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MANAGING PRODUCT VARIETY: AN INTEGRATIVE REVIEW AND RESEARCH DIRECTIONS*

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Variety management has emerged as a crucial dimension of successful business practice. In this paper, I first provide a framework for managerial decisions about variety. Variety-creation decisions determine the amount, type, and timing of end-product variety, while variety-implementation decisions focus on the design and operation of internal processes and a supply chain to support a firm's variety-creation strategy. I organize variety-related decisions into four key decision themes in variety creation: 1) dimensions of variety, 2) product architecture, 3) degree of customization, and 4) timing; and three key decision themes in variety implementation: 1) process capabilities, 2) points of variegation, and 3) day-to-day decisions. I describe each theme and review the relevant literature on each theme, with a focus on research that provides insight to problems faced in practice. Finally, I identify untapped avenues for future research that would be of value to the practicing manager, paying special attention to interdependencies among decision themes.
(MANAGING PRODUCT VARIETY; PRODUCT VARIETY, PRODUCT CUSTOMIZATION; VARIETY CREATION; VARIETY IMPLEMENTATION; FUTURE RESEARCH STREAMS)

1. Introduction

Rapidly evolving technologies, global competition, and sophisticated customers have contributed to an increase in product variety in industries as diverse as cars, chemicals, and credit cards. However, simply increasing variety does not guarantee an increase in long run profits and can in fact worsen competitiveness (Ramdas and Sawhney 2001). Rather, how firms choose to *create* variety in their product offerings, and how the firm's functions and its supply chain are managed to *implement* variety, are key determinants of the success of this strategy. Because these issues are often hard to resolve, excellent management of product variety has increasingly become a source of competitive advantage (Meyer and Lehnerd 1997).

In this paper, I discuss the key issues faced in managing product variety and then review the literature in product development, marketing, and operations that contributes to variety management. I also refer selectively to the economics literature on variety. Unlike broader reviews of cross-functional research (e.g., Eliashberg and Steinberg 1993; Fitzsimmons, Kouvelis, and Mallick 1991; Griffin and Hauser 1996; Karmarkar 1996; Wind and Mahajan 1997), I focus exclusively on product variety. Further, I examine product variety from the firm's perspective, as opposed to the individual consumer's perspective, market-equilibrium,

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or social optimality perspective (for excellent surveys of other perspectives, see Kahn 1995; Lancaster 1990).

Managing product variety requires decision making at different organizational levels, over different time horizons, within and across functional and organizational boundaries, before and after product launch. Variety decisions are driven by a combination of inertia, historical precedent, ad hoc criteria, and rational decision-making. While the way in which these decisions are made varies greatly from one instance to another, a common set of decision themes appears to emerge in any comprehensive discussion about product variety. Conceptually, variety-related decisions can be viewed as focusing on how to *create* variety in a product line, and on managing a firm's processes and supply chain to *implement* variety. I find it useful to sort variety creation decisions into four key decision themes: 1) dimensions of variety, 2) product architecture, 3) degree of customization, and 4) timing. Similarly, variety implementation decisions can be sorted into three key decision themes: 1) process and organizational capabilities, 2) points of variegation or "decoupling," and 3) day-to-day decisions. These seven themes capture the spectrum of variety-related decision making and yet provide some focus to this wide arena.

Rather than examine variety management from a functional perspective, or a methodological perspective based on the use of specific decision techniques, I will use these recurring decision themes, and the interdependencies among them, to examine both the key practical issues and the research in variety management. I seek to provide an integrative framework for variety management based on these key decision themes, to discuss the research on variety using this framework, and to identify untapped areas for future research. This review is intended for researchers wishing to gain familiarity with the literature on variety management, with a view to contributing to this area. It is not intended to be exhaustive. Instead, I have attempted to identify a set of papers that spans the key decision themes encountered in managing variety, with a focus on papers that provide insight to the practicing manager. This perspective has received little attention in the existing literature on product variety and distinguishes this paper from earlier reviews (e.g., Lancaster 1990). It is because my focus is on research that aids the practicing manager that I have chosen to begin by attempting to understand the spectrum of variety-related decisions faced in practice. Starting instead with the research on variety would run the risk of missing important issues faced in practice that have not received research attention, or of focusing on streams of research on variety that may have little applicability or practical insight.

2. A Framework for Examining a Firm's Variety-Related Decisions

How do variety management, and the decision themes introduced above, fit within the broader context of the firm's long-term objectives? In a rational approach, firms should strive to balance the revenue and cost impact of variety decisions (Lancaster 1990) to maximize long-term profits. In my view, variety creation and variety implementation decisions impact revenues via two important criteria that mold customers' perceptions about a firm's products: *differentiation* and *variegation*. The term differentiation is used in the strategy literature (e.g., Porter 1985) to describe how a firm's products are distinct from those of competitors, along either price or non-price dimensions. Thus even a single-product firm can be highly differentiated in the marketplace. In contrast, I define variegation as describing how a firm's products are perceived as distinct from one another. Variety researchers have used the term differentiation somewhat arbitrarily, sometimes to describe competitive differentiation, and sometimes to describe what I call variegation. For clarity, I distinguish between these two important criteria.

A firm's variety creation and variety implementation decisions enable it to attain a certain *degree of synergy* among its products. Synergies may accrue from sharing of underlying product or process technologies, product function, components, production or distribution

