation and diffusion are not always dependent on product characteristics, but are an outcome of economic condition (Corbett, 2008), market conditions, input materials and process characteristics, among others, thereby resulting in a unique operations strategy for each segment of product. Goyal & Netessine (2007) have described these as three dimensions of operations strategy - , production technology, which is basically either dedicated or flexible in nature and mostly deals with the process and the input, capacity investment, which deals with the plant size, product life cycle, sales and marketing and finally, the actual production that deals with the economic conditions, and product diffusion.

Gerwin (2005) categorizes these variables into two categories - time and range. Range is described as possibilities and a system is called flexible if it can adopt wider range of possibilities. Time signifies the minimum time frame within which these possibilities can be adopted. Gerwin (2005), describes operations strategy at two level, at one level it is performance driven and is closer to corporate strategy while the other level is concerned with specific methods of delivery. (Gerwin, 1993) categorized operations strategy in four generic strategies, namely adaptation, redefinition, banking and reduction, where adaptation meant adapting the environmental externalities or uncertainties (Gupta & Goyal, 1989; Klepper, 1996)) and adapting rival firm's technology and redefinition was to redefine market uncertainties or even the product definition. Banking was concerned with holding reserves for future needs. Gerwin (1993) further stated that other than reduction, the other three require flexibility for its success, thereby justifying the need for flexible operations strategy out of which two are PLC and product characteristics.

Hayes & Pisano (1996) studied the cost implication of flexibility in detail for short-run and long run. Their study differentiated the advantages of being a specialist; a broad range competitor and a lean competitor, thereby concluding that in the short run there is a tradeoff between cost and flexibility (Hayes and Pisano, 1996). Low cost and high flexibility cannot be achieved simultaneously and hence, a firm can either reduce the cost or decrease flexibility in the short-run or vice versa. However, both of them can be achieved in the long run, once initial short-run tradeoff has been successfully achieved. Hence, it could be stated that considering the various dimensions of product innovation, too frequent innovations might not necessarily lead to increased profitability. A highly flexible process setup to cater to frequent innovation would be cost prohibitive in nature, thereby not fit for the market or a less frequent innovation cycle would lead to loss of market, hence an optimal mixture of operational flexibility and product innovation supported by the marketing strategy would garner optimal profit for the firm.

In view of the earlier discussions, the following sections would discuss PLC, Innovation, Diffusion and other product and process characteristics and their relative impact on the operations strategy of the organization. This approach is closer to the user and manufacturing based approach (Garvin, 1984).

3. Impact of Technological Change on Quality

The main focus of innovation is to provide customers with better products at lower costs. However, innovation does not necessarily translate into better performance - contrarily, frequency of innovation and rate of diffusion are also important (Pae & Lehmann, 2003). The adoption of newer technology by the old user and the switching of prospective buyers of the old technology to the new technology have varied impact on the operations strategy of the firm which produces the older technology product (Product 1) and also the newer technology product (Product 2). This relative technological selection as well as relative adoption has been termed as intergeneration time as exhibited in Figure 1a and 1b (Pae & Lehmann, 2003).
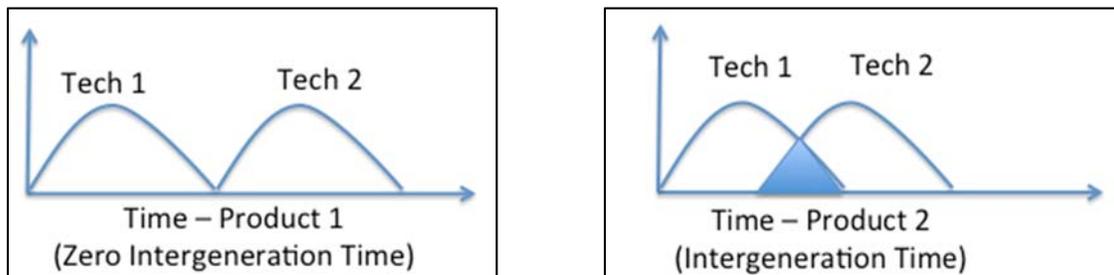

Figure 1a & 1b: Product introduction Type I & Type II
(Source; Pae & Lehmann, 2003)

Due to the ever-increasing frequency of innovation, marketing strategy attempts towards pushing the product in the market as prominently as it can. As a result it wants to achieve the diffusion stage as soon as possible. Since, continuous innovation by other firms makes the firm very unsure about the market during the product's maturity and decline phase, this leads towards optimizing the development, introduction and growth phase (Fig. 2). Hence, it could be hypothesized that:

H1 – Frequent technological innovation would reduce PLC, thereby would require flexible plant operations.

