THE IMPACT OF PRODUCT VARIETY ON BUSINESS OPERATIONS IN THE SUPPLY CHAIN: A LITERATURE REVIEW

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ABSTRACT

Companies are continuously trying to increase market share and profits by increasing customer satisfaction through the variety in the products they offer. In this paper, we study the impact of product variety on several business operations in the supply chain through literature review. By study of literature, this paper presents the benefits and drawbacks of increasing product variety on functions performed in several departments, such as marketing, logistics, purchasing, engineering, and manufacturing. It also provides a brief overview of the various techniques like modularity, lean manufacturing, component sharing, and platform based development, which are helpful in reducing the costs, when designing for variety. Future research directions are discussed.

INTRODUCTION

Recently, companies are increasing variety in their products to gain more market share and to be competitive in the global market where customers' preferences to products change rapidly and customers would like to buy just what they need or want. In the U.S. automotive market, the number of models offered increased from 84 in 1972 to 142 models in 1989 (Fisher et al., 1996). By increasing product variety in style, function, package, size, and so on, it may be possible to satisfy customers more, resulting in enhanced competitiveness and more market share in the market. Even though increasing product variety might have a potential to increase sales, it has its share of drawbacks so that it might not be profitable. Thus, a challenge faced by companies today is to offer variety in order to satisfy customer's wants while maintaining the competitive price and quality.

Increasing product variety might have strong impact on a firm's business operations. However, more product variety may increase the manufacturing costs and complexity. Increasing product variety causes higher complexity of demand forecasting and matching of supply with demand in the supply chain (Whang and Lee, 1998; Ulrich and Randall, 2001). Therefore, companies increasing variety in their product lines should also

understand the impact of product variety on all relevant costs and the various functions performed by its manufacturing, marketing, logistics, purchasing, and engineering departments. Thonemann and Bradley (2002) developed a model for analyzing the effect of product variety on supply chain performance for a supply chain with single manufacturer and multiple retailers. Silveira et al. (2001) surveyed the literature on mass customization and discussed enablers to the mass customization and its impact on the development of production systems. In a recent literature review, Ramdas (2003) discussed key issues on variety-creation decisions and variety-implementation decisions. Previous research indicated the impact of product variety on businesses functions fragmentally. Until now, the research mostly focused on the impact of product variety on individual functional areas or in only one industry.

Thus, it is timely to extensively study the impact of product variety on various business operations. This research will show a comprehensive list of past research appeared in the literature, the positive or negative impacts of product variety on various business functions, and finally, will discuss the directions for future research.

DEFINITIONS AND DRIVERS OF PRODUCT VARIETY

There are several definitions of product variety available in the literature. Ulrich and Randall (2001) defined product variety as the number of different versions of a product offered by a firm at a single point in time. Fisher et al. (1999) stated that product variety can be defined in two dimensions: the breadth of the products that a firm offers at a given time and the rate at which the firm replaces existing products with new products. Martin (1999) defined two types of variety: spatial variety and generational variety, where spatial variety indicates the variety that a company offers the marketplace at a point in time, and generational variety means variety across future generations of products.

Various drivers of product variety are classified in Table 1, based on market segmentation and product characteristics. Geographical, Lingual, and Demographical segments are referred from (Kotler, 2003).

Table 1. Drivers of Product Variety

1. Based on Market Segmentation	
Geographical	Regions, Countries, States, and Cities
Demographical	Age, Gender, Occupation, Income, Family size, Occupation, Education, Religion, and Social Class.
Lingual	Language
Psychographical	Lifestyle, Personality, and Values
2. Based on Product Characteristics	
Form	Size, Shape, and Structure
Feature	Options provided
Style	Color, Appearance
Technology	Changes in technology
Functionality	Functions performed
Materials	Material used

IMPACT OF PRODUCT VARIETY ON BUSINESS OPERATIONS

Several functions in a firm have directly related to product variety, as illustrated in in Figure 1. A marketing department in a firm usually plays a main role to determine what customers want and need. However, the degree of product variety in a product line should be a crossfunctional decision, and further company's strategic decision because it will directly affect the company's sales. In this section, the impact of product variety on the various functions will be thoroughly investigated through literature review.