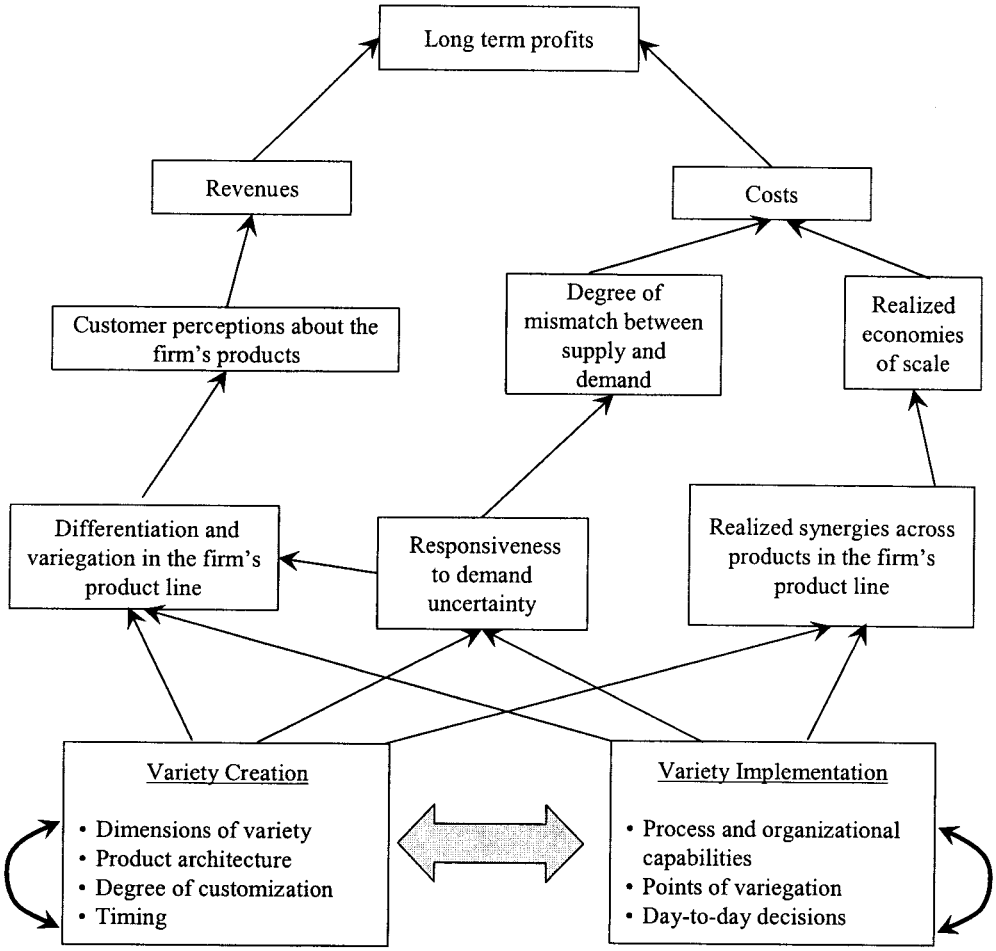

FIGURE 1. Framework for a Firm's Variety-Related Decisions.

processes, or knowledge about the needs of a customer segment. They enable the firm to realize economies of scale in design, production, distribution, and after-sales support; these in turn drive costs.

In addition, variety creation and variety implementation decisions determine a firm's *responsiveness* to demand uncertainty. For example, reducing lead-time by locating production geographically close to demand or by increasing manufacturing flexibility increases responsiveness. Responsiveness enables firms to reduce costs by better matching supply with demand and creates a differentiating edge in the market place.

Variety creation and variety implementation decisions are inextricably linked together, as both impact perceived variety as well as costs. Although more complex than a framework that separates decisions that impact revenues from those that impact costs, this framework of variety decisions (see Figure 1) captures more accurately the true width of their impact. While it is useful to think about variety-related decisions along several key decision themes, it would be both simplistic and shortsighted to overlook the many interdependencies across themes. It is these interdependencies that make variety management so challenging, and make it an issue that cannot reside within any one functional area. Unfortunately, these interdependencies have received little attention in the research literature. They present many research opportunities.

I use the above framework to understand the spectrum of variety decision-making and to discuss both the literature and the untapped research avenues in product variety management.

2.1 *Variety Creation*

Variety creation involves deciding what and how many products to offer, the target markets, and introduction timing for each product.

2.1.1 Dimensions of Variety. Variety stems from differences in physical form and product function. For example, bicycle manufacturers create variety by varying frame geometry and materials, color, and components. Less obviously, augmenting product features such as brands, packaging, marketing channels, warranties, and levels of after-sales support can be just as important in creating perceived variety, as can service dimensions such as availability and delivery lead-time. The dimensions of variety a firm chooses to compete on must be of value to the customer; in addition, being in a unique position to offer value along a specific dimension is a source of competitive advantage (Porter 1985).

Creating distinctive new products can increase costs. Creating high levels of perceived variety without high cost hinges on building synergies across products. Therefore, a key element of variety-creation strategy is identifying physical or augmenting features that do *not* drive differentiation and variegation and *reducing* variety along these dimensions.

2.1.2 Product Architecture. For an assembled product, architecture determines the relationship between the product's functions and its components (Ulrich 1995). For process or service industries, I view product architecture more generally as a mapping from product functions to process steps. Architecture is a major determinant of how a firm can differentiate and variegate its products. A *modular* architecture, with a one-to-one mapping between functions and components and standardized interfaces between components, can allow a firm to focus differentiation or variegation on specific components; a more *integral* architecture compromises this ability but may enhance overall product integrity (Ulrich 1995).

2.1.3 Degree of Customization. A firm may create variety in anticipation of customer needs, offering consumers a choice from a set of ready-made offerings. A contrasting strategy is full customization based on individual specifications. An intermediate strategy, mass-customization, is to partially customize to individual needs based on a standardized set of components or allowable features. Of course, a firm may also follow a mix of these strategies. In a rational approach, the degree(s) of customization a firm offers should be driven by a combination of what the market values, and a firm's own internal and supply chain capabilities.

2.1.4 Timing. Managing variety is an inherently dynamic process. How a firm's product line unfolds over time impacts perceived variety, whether or not these decisions are made consciously. In a deliberate approach, all variety-related decisions must consider timing.

2.2 *Variety Implementation*

Variety implementation decisions focus on how a firm's manufacturing/service delivery processes, and supply chain, are managed to implement its variety creation strategy.

2.2.1 Process and Organizational Capabilities. Broader, frequently refreshed product lines result in costly changes to manufacturing and other processes. Manufacturing process flexibility is a key capability that determines the ability to accommodate such changes cost effectively (De Groote 1994; Upton 1994). A similar concept applies to other processes. A firm can increase flexibility by investing in more flexible technologies, by changing work-force practices or supply chain elements—e.g., by outsourcing to flexible vendors, and by accelerating information transfer.