Klepper (1996) argues that evolution of an industry and operations strategy is a function of technological change & market structure, and varies from birth to maturity. However, unsure about the long-term product demand in the frequently changing market, the marketing strategy will try to optimize the market share in the initial product introduction stage only, thereby pushing the product in the market to increase volume. Their approach can be seen in Fig. 2.
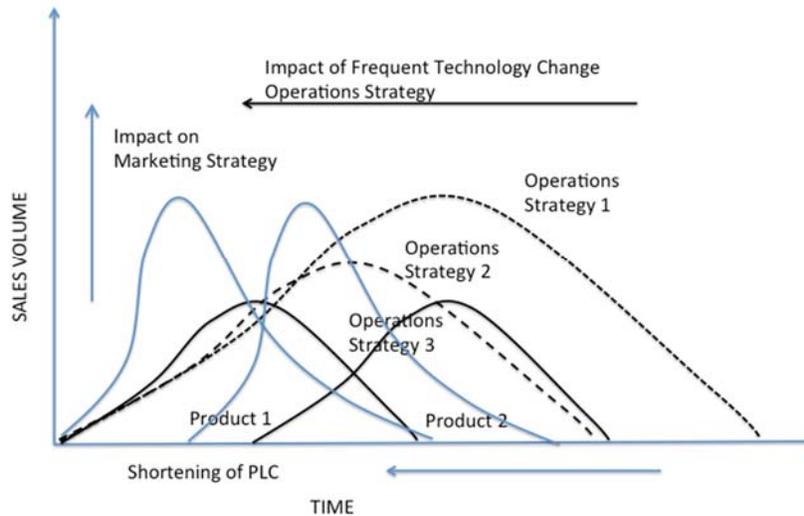
Figure 2: Joint Impact of Technology Change on Operations Strategy and Marketing Strategy
(Adapted from Bass, 2004; Easingwood et al., 1983 and Mahajan et al., 1990)

The phenomenon has been explained through the use of Bass Model and creating multiple variations. However, most of the times the variations have been used to add one specific dimension to the model to understand the sales of a certain product line. These dimensions are price, advertising, product inter-relationships, market size, repeat purchase and competition (Easingwood et al., 1983). Bass model states that technological products evolve generation after generation and hence, go through innovation, diffusion and cannibalism, among other processes, while reaching their sales peak at some point in time and finally go through decay. Using the model one can predict the sales of each generation by using time, and p and q as coefficients of innovation and diffusion respectively, p and q generally vary between 0 and 1 (Bass & Bultez, 1982). For a three-generation product the equations would be:

$$S_{1,t} = F(t_1)m_1[1 - F(t_2)] \qquad \dots\dots\dots\dots\dots\dots\dots\dots \text{(i)}$$
$$S_{2,t} = F(t_2)[m_2 + F(t_1)m_1][1 - F(t_3)] \dots\dots\dots\dots\dots\dots \text{(ii)}$$
$$S_{3,t} = F(t_3)[m_3 + F(t_2)\{m_2 + F(t_1)m_1\}] \qquad \dots\dots\dots\dots \text{(iii)}$$

Where, $m_i = a_i M_i$, where, a_i (represented as a fraction of total sale) is the average repeat buying and M_i is incremental number of ultimate adopters.

However, the basic Bass Model assumes the PLC to be symmetric, which is not always the case, as shown in Fig. 2. A possible reason for this might be the friction between the marketing and operations strategy. A possible explanation for this was provided by Easingwood et al., (1983) as imitation (Fig. 2) and introduced a new coefficient α *(0< α <1)* that took care of the imitation dimension.