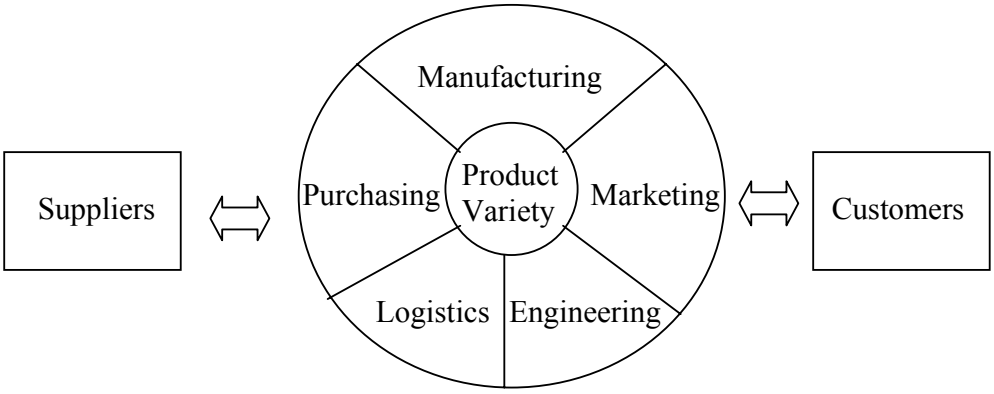

Figure 1. Business Functions Affected by Product Variety

Marketing

Consumers are the ultimate source for demand for product variety, as each individual has preference for different product variants (Ho and Tang, 1998). Companies try to satisfy these demands by offering a wide range of products. Multi product firms offer a variety of choices in a single product category to capture the surplus of consumers who may have heterogeneous quality valuations, tastes or budget constraints (Hui, 2003). Companies, which try to satisfy the rapidly changing needs and wants of consumers quickly with appropriate products have advantage over their competitors (Dertouzos et al., 1989; Stalk and Hout, 1990).

Many companies expand their brands by introducing more products to compete for higher market share. Hui (2003) stated that setting aside manufacturing costs, Bayus et al. (2003) found that product line extension (new product introduction) increases PC firms' profitability through reductions in selling, general and administrative (SG&A) expenses, and other marketing and advertising costs. Even though initially increasing variety improves sales and profits, the law of diminishing returns means the benefits do not keep pace (Child et al., 1991). In the case of mature firms, increase in variety does not increase the total demand, but firms increase variety to retain market share (Rajagopalan and Swaminathan, 2001).

Offering products, which do not satisfy the customer needs, might not increase the market share, but might adversely affect the costs. Marketers have to be careful in assessing the customers needs, since, increasing product variety increases the costs and complexity in manufacturing (Alford et al., 2000). Higher product variety also evokes the complexity of demand forecasting and matching of supply with demand in the supply chain. Thus, companies must assess the level of variety at which the customer's will find the offerings attractive, and the level of complexity that will keep the costs low (Jiao et al., 1998). Martin and Ishii (1996) develop a tool that helps product managers in estimating the cost of introducing variety into their product line. This tool will help managers to maximize the market coverage while maintaining required profit margins. Various marketing operations that are impacted by product variety are presented in Table 2. The notations used in this table are described below the table. These notations will be used in the tables in the following sections.