I view ease of interaction between organizational entities as an organizational capability.

Ease of interaction across functions or supply chain partners enhances a firm's ability to quickly introduce new products. Ease of interaction across development projects enables design synergies across products. Another organizational capability is a firm's ability to accurately measure the revenue and cost implications of its variety-related decisions.

2.2.2 Points of Variegation. An important decision in variety implementation is at what point in the supply chain generic widgets should take on the form of specific end products. Consistent with the terminology I introduced earlier, I call this the point of variegation. It is also commonly called a "decoupling point." Typically, a make-to-stock policy is used upstream of this point, whereas a make-to-order policy is used downstream. Delaying the point of variegation facilitates differentiation via reduced lead-time to meet customer orders and increases revenues, if customers will pay more for such responsiveness. It also reduces inventory costs, partly due to risk pooling from carrying generic, instead of variegated inventory, and partly due to shorter forecast horizons. However delaying variegation may result in costly modification of production process sequence, material flow through the supply chain, or the product's design to enable a modified manufacturing sequence.

2.2.3 Day-to-Day Decisions. Variety implementation involves many repetitive decisions ranging from manufacturing/service delivery and day-to-day logistics to pricing and promotion changes, throughout the product lifecycle, within a predefined supply chain structure, that impact ongoing profits. Higher variety can increase demand variability and forecast errors, increasing excess inventories and shortages, buffer capacity, and workforce fluctuations; this results in "market mismatch" costs (Fisher 1997). Effective day-to-day decision-making enables a firm to differentiate its products based on low cost, high quality, and responsiveness.

3. Research on a Firm's Variety-Related Decisions

Variety management has been the topic of a large number of research papers and recent books (Ho and Tang 1998; Meyer and Lehnerd 1997; Pine 1993; chapters of Tayur et al. 1998). In this review, I find it useful to discuss the research on product variety using the decision-based framework I developed above. Tables 1 and 2 contain lists of variety-related decisions addressed in the literature, organized by the key decision themes in my variety framework, with selected references for each decision. Below, I discuss the research in each decision theme of the framework, and how the research on variety has added to what we know about variety management. I also discuss the research on interdependencies across decision themes, where such research exists. Due to space considerations, I do not discuss all of the papers listed in the tables. Also, wherever possible, I refer the reader to other reviews. As there are several reviews of day-to-day decisions, I focus to a greater extent on the other themes.

3.1 *Research on Variety Creation*

3.1.1 Dimensions of Variety. Academic researchers have thought about the dimensions of variety in several different ways. Economists and marketing researchers popularized an attribute-based model, where products are characterized via key perceptual or tangible attributes, e.g., efficacy, ease-of-use, and price of a drug, and customer preferences are elicited over these product attributes. Many researchers have modeled product line design using an attribute-based approach, selecting a portfolio to maximize revenues or market share (Green and Krieger 1989 and Schmalensee and Thisse 1988 provide excellent reviews). While these models are mostly static, some examine dynamic product positioning and competitive reaction, though typically using simplistic market structures for analytical tractability. Attribute-based models generally address both differentiation and variegation, by including competitors' models and the firm's existing offerings. They enable a firm to

TABLE 1

Research on Variety Creation Decisions

Dimensions of variety	Along what perceptual or tangible attributes should a firm differentiate and variegate its products?	Dobson & Kalish 1988, 1993; Dobson & Yano 1995; Green & Krieger 1989; Raman & Chhajed 1995; Schmalensee & Thisse 1988; Yano & Dobson 1998
	How can an assembled product manufacturer use components to differentiate and variegate its products?	Desai et al. 2001; Ramdas & Sawhney 2001
	How do individual products affect the revenue potential of the entire line?	Kahn 1998; Kim & Chhajed 2001; Randall, Ulrich, & Reibstein 1998
Product architecture	What is product architecture? What are the costs and benefits of modular architecture?	Baldwin & Clark 1997, 1999; Henderson & Clark 1990; Ulrich 1995
	How is architectural innovation different from innovation on core concepts?	Henderson & Clark 1990
	How to standardize components that have weak influence on perceived quality?	Fisher, Ramdas & Ulrich 1999; Ramdas, Fisher, & Ulrich 2002; Gupta & Krishnan 1999; Rutenberg 1969; Thonemann & Brandeau 2000
	What drives company differences in component variety strategy?	Clark 1989; Fisher, Ramdas, & Ulrich 1999
	How to standardize components that have strong influence on perceived quality?	Desai et al. 2001; Morgan, Kouvelis, & Daniels 2001; Ramdas & Sawhney 2001
	What is a product platform? How to design a product platform?	Krishnan & Gupta 2001; Krishnan, Singh, & Tirupati 1999; Meyer & Lehnerd 1997; Robertson & Ulrich 1998
	How to share design resources effectively across product platforms?	Cusumano & Nobeoka 1992; Meyer & Lehnerd 1997; Nobeoka 1995; Nobeoka & Cusumano 1997; Robertson & Ulrich 1998
	How to measure the performance of platform products?	Meyer, Tertzakian, & Utterback 1997
	How does product architecture impact supply chain decisions?	Novak and Eppinger 2001; Randall & Ulrich 2001; Ulrich & Ellison 1999
Degree of customization	What are the benefits of mass customization?	Pine 1993; Gilmore & Pine 1997
	What drives different degrees of customization within a single industry?	Ulrich et al. 1999
Timing	How to time the introduction sequence for related products?	Bhattacharya, Krishnan, & Mahajan 2003; Moorthy & Ping 1992