4. Bass Model – Price Variation

Bass & Bultez (1982) discuss the variation in the Bass model due to price fixing on new product. They discuss that the marginal price needs to be dynamic in nature to capture the market and hence, providing the optimal price. According to them,

$$MC\,[\,E(t)\,] = \; C_1[E(t)]^{-\tau} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{ (iv)}$$

Where, *MC[E(t)]* is the cost of producing Eth unit, *E(t)* is the accumulated output at time *t*, C_1 scaling parameter and τ is experience and learning parameter and is always greater than zero. Using the modified equation (ii) in the form,

$$S(t) = \; m\,f(t) = \; m\,(a + bF(t))(1 - F(t)) \;\;\ldots\ldots\ldots\ldots\ldots\text{ (v)}$$

Where, *a* and *b* are replacements for *p* and *q* and *m* is the total no. of adopters over the life time of sales then,

$$S(t) = \; am \; + (b - a)E(t) - b/m(E(t))^2 \;\;\ldots\ldots\ldots\ldots\ldots\text{ (vi)}$$

Where, *E(t) = m F(t),* which is also the accumulated sales till time *t*

Hence, it could be hypothesized that,

H_3 – Technological Innovation reduces the product prices; however, high prices also push towards frequent technological innovation.

Bass & Bultez (1982) also state that, the optimal pricing of the product can also be identified through identifying the optimal accumulated profit through all the generations of the product, Hence, for the profit equation

$$\Pi = \Sigma_{t=0}^{T}\,\rho^t\,[p_t q_t - \; C_t] \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{ (vii)}$$

Where $\rho = 1/(1+r)$, where *r* is the rate of return for the product, p_t and q_t are price and quantity at time *t* and C_t is cost at time *t* (the profit would be accrued over a time period *T+1).* For optimal Profit the partial derivative of the function w.r.t. to price would be,

$$\partial\Pi/\partial p = \; \rho^t[p_t\partial q_t/\partial p_t + \; q_t] = 0 \ldots\ldots\ldots\ldots\ldots\ldots\text{ (viii)}$$

Here, q_t is nothing but sales between time t and t-1 which is actually *E(t) – E(t-1),* whereas $\partial q_t/\partial p_t$ is the rate of sales with unit change in price at price point p_t. This unit change in price would reflect the incremental innovation, along with the marginal cost. Hence,

$$\frac{\partial q_t}{\partial p_t} = \; -\,\frac{E(t)-E(t-1)}{p_t} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{ (ix)}$$

$$where\; p_t = FC + \frac{RD_1 - \; RD_0}{E(t)-E(t-1)} + \Pi\;(Per\;unit\;profit)\ldots\ldots\ldots\ldots\ldots\text{ (x)}$$

According to Goel (2000), optimal innovation $x^{\alpha_t} = RD_1 - RD_0$, where α_t is coefficient of technical opportunity, '*x*' is spend on R&D, and RD_1 and RD_2 are spend on R&D for respective time periods. Then considering a demand curve, which is negative sloping with quantity along X axis and R&D cost along Y axis (a case of optimal incremental innovation leading to more quantity sold),

$$x^* = \left[\frac{\alpha_t}{Slope}\right]^{\alpha_t/1-2\alpha_t} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\text{(xi)}$$

Then Optimal R&D x^*, is inversely related to the slope as well as quantity sold. Easingwood et al. (1983) provide the variation of Bass model to understand the impact of promotional activities. They state that through the equation,

$$z(t) = N(1 - e^{-\rho t})/(1 + \beta N e^{-\rho t}/\mu) \dots\dots\dots\dots\dots\dots\dots\dots \text{(xii)}$$

Where, $\rho = \beta N + \mu$, and, μ and β are a and b as coefficient of innovation and imitation. All $\mu, \beta, a,$ and b are greater than zero. They also state that the domination of advertising in terms of promotional activities over the product innovation and imitation can be seen when from the equation (vi) "b-a" < μ.

H₄ – High investment would lead towards frequent technological innovation. However, its relationship with optimal profit would be a non-linear one.