Table 2. Impact of Product Variety on Marketing

Customer Satisfaction	I	Kekere & Srinivasan, 1990; Yeh and Chu, 1991; Khan, 1998.
Market Advantage/ Market share	I	Tang and Yam, 1996; Kekere & Srinivasan, 1990; Bayus et al., 2003
Competitive advantage	I	Tang and Yam , 1996; Martin et al., 1998; Yeh and Chu, 1991
Profitability	I	Bayus et al., 2003
Demand Forecast uncertainity/complexity	I	Whang and Lee, 1998; Ulrich and Randall, 2001; Er and MacCarthy, 2003; Fisher et al., 1995

[Notations] I- Increases; D-Decreases; IS-In significant; SI- Slight increase; FI-Favorable impact; NI- Negative impact; NNI-No negative impact, LNI-Little negative impact

Logistics

Increasing variety has impact on various logistics operations and costs . Variety incurs many indirect costs, such as raw material costs, work-in-process, finished goods, and post-sales service inventories, and logistics costs that are difficult to capture, and are often neglected when making the decision about introducing variety (Martin and Ishii, 1996). Due to the uncertainty in forecasting demands, a firm offering more variants usually tends to carry more finished goods inventory than a firm with less variants.

Increase in variety increases the inventory levels and inventory costs (Ittner and Fisher, 1999; Thonemann and Bradley, 2002). The introduction of new products increases the number of SKU's over product life cycle. Increasing variety also increases the inventories of purchased and semi-finished parts (Forza and Salvador, 2001). Benjaafar, et al. (2002) examined the effect of product variety on inventory-related costs, and showed that total cost increases linearly with the number of products. In contradiction to the above general perception, Rajagopalan and Swaminathan (2001), using a mathematical programming model, show that if the plant has the ability to acquire

additional capacity, increasing product variety may not result in excessive inventory, and the total inventory costs are insignificant. Er and MacCarthy (2003) also asserted that increasing variety alone does not have a significant impact on the average of total inventory. They stated that the average of total inventory is affected highly by the uncertainty in supply delivery time.

Increasing variety increases the inventories of purchased and semi-finished parts (Forza and Salvador, 2002). As the product variety increases the variety in purchased parts and materials also increases (Fisher et al., 1999; Forza and Salvador, 2002). Increase in part/ material variety may lead to uncertainity in delivery times (Fisher and Ittner, 1999). Er and MacCarthy (2003) suggested that the negative impact of variety driven material variation in the supply chain can be reduced through standardization of materials, and by arranging service level agreement between manufacturer and buyer. Commonizing raw material parts also reduces the part count. This allows the supplier to deliver higher volumes with fewer part numbers (Jina et al., 1997). The impacts of product variety on various logistics operations are presented in Table 3.

Table 3. Impact of Product Variety on Logistics

Work-in-process inventory	I	Yeh and Chu, 1991
Finished goods inventory	I	Yeh and Chu, 1991; Ulrich and Randall, 2001
Inventory costs	I	Fisher and Ittner, 1999; Martin and Ishii,1996; Thonemann and Bradley, 2002; Benjaafar et al., 2002
	IS	Rajagopalan and Swaminathan, 2001
Purchased Parts inventory/ Parts inventory	I	Forza and Salvador, 2002; Jina et al., 1997
Inventory levels	I	Anderson, 1995; Child et al., 1991; Fisher and Ittner, 1999; Flynn and Flynn, 1999; Forza and Salvador, 2002; Kotteaku et al., 1995; Miller and Vollmann, 1985; Prasad, 1998; Fisher et al., 1995; Yeh and Chu, 1991
	IS	Er and MacCarthy, 2003
Delivery time	I	Anderson, 1995; Child et al., 1991; Fisher and Ittner, 1999; Flynn and Flynn, 1999; Forza and Salvador, 2002; Kotteaku et al., 1995; Miller and Vollmann, 1985; Prasad, 1998
Component Inventory	I	Krishnan and Gupta, 2001; McCutcheon, 1994
Material inventory/handling/ costs	I	Yeh and Chu 1991; Fisher et al., 1995; Abegglen and Stalk, 1985
Market Mediation Costs	I	Fisher et al., 1996