TABLE 2

Research on Variety Implementation Decisions

Process and organizational capabilities	How does product variety impact operational complexity?	MacDuffie, Sethuraman, & Fisher 1996
	What is operational flexibility? What are the dimensions of operational flexibility?	De Groote 1994; Suarez, Cusumano, and Fine 1991; Upton 1994
	How does product variety impact manufacturing operations?	Anderson 1995; Fisher & Ittner 1999; Foster & Gupta 1990; Kekre & Srinivasan 1990; MacDuffie, Sethuraman, & Fisher 1996; Singhal & Singhal 2002
	How can supply chain structure be used to manage variety?	Fisher 1997; Graves & Tomlin 2000; Jordan & Graves 1995; Ramdas & Spekman 2000; Randall & Ulrich 2001
Points of variegation	What are the benefits of delayed variegation?	Lee 1996; Lee & Tang 1997, 1998; Whang & Lee 1998; Swaminathan and Lee 2001
	How can delayed variegation be implemented?	Feitzinger & Lee 1997; Lee, Billington, & Carter 1993
	How to delay variegation for assembled products?	Gupta & Krishnan 1998; Swaminathan & Tayur 1998, 1999; Swaminathan & Kukukyavuz 2001
Day-to-day decisions	For products that share components, how to manage production and inventories of common and unique components?	Garg and Lee 1998; Swaminathan and Lee 2001
	How to manage manufacturer-controlled downward substitution, where a better product that is in stock is substituted for an unavailable one?	Mahajan & van Ryzin 1998
	How to manage consumer-controlled substitution, where consumers substitute available products for preferred but unavailable products?	Mahajan & van Ryzin 1998
	How to make category management decisions for retail categories, with a revenue generation perspective?	McAllister, Broniarczyk, and Hoyer 1998
	How to make production and inventory decisions for fashion goods? How to coordinate pricing and inventory decisions for such goods?	Raman 1998; Hammond 1994

estimate *how much* revenue is gained from a chosen set of products, and its *source*: cannibalization, competitive draw, or market expansion. However they largely ignore the cost implications of product line choice, which perhaps explains their limited implementation.

To address this shortcoming, Dobson and Kalish (1988, 1993) introduced product-level fixed and variable costs in an attribute-based model. Dobson and Kalish's modeling approach does not capture any potential design synergies across products. Raman and Chhajed (1995) address this issue by assuming that the product attributes that consumers evaluate also determine manufacturing costs and include attribute-level costs for attributes that share production resources. A limitation of this approach is that the attributes along which consumers perceive variety often do not coincide with those that drive costs. Dobson and Yano (1995) present a rich model that allows for cost interactions based on the usage of common technological resources, distinct from attribute sharing, within an attribute-based revenue framework. Morgan, Kouvelis, and Daniels (2001) use a similar revenue framework, but move away from attribute-based costs, modeling manufacturing cost interactions by defining classes of products that share a class setup cost, aside from product setup costs. Future research should uncover issues that might arise in implementing such models in practice.

Ramdas and Sawhney (2001) provide an alternative to the attribute-based approach, arguing that while consumers perceive variety at the product level, costs are driven by components. Rather than elicit attribute-based preferences to estimate cannibalization, competitive draw, and market expansion, they estimate these at the product level by showing consumers prototypes, in a wristwatch industry implementation. A limitation to this model is that it requires decomposition of the product line into baseline sets, within which all cannibalization is limited; this could be unrealistic in some application settings. Also, similar to the attribute-based models, this model fails to capture the full complexity of product demand interactions. Randall, Ulrich, and Reibstein (1998) have found empirically that for low-quality segments, brand price-premium is significantly positively correlated with the quality of the lowest quality model in the product line, while the reverse holds for high-quality segments. Kim and Chhajed (2001) and Kahn (1998) also stress that customers' perceptions about individual products are a function of the entire set of products offered over time, highlighting the shortcoming of ignoring complex demand interactions, both in prescriptive modeling and in actual decision-making.

3.1.2 Product Architecture. Product architecture has received growing attention in academic circles, perhaps following industry interest. Henderson and Clark (1990) distinguish between innovation on core concepts, which define individual components, and architectural innovation, which defines linkages between core concepts.

For assembled products, architectural choices constrain the extent to which components may be shared across products. Modular architecture facilitates component sharing (Ulrich 1995; Baldwin and Clark 1997), but even after architecture is specified, component-sharing decisions can be complicated. Conceptually, some components, e.g., car body panels, have a strong influence on perceived variety; sharing them can result in "look alike" products. Others, e.g., passenger car brakes, do not affect perceptions about variety, as long as they meet certain threshold performance requirements.

For either type of component, designing a unique component-version for each end product increases one-time design costs. On the other hand, sharing components across products also incurs costs. For components that do not impact perceptions much, a component-version can be used across multiple products if it meets the most stringent performance requirements, resulting in excessive unit costs for some products. Thus, downward substitution by using a better-than-needed component-version saves the one-time cost of designing an ideally matched component-version, but results in extra ongoing unit costs. In an early model,

Rutenberg (1969) selects a product line that minimizes these costs while meeting demands for products with varying performance requirements (this problem resembles the classical assortment problem of Sadowski 1959). Fisher, Ramdas, and Ulrich (1999) model a similar tradeoff for automotive brakes and use their model to develop testable hypotheses about component variety. They predict that for components that do not impact perceptions much, component variety is increasing in product line breadth and total volume, is decreasing in component design and production costs, and is variable in individual product volumes. The negative relationship of variety with volume variability occurs because with high variability in volumes, some models will not have sufficient volume to justify the design cost for a unique component. They find strong empirical support for their hypotheses through a study of component variety strategies adopted by major automakers.

Gupta and Krishnan (1999) extend the modeling of component sharing to include multiple component types, with economies of scale in procuring multiple component types from a single supplier due to reduced vendor management. However they ignore the possibility of any design interactions between the distinct component types.

For many real problem instances, the above component-sharing models would provide at best a decision heuristic, even in their intended area of use, i.e., components that do not impact perceptions about variety. This is because in practice distinct component types often work together as systems. For example, an automotive braking system comprises brakes, pedal, master cylinder, and booster and faces system-level performance requirements that are a function of all of the components taken together. Rutenberg (1969) models a situation where multiple component types can be shared across products, but under restrictive assumptions about how these interact. Ramdas, Fisher, and Ulrich (2002) model a general form of the system-level design problem that includes arbitrary design interactions between component types. This model selects a cost-minimizing set of component-versions for each component type that satisfies system-level performance requirements for each end product and component-interaction constraints.

A challenge in implementing models of this type is that designers may view them as a distraction from the main design task. Krishnan, Singh, and Tirupati (1999) note that to overcome this issue, future models must be integrated into existing design tools. Engineers may also be uncomfortable providing the inexact demand and engineering cost estimates required for such models—a problem that would be mitigated by more reliable data gathering and by building confidence in the power of such models.