5. Bass Model and Competition

Eliashberg & Jeuland (1986) discuss the impact of competition, with shift from monopoly to duopoly, and various levels of information and actions on the pricing strategy of a firm through the Bass Model. The model assumes that from time 0 to T_1, only one firm was functioning and second firm came into the market at T_1 only. Hence, the profit equations for the two firms would be:

$$\Pi_1 = \int_0^{T_2}(p_1 - c_1)x_1 dt \dots\dots\dots\dots\dots\dots \text{(xiii)}$$
$$\Pi_2 = \int_{T_1}^{T_2}(p_2 - c_2)x_2 dt \dots\dots\dots\dots\dots \text{(xiv)}$$

Where, cumulative sales $x = x_1 + x_2$

Using this, the Bass Model basic equation and the Game Theory based on the strategy adopted by the firm in case of introduction of competition, the authors derive price model, given through first order quadratic differential equation system

$$\frac{dp_i}{dt} = A_i p_i^2 + B_i p_i p_j + C_i p_j^2 + D_i p_j + E_i p_i + F_i \dots\dots\dots\dots\dots\dots \text{(xv)}$$

Where $i, j = 1, 2$

This equation can be further modified based on the number of firms and strategy they adopt.

H₅ – High level of competition would push towards technological innovation; however, high competition would also reduce the profit margins.

6. Durability, Repeat Purchase and Bass Model

Lilien, Rao, & Kalish (1981) discuss the sales, price and marketing efforts in a repeat purchase environment, however, their study considers the services aspect and the subsequent

repeat customers. Mahajan & Peterson (1978) discuss the impact in terms of controllable/uncontrollable and exogenous/indigenous factors. Few of those factors are socio-economic condition, social system, population increase/decrease, government actions and marketing efforts. However, impact of improved product durability and hence, changes in repeat purchases has not be addressed as part of Bass Model variation. Additionally, there is a lack of research work which considers the effects together. Since, products and their markets, influence the firm's strategy i.e. marketing and operations strategies, various factors can be clustered among these two categories and their combined effect on the overall sales volume and their resistance to each other can be understood for frequent product innovation. The following section discusses the improved product and its implication on marketing and operations strategy.

7. Durability and Product Purchase Frequency

The marketing strategy, the operations strategy and innovation work towards improving the product quality. The improvement can be represented in terms of reliability and durability of the product. Improvement in quality would lead to a subsequent increase in the length of useful life of the product resulting in longer bathtub curve of the product, resulting towards less frequent purchase by the consumer (Fig. 3).
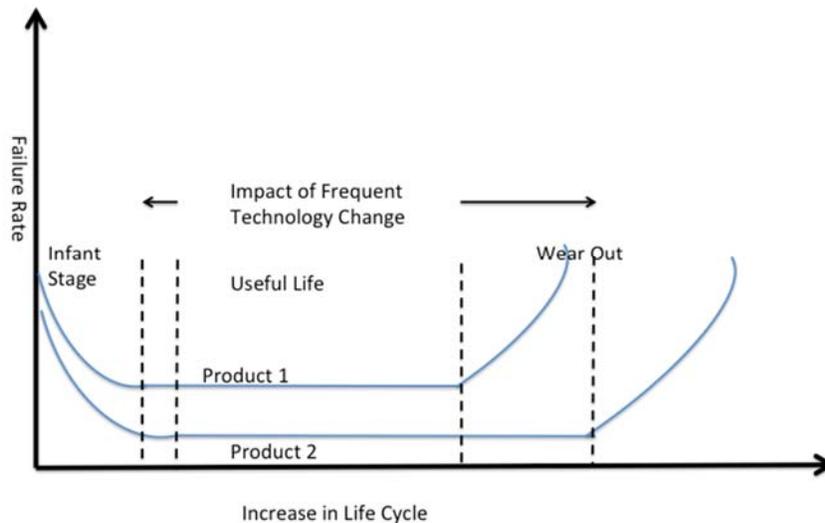

Figure 3. Impact of Improved Durability on Bathtub Curve
Source: (Klutke, Kiessler, & Wortman, 2003; Mishra, Pecht, & Goodman, 2002)

The reliability function in this case is given by Goel (2007) as:

$$h(t) = -\frac{1}{n_s(t)} \cdot \frac{d[n_s(t)]}{dt} \quad \text{.......................... (xvi)}$$

Where, $h(t)$ is the hazard/failure rate and $n_s(t)$ is the number of products surviving after time t.