Purchasing

Increase in variety increases the purchasing costs (Ulrich and Randall, 2001). The increase in purchasing overhead costs might not be significant when e-purchasing is used as opposed to using traditional purchasing processes. The increases in purchasing costs are mainly attributed to the increase in variety and reduction in volumes of purchased parts and components (Fisher et al., 1999). As product variety increases, the volume is split among multiple products and the quantity discounts in purchasing are unattainable (Ulrich and Randall, 2001). Forza et al. (2002) stated that suppliers may experience diseconomies due to component variety, with potential negative impact on component prices, delivery times, and component inventory levels (Krishnan and Gupta, 2001; McCutcheon et al., 1994). In high variety and low volume manufacturing, it is difficult to develop the most profitable partnership with the supplier, in terms of delivery quantity, frequency, and price (Jina et al., 1997). Carr and Pearson (2002) revealed that the purchasing/supplier involvement has a positive impact on strategic purchasing, and this purchasing has a positive impact on a firm's financial performance. The impacts of product variety on various purchasing operations are presented in Table 4.

Table 4. Impact of Product Variety on Purchasing

Purchasing Costs	I	Ulrich and Randall, 2001
Order Processing	I	Forza and Salvador, 2002
Purchased Component/Part Variety	I	Fisher et al., 1999

Engineering

Increasing variety increases the design workload connected to the development of numerous new product variants (Forza and Salvador, 2002). Introducing modular architecture, when designing for variety, increases flexibility in design and manufacturing through separation of subparts of products (Fujita, 2002). By pursuing modularity in the design of product family architecture, the negative impact of product variety on operational performance can be reduced (Forza et al., 2002).

Modular product design is the best way for achieving product variety. Modular approach enables to offer a great range of end products, while reducing the variety of components (McCutcheon et al., 1994; Alford et al., 2000). A competitive company must consider product families and generations and seek commonality between parts and subsystems (McDermott and Stock, 1994). Modularity in product design plays an important role in many activities: product cost, DFM/DFA, manufacturing cycle (flow) time, product flexibility, supplier capabilities, supply chain management issues, serviceability, and multi-generation product platform planning (Ishii, 1998).

The challenge is to introduce the high degree of product variety, while retaining low unit costs which have been achieved through mass production with a few standardized

products. Investments in new products include the costs of product development and production, and each new component has to be designed and tested, and requires investment in tooling (Fisher et al., 1999). An alternative way to reduce the unit costs is to share more common components among the variants of a product. So, firms can offer high variety in the market by component sharing while retaining low variety in their operations (Ramdas et al., 2003).

To manage the complexity of offering greater product variety, firms in many industries are considering platform-based product development (Krishnan and Gupta, 2001). Platforms, in their most general sense, are intellectual and material assets shared across a family of products. The advantages of using platform-based product development are reduced fixed cost of developing individual product variant, greater degree of reuse, better architecture, lower unit variable cost, quicker development of product variants, and increase in the optimal quality level of the product targeted by the high-end segment. However, the product platforms are not appropriate for all product and market conditions, and product-planning decisions are strongly impacted by the presence of platforms over design of low-end variants and under design of high-end products. Their results confirm that the platform-based development approach is more profitable than independent development of products. The impacts of product variety on various engineering operations are presented in Table 5.

Table 5. Impact of Product variety on Engineering

Design Complexity	I	Forza and Salvador, 2001
R &D cost	I	Yeh and Chu 1991
Unit cost of product	I	Hayes and Wheelwright, 1984
Engineering/ model changes	I	Yeh and Chu, 1991; Fisher et al., 1995

Manufacturing

Increasing product variety increases the costs and complexity in manufacturing (Alford et al., 2000). As product variety increases, the performance of the firm's internal operations decreases due to higher direct manufacturing costs, manufacturing overhead, delivery times, and inventory levels (Forza, et al., 2002). Increasing the variety level also generates a range of difficulties in ensuring operational efficiency (McCutcheon et al., 1994; Ahlstroom and Westbrook, 1999). A broader product line with corresponding low volumes for each item in the line can result in higher unit costs, mainly because of increases in overhead expenses (Hayes and Wheelright, 1984), and higher direct labor and material costs (Abbegglen and Stalk, 1985). Especially, if setup times are significant, the effect of product variety on cost is substantially greater than that suggested by the risk-pooling literature for perfectly flexible manufacturing processes (Thonemann and Bradley, 2002). However, using flexible tooling and fixturing can reduce increase in setup costs arising due to increase in variety (Fisher et al., 1996).