For components that have a strong influence on consumer perceptions, even if the underlying architecture is modular enough to permit component sharing, the tradeoffs involved in component sharing are more complicated. This is because such components often have an impact on customer perceptions that is either difficult to measure, or that is not clearly separable from the impact of other components. For example, how does one evaluate the impact of a specific body panel on perceptions about variety? One practical approach to this problem is to estimate the market impact of sharing components at the product level, and its cost implications at the component level (as in Ramdas and Sawhney 2001). In a different approach that focuses on insights rather than implementation, Desai et al. (2001) assume, as in Mussa and Rosen (1978), that product quality varies along a single dimension and that there are two customer types, with differing willingness to pay for quality. In addition, they assume that a product consists of two components, each available in a basic and premium version, and that quality is additive. For two products, they show that relative to not sharing components, sharing the premium component increases revenues from the low-end segment, but may not increase overall revenues as it decreases the perceived variegation between the two products. In addition, they determine the conditions under which no sharing, premium-component sharing, and basic-component sharing are optimal. Although these models are a starting point, there has overall been little research that addresses component-sharing issues for components with a strong influence on consumer perceptions. I posit that the negative

impact of poor decision-making is in fact far larger for this type of component, making this a rich area for future research.

Increasingly, firms are investing in platform-based product architectures that enhance component sharing. Robertson and Ulrich (1998) define a product platform broadly as a collection of assets that are shared by a set of products. They recommend that the core elements of a platform be identified via an internal assessment of distinctive capabilities and resources, and an external assessment of the drivers of perceived variety. Meyer and Lehnerd (1997) describe platform strategy as a way to map platforms onto differing market segments. These works focus more on the benefits than the costs of a platform approach. Also, they do not stress organizational capabilities such as the ability to create different incentive systems, performance metrics, or accounting methods that may be crucial to support a platform approach.

Meyer, Tertzakian, and Utterback (1997) attempt to bridge this implementation gap by applying traditional efficiency and effectiveness metrics of R&D performance to platform products; they demonstrate that keeping track of such metrics can signal the demise of a platform or help compare performance across platforms. Cusumano and Nobeoka (1992) also examine implementation issues in managing the development of platform products. Based on empirical evidence from the auto industry, they report that rapid design transfer, where a platform is transferred between two concurrent projects, is faster and uses less engineering resources than designing from scratch. It also dominates transferring a platform from a project completed much earlier, in which the new product was not considered when designing the original platform. Nobeoka and Cusumano (1997) report that rapid design transfer results in greater sales growth than sequential design transfer, because it allows leveraging of more recent technologies. This work highlights the importance of timing in platform strategy, an understudied area.

In one of the few attempts to weigh costs against benefits in deciding on platform strategy, Krishnan and Gupta (2001) define a product platform more narrowly than Robertson and Ulrich (1998), as a set of component and subsystem assets that are shared across a family of products. Their model incorporates over-design costs associated with using a standard platform over products with differing performance requirements, similar conceptually to the component sharing models described earlier. An additional offsetting twist is that integrating several discrete components into a standard platform subassembly can lower production costs. The primary focus of this model is on insights, rather than implementation. Thus there is a need for both implementable models of platform design and research on how to implement specific platform designs in practice.

3.1.3 Degree of Customization. Ulrich, Randall, Fisher, and Reibstein (1998) note distinctly different degrees of customization offered by different firms within a single industry—implying different underlying variety strategies. Yet the academic research on variety invariably assumes a particular degree of customization and then optimizes variety given that constraint. For example, all the prescriptive variety models discussed in Sections 3.1.1 and 3.1.2 assume the lowest degree of customization—i.e., choice among a fully specified set of end products. Only recently have researchers identified that the degree of customization is in itself an important decision (Kahn 1998; Ulrich et al. 1998). The question of what degree of customization a firm should adopt, and what factors influence this decision, has been left largely unanswered.

To answer this important question, a key ingredient is to understand to what extent, and how, moving from an "off the shelf" product line to a more customized line will impact consumer buying behavior and revenues. This issue is particularly important today, as the Internet makes it increasingly easier to reduce the costs of mass-customization.

3.1.4 Timing. Timing has received little attention from variety researchers. Much has been written on managing a firm's product line at any time (see Sections 3.1.1 and 3.1.2 above),

but little on how a firm's product line should evolve over time. While this may be due in part to the complexity of this issue, in my experience firms persistently struggle with timing.

The little research in this area is largely of an insights providing flavor. Moorthy and Png (1992) have shown that to minimize cannibalization in a market where consumers agree on their ranking of available products but differ in their willingness to pay, a monopolist offering two products should introduce the high-end product before the low-end product, rather than simultaneously. Thus customers who want the low-end product are forced to wait. However to obtain the greatest reduction in cannibalization, the firm needs to commit in advance to the design of the low-end product that will be introduced later. Intuitively, this is because without commitment, cannibalization is reduced only by the unavailability of the low-end product; with commitment, it is reduced in addition by how different its design is from that of the high-end product. More recently, Bhattacharya, Krishnan, and Mahajan (2003) have shown that in a similar market, the reverse strategy may be optimal in the face of technological improvement, as the option to introduce the high-end product first does not exist until technology is sufficiently advanced. Given the paucity of research on variety timing, and the importance of timing decisions in practice, I believe it is a ripe area for future research.

3.2 *Research on Variety Implementation*

3.2.1 Process Capabilities. Increased variety typically increases operational complexity, which in turn raises costs (MacDuffie, Sethuraman, and Fisher 1996). Conceptually, the actual degree to which variety impacts costs is a function of a firm's inherent flexibility (see Suarez, Cusumano, and Fine 1991 for a review of flexibility).

In recent years, several researchers have empirically examined the impact of variety on manufacturing processes. I have observed an evolution and sharpening in the focus of research hypotheses over time. Foster and Gupta (1990) and Kekre and Srinivasan (1990) report that broader product lines do not significantly impact costs. However these studies ignore product mix heterogeneity, i.e., the amount of attribute level variation across products. Anderson (1995) finds that after adjusting for product mix heterogeneity, variety has a significant positive impact on costs.