H₆ - Frequent technological innovation would improve the quality and durability of the product and would reduce repeat purchases.

H₇ - Frequent technological innovation would improve reliability of the product and therefore would improve repeat purchases.

The competitive environment influences the marketing strategy to push for technological changes while keeping the costs low. This would result towards increased useful life of the product and reduced repeat purchase, thereby increasing $n_s(t)$ and hence, further reducing $h(t)$. Additionally, the continuous cycle of technological changes demands highly flexible operations strategy, which increases the cost of production. Sood & Tellis (2009) have also discussed this conflict of strategies, which is based on four dimensions of inter-technological competition - functionality, reliability, convenience, and cost. They argue that functionality is the main attribute for consumer selection. Since, functionality is a direct function of innovation and diffusion, it can be said that high innovation and high diffusion would require as operations strategy that is sensitive and flexible enough to accommodate the high frequency product innovation. However, organizations, which are continuously going under technological changes, may find the shifts in terms of product transition as well as production change, difficult to handle (Barnett & Freeman, 2001; Khessina & Carroll, 2008; McKendrick & Wade, 2010). Collins (2001) and Corbett (2008) argue that technology should be used as an accelerator and not as a creator of momentum. Meaning, innovation should be done to accommodate the production flexibility based on the market demand and should not always push towards creating market demand, thereby increasing risks of failure.

H₈ - Frequent technological innovation would require high plant flexibility and product push, thereby increasing marketing and operations strategy cost and hence, reducing profit margins.

Hence, a balance between level of innovation and flexibility of the operations strategy is needed for an organization to successfully exploit the existing products and future products PLC. Thereby understanding the value of the routine strategy and through learning, firms should become efficient for certain technology, as increased cost of operations used be justified because of the overall longer PLC where the profit was accrued over a longer period. However, in a competitive market strategy, the option of longer PLC for any product has very low probability. This leads a condition what a few of the authors have stated as marketing strategy moving towards conspicuous consumption of the product. Furthermore, other than the product specific reason for purchase a shift from the older product to the newer product can be termed as 'obsolesce reasons' and one of the major reasons were 'new consumer needs.' This specific reason 'new consumer needs' becomes even more important for today's consumer durables, where the obsolesce rates are high and technological improvement are rapid and frequent, and a plethora of marketing strategies that end up creating new consumer needs. It can be stated that, these product shifts are sub-optimal exchange point. van Nes & Cramer (2005) define this as lifetime optimization, where durability is not about extending the useful life but to optimize the efficiency during the lifetime. Other reasons that can be cited consists of company's economic interests, the actual design practice in the firm (where a firm may put too much emphasis on product innovation or not at all) as well as the timing of the replacement purchase. van Nes & Cramer (2005) further categorize the various reasons in three major categories that are product characteristics, situational influence and external influences & consumer characteristics.

They also states that there are four major replacement motives which are wear and tear, improved utility, improved expression and new desires, the first two are part of the operations strategy and the latter two are part of marketing strategy. However, in terms of durability the authors add two more dimensions that are reparability and upgradability which are defined as self-performed, less expensive improvement post breakdown and change of parts or modules for advance use. However, these remain mostly as customer's perspective having little or no implication on operations and marketing strategy. Eichner & Runkel (2003) state that durability may be inefficient in perfectly competitive economy, lacking externalities. Their work and the model developed, focuses more on durability and recyclability, and relate them to modularity and product weight. However, their model for overall life of the product and its recyclability can be modified for understanding the relationship between product innovation, flexibility, durability and overall organization profitability. According to them, if at time t, a virgin material $v(t)$ is extracted with help of labor $l_v(t)$ then the function would be;

$$v(t) = V[l_v(t)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{(xvii)}$$

For durable goods produced in quantity x(t), the production function would be;

$$x(t) = X[l_v(t), m(t)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xviii)}$$