Banker et al. (1990) studied an auto component manufacturer and observed that product complexity had a significant impact on the cost of supervision, quality control, and tool

maintenance. In contradiction, research done by Fisher et al. (1996) in the automotive plant showed that the product complexity does not have a negative impact on quality and labor productivity, but there is a statistically significant negative effect of parts complexity on productivity. Using data from the U.S. bicycle industry, Ulrich and Randall (2001) showed how product variety can be matched with a supply chain structure. Increasing product variety within a supply chain increases both production costs (Stalk and Hout, 1990; Cooper, 1990) and market mediation costs (Fisher, 1996).

Yeh and Chu (1991) showed that broadening product lines increases firm's power to compete, but it also causes the firm to lose its cost advantage. On the other hand, the results of Kekre and Srinivasan (1990) showed that product variety has a small significantly favorable impact on direct costs and manufacturing costs. Using modern production technology and sophisticated operations management will only cause slight increase in these costs (Tang and Yam ,1996; Kekre and Srinivasan, 1990). Jaikumar (1986) observed that simply procuring flexible manufacturing systems is no panacea for handling the complexity arising from product variety. Management has an important role in making the entire production system flexible both by insuring that production scheduling, equipment setup, and maintenance policies support the effective utilization of flexible tooling, and by training workers in multiple skills so they can handle the demands of higher variety. Modularity can be a solution to the growing complexity in assembly processes cost (Baldwin and Clark, 1997).

Martin and Ishii (1996) developed a model that helps in understanding the true costs associated with providing variety. They tried to capture the indirect costs through the measurement of three indices: commonality, differentiation point, and set-up cost. Martin and Ishii (1997) developed qualitative and quantitative tools, which will help engineers in developing products with minimum costs. With increase in variety, assembly line task balancing becomes problematic, and parts planning and production-scheduling systems becomes complex (Fisher et al., 1996).

A recurring theme in popular management press is that marketing and manufacturing have conflicting objectives (Crittenden. et al., 1993). In contradiction to the common theme, Gupta and Srinivasan (1998) showed that it is not always true that marketing benefits from increase in product variety, whereas manufacturing pays the price due to higher production costs. To optimize product variety, the benefits of product variety have to be assessed compared with all the relevant costs. Focusing on make-to-order environment and using queuing models, Gupta and Srinivasan (1998) derived conditions under which an increase in product variety improves both individual product performance and system performance.

Jina et al. (1997) studied how lean manufacturing can be applied to high-variety and low-volume segments. Study in an automotive assembly plant by Fisher et al. (1996) provided partial support of the hypothesis that lean production plants are capable of handling higher levels of product variety with less adverse effect on labor productivity than traditional mass production plants.

Keeping the system as common as possible and postponing the commitment to variety requirements, commonly known as "late point differentiation or postponement," have been proven effective for appliances (Ishii et al., 1995) and computer peripherals (Lee and Tang, 1997), and many other industries. Using postponement increases flexibility and also improves the forecast accuracy for the demand of final products in the distant future (Whang and Lee, 1998). Forza, et al. (2002) provided empirical insights into the relationships among the type of modularity, product variety, and component sourcing decisions. They suggested that the appropriate type of modularity is component swapping modularity when product variety level is low, and production volume is high, whereas if the product variety level is high, and production volume is low, then the appropriate type of modularity is combinatorial modularity. They also showed how modularity is helpful in limiting the negative implications of product variety on operational performance. In Table 6, the various manufacturing operations that are impacted by increase in product variety are summarized.