In a cross-sectional empirical study of automobile plants, MacDuffie, Sethuraman, and Fisher (1996) identify three types of variety—model-mix variety, options variety, and parts variety. They find that model-mix variety has no impact on labor productivity—possibly because plants with a wider model mix build in more flexible equipment and workforce, while increased parts complexity significant reduces productivity. They report that increased car-to-car variability in installed options significantly improves productivity, a result they find puzzling. In contrast, in a single-plant, time-series study that focuses on the impact of options variety on assembly, Fisher and Ittner (1999) report that increased car-to-car variability in option content significantly reduces labor productivity. They argue that this is because high option variability increases problems in scheduling and parts delivery. They show that this impact can be reduced either by bundling options or by providing capacity buffers at workstations that face high variability. While it is difficult to make apples-to-apples comparisons between the studies of MacDuffie, Sethuraman, and Fisher (1996) and Fisher and Ittner (1999), the conflicting results on options variety highlight that estimating the plant-level impact of variety is far from straightforward. I believe there is scope for further research in this area, to fully understand the subtleties of how variety impacts manufacturing processes.

The above research focuses on the impact of variety on manufacturing. I find that researchers have not examined empirically the impact of variety on downstream processes such as distribution, after-sales support, and end-of-lifecycle management, e.g., product take-back. These areas could be very important in practice, depending on the relative proportion of costs attributable to each stage of the supply chain and the impact of variety in each stage. To maximize value to the practicing manager, researchers should pursue a

telescopic approach, where they first determine which link of the supply chain faces the greatest variety costs and then focus their efforts on better managing that link. Of course, this weakest link would vary by company and industry.

While I believe it is important to identify such high-leverage links in the supply chain to focus research efforts on, doing this is not enough. Flexibility is a function not only of the technology and organization within specific plants, distribution centers, or other supply chain links, but also of the entire supply chain structure. Jordan and Graves (1995) focus on one type of flexibility: a plant's ability to process multiple products. Many flexible plants give a firm multiple options to accommodate product demand uncertainty. The authors show that while maximum flexibility is obtained if all plants can make all products, most of the benefits are reaped by creating a "chain": using graph theory, a product and plant are linked if the plant can build the product, and a chain is a set of products and plants that are all connected. They develop guidelines on how to effectively create such chains and apply this powerful concept successfully in auto supply chains. Graves and Tomlin (2000) extend this framework to multi-stage supply chains.

Some recent conceptual and empirical work also examines the relationship between product variety and overall supply-chain structure. Fisher (1997) suggests that firms that compete on product innovation require different types of supply chains than firms making commodity-type products. While commodity product firms can focus on cost and efficiency, innovative product firms, with broad product lines and high demand variability, need to find ways to reduce market mismatch costs. Ramdas and Spekman (2000) find empirically that information practices, supplier relationships, and supply chain thinking indeed differ for innovative and commodity supply chains. In a bicycle industry study that relates dimensions of variety with supply chain structure, Randall and Ulrich (2001) find empirical validation for their hypothesis that firms centralize production when the dimensions of variety they compete on involve relatively high production costs—for example, for special tooling to make certain frame shapes and decentralize production when the dimensions of variety they offer result in mismatch of supply and demand, such as when many color variations are offered. This is intuitive because economies of scale due to centralization alleviate high production costs, while reduction in lead-time due to decentralization alleviates market mismatch costs.

3.2.2 Points of Variegation. The point at which generic products take on different physical features is increasingly moving closer to the point of sale (Lee 1996). Variegation may even occur after the sale; e.g., customers custom fit a generic Herman Miller Aeron chair via adjustable levers.

Lee and Tang (1997) model the benefits from delaying variegation via standardization, modular design, or process restructuring via postponement or reversal of operations (a clarification: these authors use the term "differentiation" in the sense of variegation, as opposed to competitive differentiation). For each method, the costs are a one-time investment in design, and higher unit production costs. The benefit is reduced market mismatch costs due to reduction in buffer inventories via risk pooling, and increased flexibility of their use. A simple intuitive two-product multi-stage inventory model with an order-up-to policy at each stage, and high service levels to decouple the stages, helps build insights and highlights when each method is effective, e.g., standardization works well if the one-time investment and incremental production cost is low. Notice that these methods do not impact end-product variety, only intermediate variety. Also, they impact competitive differentiation via reduction in response time and product cost.

Lee and Tang (1998) focus on operations reversal and examine how it impacts variability in production volumes in a multistage process, again for two products. While Lee and Tang (1997) showed that the savings from delayed variegation by various methods including operations reversal are determined partly by demand variance and covariance, they did not consider the impact of the coefficient of variation of total demand, or differences in variance

among products, on order of operations. By explicitly modeling these factors, Lee and Tang (1998) show under what conditions operations reversal may reduce production variability. But unlike Lee and Tang (1997), they do not explicitly model the cost impact of variability reduction. While these papers focus on the operational impact of delayed variegation, Whang and Lee (1998) model how it impacts the marketing function via improved forecast accuracy. Swaminathan and Lee (2001) provide a recent review of the research on delayed variegation.

Lee and Tang's (1997, 1998) models were necessarily simple as they focused on obtaining managerial insights. These ideas have also seen several applications (e.g., Feitzinger and Lee 1997; Lee, Billington, and Carter 1993). In another implementation, Swaminathan and Tayur (1998) consider delayed variegation for an assembled product manufacturer that produces multiple end products by adding product-specific components to generic semi-finished inventory that is termed vanilla boxes. This problem resembles the probabilistic assortment problem (Pentico 1974). For a given product line, the firm must decide how many and what vanilla-box configurations to use and how to allocate these to products to minimize production and market mismatch costs, subject to capacity constraints. Swaminathan and Tayur (1999) extend this model to include the one-time costs of designing alternative assembly sequences for the vanilla-box manufacturing process. In related work, Gupta and Krishnan (1998) develop an algorithm for designing assembly sequences for product families that minimize support costs and market mismatch costs for subassemblies. Unlike Swaminathan and Tayur (1998, 1999), they do not consider capacity constraints. However they do consider component interactions and precedence constraints among assembly operations. While this model's intended use is in a product line's design stage, it focuses, as do the other papers above, on the manufacturing implications of design decisions.