Where, the durable is produced with input $l_v(t)$ labour and $m(t)$ material.
If weight of vintage unit left at time $t = m(t)$, then quantity;

$$q_x(t) = m(x)/x(t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{(xix)}$$

If ø (t) is the durability function, then

$$ø(t) = Ø[q_x(t)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\text{(xx)}$$

Then the decay function at age *'a'* for the quantity produced at time *t* can be written as

$$D[a, ø(t)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\text{(xxi)}$$

Then physical units scrapped at time *a* would be

$$1- D[a, ø(t)] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \text{(xxii)}$$

8. Conclusion

The value of equation (xxii) will impact the value of *h(t)* (equations (xi) and (xii)) Additionally, since *S(t)* is directly proportional to *E(t)* (equation (iv)) and *E(t) and E(t-1)* are inversely related to p_t which is directly related to profit and RD_1 and RD_0 (refer equation (x)), we can assume that there is an optimal mix of frequency of technological change – significant and incremental, in product innovation, production cost, durability of the product,

flexibility of the operations strategy towards product innovation, cost of R&D, marketing and similar other variable. The construct for the same has been shown in Fig. 4.

$$\Pi^* = g(D, h(t), RD, E(t), \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(xxiii)}$$
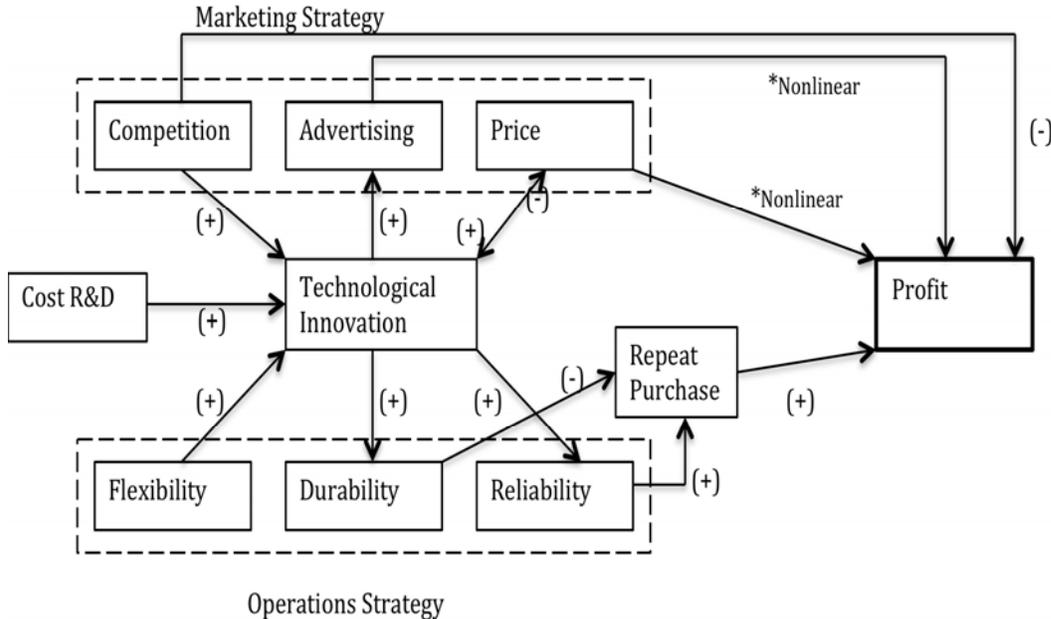

Figure 4: Technological innovation and marketing and operations strategy

The function (xxiii) along with the construct can provide what is the optimal level of profit for a certain firm at certain level of innovation for a certain kind of product category. A longitudinal study of an organization may provide the direction in which the organization should move in terms of technology management, and will reduce the conflict between marketing strategy and operations strategy. Some of the additional variables for future scope of research could be the number of innovations per year within the same product line, average no. of years spent with the customer (actual user life) vis a vis average number of years as per the product design (durability, designed life from bath tub curve), effect of the eco-system for the product (network effect), cost of flexible operations management (Plant life and designed for number of new product introduction per year) and profit per product, to name a few.

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