Table 6: Impact of Product Variety on Manufacturing

Labor Productivity (due to Product Complexity)	NNI	Fisher et al., 1996
Quality	IS	Yeh and Chu, 1991
	(Quality Control Cost) I	Banker et al., 1990
	(Quality problems and rework) I	Fisher et al., 1995
	Quality (due to Product complexity) NNI	Fisher et al., 1996
Manufacturing Costs	I	Anderson, 1995; Child et al., 1991; Fisher and Ittner, 1999; Flynn and Flynn, 1999; Forza and Salvador, 2002; Kotteaku et al., 1995; Miller and Vollmann, 1985; Prasad, 1998; Yeh and Chu, 1991; Tang and Yam, 1996; Alford et al., 2000; Thonemann and Bradley, 2002
	FI	Kekre and Srinivasan, 1990
	SI	Tang and Yam,1996
Production Costs	I	Stalk and Hout, 1990; Cooper,1990; Fisher et al., 1995; Bayus et al., 2003
No. of setups	I	Yeh and Chu, 1991
Set up costs	I	Fisher and Ittner,1999

Manufacturing Flexibility	I	Silveira,1998.
Process variety	I	Yeh and Chu, 1991
Part Variety	I	Yeh and Chu, 1991
Manufacturing Complexity	I	Alford et al., 2000; Yeh and Chu, 1991
Direct Labor costs	I	Abegglen and Stalk, 1985
Supervision effort	I	Yeh and Chu, 1991 Fisher et al, 1995
Scheduling Complexity	I	Yeh and Chu, 1991; Fisher et al., 1995
Material costs	I	Abegglen and Stalk,1985; Tang and Yam, 1996
Part Complexity	NI	Fisher et al., 1996
Productivity (due to Product Complexity)	NI	Fisher et al., 1996
Overhead costs	I	Stalk, 1988; Fisher et al., 1995; Tam and Yang, 1996; Hayes and Wheelright, 1984; Fisher and Ittner, 1999

FUTURE RESEARCH DIRECTIONS

Most of the research focused on designing for product variety and the impact on manufacturing and engineering costs incurring due to variety. Various issues in marketing, manufacturing, and engineering are dealt with, but not much work has been done in the logistics and purchasing. There is a scope for research on how increase in product variety affects various purchasing activities. Carr and Pearson (2002) focused on the impact of purchasing and supplier involvement is helpful in increasing the profits, future research can focus on integrated study of purchasing, supplier involvement, and increase in variety. Not much work has been done on how product variety affects various logistics costs; specifically, transportation costs, warehousing costs, and packaging costs. Some theories were developed and proved based on research done and data collected in a single industry. These theories could further be researched in other industries. For example, most of the research on the impact of product variety on quality has been done in the auto industry.

Some research on the impact of product variety on inventory costs, production costs, and quality of the product revealed conflicting findings so that they can be investigated further. Fisher et al. (1996) found through their study in the automotive assembly plant that product complexity occurring due to increase in variety has no negative impact on the quality of products, whereas Banker et al. (1990) showed through their research in auto component manufacturer that product complexity has significant impact on quality control costs. Fisher et al. (1995) revealed through their field research in the auto industry that increasing product variety results in quality problems and rework. The general perception is that increasing variety increases the inventory costs, but Rajagopalan and Swaminathan (2001) showed that if the plant has the ability to acquire additional capacity,

increasing product variety may not result in excessive inventory, and the total inventory costs are insignificant.

CONCLUDING REMARKS

Increasing product variety has become an important strategy to increase market share, sales, and profits. This paper presents a comprehensive review on the impact of product variety on various business operations and some directions for future research. The thorough literature review reveals that past research studied the impact of product variety on businesses functions fragmentally, and mostly focused on the impact of product variety on individual functional areas or in only one industry. Thus, it should be cautious to use the research findings from a particular industry for other industries, and benefits shown in one business function through product variety may be diminished by increased costs or inefficiency in other functions that will be caused by the product variety. Before increasing the variety in their product lines, companies should also take into consideration all the relevant functions and operations effected by higher product variety. As mentioned in the above sections, increasing variety has significant positive as well as negative impacts on the manufacturing, inventory, engineering, and purchasing costs, and on the manufacturing and forecasting complexity. Therefore, companies should carefully assess both benefits and detriments from offering product variety throughout all relevant functions.

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