3.2.3 Day-to-Day Decisions. As there are several reviews of issues in this theme, I point the reader to these. When a firm's variety-creation strategy involves component sharing, day-to-day implementation requires managing production and inventories of the shared and unique components. Research on component commonality examines how to make these decisions so as to minimize production costs and market mismatch costs, subject to service constraints (for reviews, see Garg and Lee 1998; Swaminathan and Lee 2001).

Just as firms use downward substitution to reduce product and component variety in variety-creation, similarly for a given product line, substitution can reduce inventories. In *manufacturer*-controlled downward substitution, firms choose to substitute a better product that is in stock, for an unavailable one, resulting in an assortment problem (Sadowski 1959), as in the case of downward substitution when creating variety. In *consumer*-controlled substitution, *consumers* substitute available products for preferred but unavailable products. These decisions focus on what varieties within a category to stock and how to allocate shelf space and make stocking decisions. Mahajan and van Ryzin (1998) review the operations literature on substitution. McAllister, Broniarczyk, and Hoyer (1998) examine substitution from a revenue generation perspective.

Several researchers have also examined how to support product variety on a daily basis for fashion goods with globally dispersed production, whose demand can be highly uncertain with better resolution being obtained closer to the selling season. (See Hammond 1994 for practical issues and Raman 1998 for a review of this literature.)

4. Future Research

I discuss below areas for future research of practical value that fall into the key decision themes in variety-related decision-making. I also highlight opportunities for research that address interdependencies between these themes, an area that has received little attention to date. Table 3 summarizes these new research ideas. In the concluding section, I discuss some common elements that emerge across the themes.

TABLE 3

Under-Explored Areas for Future Research of Practical Value

	Dimensions of Variety	Product Architecture	Degree of Customization	Timing	Process and Organizational Capabilities	Points of Variegation	Day-to-Day Decisions
Dimensions of Variety	How to identify altogether new dimensions?	Which design dimensions of the product should be modular?	Which dimensions of variety should be customized?	How to design ahead architecturally for later changes in the dimensions of variety that a firm competes on?	What dimensions of variety are most pernicious to activities upstream (e.g., design), and downstream (e.g., after-sales support) of manufacturing?	How to identify dimensions of variety that can be variegated late in the supply chain?	
Product Architecture	How to capture complex interactions among a firm's products, for which decomposition along dimensions is inadequate?	How to *implement* architectural decisions?	How can a modular architecture be used to facilitate customization?	How to plan architecturally for new variants over time? How to prevent architectural inertia?	What incentive systems, metrics, and organizational structures will help implement architectural design decisions?	How to use product architecture to delay variegation in the *product development* phase?	
Degree of Customization			What degree of customization to offer? How to customize the *design* process?	How to change the degree of customization offered over time?	How to measure the revenue and cost impact of increased customization?	How to identify dimensions that can be customized late in the supply chain?	
Timing				How to use variety timing to manage uncertainties that resolve over time?	How to plan for flexibility requirements that vary over time?	How to plan changes in variegation strategy over time?	
Process and organizational capabilities					How does variety impact stages other than manufacturing, such as design, distribution, etc.?	How to combine decisions on process flexibility and points of variegation, in a dynamic fashion?	
Points of Variegation						How to use this concept in the product *development* phase? How can multiple points of variegation be used to give customers greater flexibility?	
Day-to-Day Decisions							How to integrate production and inventory decisions with pricing and operational changes?

4.1 *Dimensions of Variety*

Much of the research on dimensions of variety relies on product decomposition, via perceptual attributes, physical attributes, or components, to make inferences about the revenue and cost impact of variety. While these models capture some types of revenue interactions among products, specifically cannibalization and competitive draw, they do not capture a product's impact on the entire line. For example, they do not capture the notion that a high-end "image leader" product can raise consumers' willingness to pay for even low-end products. Also, they do not capture dynamic purchasing behavior—e.g., a customer who buys a low-end "value leader" product may be more likely to upgrade later to a higher end product in the same line. These models also ignore that firms often reposition over the design cycle in response to new information, and they typically ignore competitive response. Also, they cannot help identify revolutionary new products that have totally different attributes, architecture, or degree of customization from current products. Admittedly, for such complex problems, obtaining analytical or algorithmic solutions is difficult. Building insights based on advanced simulation modeling or empirical research should advance the frontier in these areas.

Current models also do not capture fully cost interactions among products. Traditional costing systems cannot accurately trace overhead costs to individual products, because they assume that overheads are consumed proportional to volume. Activity-Based Costing (Cooper and Kaplan 1988) allows more accurate overhead allocation by using fine-grained cost drivers to measure consumption of support resources, but it assumes that overhead costs are linear in the cost drivers. Future research should relax this assumption and develop methodologies to measure the non-linear impact of variety on costs. Research that results in implementable methodologies is especially needed.

4.2 *Product Architecture*

The research on product architecture explains clearly how modular and integral architectures differ. However I believe a fundamental, yet understudied, issue is what type of architecture a firm should in fact choose. Modular and integral architectures are really two conceptual models, with most products falling somewhere in between, with some modular components or subsystems. Future research should examine which parts of the product should be modularized alongside decisions on what dimensions the firm should compete on, which design elements to customize, product introduction timing, and, in fact, variety implementation choices. This is because modular architecture allows focused variety, via selective upgrading of components or technologies. Customization is also not an all or nothing affair, and firms often choose to focus customization on specific design elements, which ought to coincide with the dimensions along which they choose to compete. These choices need to be part of the architectural decision.

Given architectural decisions, there is a need for modeling component sharing decisions for components that strongly influence perceived variety. Yet, although it is important to optimize the current architectural configuration and component sharing within this configuration, I believe that firms that do this well run the risk of architectural "inertia"—not looking ahead to totally new architectural designs. Future research on the dynamics of product architecture should document how firms that avoid this trap manage to do so.

Creating platform-based product lines requires architectural design. Existing research focuses on the benefits of platforms. More research is needed to identify when platforms are appropriate. Also, the research on platforms has focused on physical products, while diverse services, e.g., banks, hospitals, and consulting firms, grapple with platforms. For physical products, modularity is achieved by standardizing component interfaces. The equivalent for service products is unclear. I posit that standardizing the information flow between modules in a service platform would facilitate modularity. Research is needed to understand how this standardization occurs and when it is appropriate.

In platform research, the few papers that consider platform costs focus on the risk of look-alike products and of higher up-front design costs. Organizational changes such as revised incentive systems needed to support a platform approach have been ignored. Such incentive mechanisms could help alleviate tensions across functional boundaries—e.g., between marketing and manufacturing, and within functional boundaries—e.g., among multiple development projects, or brand managers for different product families.

While academic researchers often analyze narrowly defined problems to build insight, I believe that for architectural decisions this is of limited value, as these decisions by their very nature have far-reaching ramifications. Simulation, systems modeling, and empirical research may help improve these decisions without unduly compromising complexity.

4.3 *Degree of Customization*

Researchers have not examined the important issue of what degree of customization is appropriate for a firm. This requires understanding to what extent, and how, moving from an "off the shelf" product line to a more customized line will impact consumer buying behavior. For example, what demand patterns will emerge as a result of customization of one or more features? Traditional attribute-based new-product demand forecasting approaches such as multi-dimensional scaling or conjoint analysis are inappropriate, given the combinatorial end-product variety with customization. Forecasting demand and substitution patterns in this situation are an important untapped research area. Also, while the Internet makes it easier for firms to offer custom building of products from standardized components, firms are still groping with what types of features such web-based customization works best for. A related issue is *how* to offer customization to the consumer. Customization along every design dimension is cumbersome and confusing to the customer. How can thousands of decisions be reduced to a few key specifications that capture most of the important information? Additionally, as I discuss in Section 4.4, timing is important in choosing the degree of customization.

Future empirical research should also examine how internal process and supply chain capabilities impact degree of customization—e.g., a geographically dispersed supply chain could hinder customization. How do firms deal with this? Also, what types of downstream supply chain changes are driven by the degree of customization?

Firms sometimes offer more than one degree of customization. For example, in addition to its off-the-shelf product line, watch manufacturer Seiko sells custom watches in which a scanned photograph is printed on the face of the watch, for a premium price. Further research should examine how to make such decisions about a customization "portfolio."

Another untapped research area is customization in the *design* process. As currently offered, mass customization allows customers to mix and match from among an array of options to create products that can be delivered using the firm's manufacturing/service delivery process. However, customers cannot choose options other than those offered. Von Hippel (2001) documents a new trend: some firms are instead providing their customers with "design toolkits," consisting of design software with embedded constraints, using which customers can totally customize certain portions of the overall design to meet their individual needs and yet create products that the firm can deliver. For example, by using "gate array" architecture, some custom chip designers have standardized circuit design and concentrated all user-needs-related input in the design of the electrical wiring that is placed over the chip. Users design this wiring with the aid of a toolkit. Future research should examine how to modify a product's architecture so as to separate out all user-needs-related inputs into a portion of the overall design, so that the remaining portions can be designed by the firm's own development teams.

4.4 *Timing*

Timing has gone largely unnoticed by variety researchers. Yet decisions in every decision theme should in fact be considered over time, and if not, a time sequence will simply emerge by default. Consider an example in architectural design. An auto manufacturer may wish to focus on engines as a key source of differentiation and variegation in the near future, which might entail relatively modular engine design. A shift toward differentiating via another design element further out would require later architectural changes to allow for easily varying that element, or building flexibility into the original architecture, thus creating a real option: a tradeoff amenable to modeling. A modular architecture may also enable product upgrading by customers. For example, Nortel developed an upgradeable architecture for its PowerTouch line and has spun several generations of telephones off a single platform, always offering its current customers the option to move up by purchasing an upgrade module. A similar strategy is very common for software makers. Future research should examine how a decision to offer later upgrades impacts the upfront architectural decision and how upgrade modules impact sales of new product versions.

Since many uncertainties about a new product resolve over time, variety-timing decisions can be used to manage these uncertainties. For example, when introducing a new product category, there is uncertainty about aggregate demand for the new category, as well as the demand for specific varieties within the category. How should a firm optimally introduce products within the category over time to reduce these uncertainties? It may make sense to offer only limited variety at first, to gauge demand for the category. Which variants should be introduced first? Similarly, while introducing a new product category, a firm may be able to obtain insight on what degree of customization to offer by conducting market "experiments"—first offering a limited set of ready-made products and then introducing customization where it is most desirable. How should the initial offerings be chosen and how can the firm maximize learning from such market experiments? There are efficient statistical methods such as fractional factorial design that reduce the number of options that need be considered in experimental design. Can such ideas be applied in the context of increasing learning about market uncertainties over time?

4.5 *Process and Organizational Capabilities*

The research on process capabilities needed to implement a firm's variety strategy has focused on manufacturing and has largely ignored other functions. New product development is a case in point. Cohen, Eliashberg, and Ho (1996) estimate design production functions to estimate the impact of R&D activities on product performance. Future research should examine how variety impacts design productivity. Researchers and practitioners have noted that moving to a modular architecture can reduce the design costs to offer high variety. However, what if a modular architecture is simply not feasible? As an example, it would not work for an airplane. How can a firm improve its design productivity so as to offer high variety despite integral architecture? What dimensions of variety have the most detrimental impact on design productivity?

Similarly, we know little about how variety impacts processes downstream of manufacturing, e.g., sales, distribution, after-sales support, and end of lifecycle product management. This last category, related to environmental impact, is likely to become increasingly important. The environmental costs of high variety have to date been largely ignored in variety research (Ramdas 2000). For example, product architecture is an important determinant of environmental impact. With a modular architecture, investment in reducing the negative environmental impact of a particular component, say by developing eco-friendly materials, can be spread over higher volume due to component sharing. Similarly investing in modular architecture facilitates take-back and reuse, reducing variable costs and negative environmental impact. These tradeoffs are amenable to modeling and are valuable areas for future research.

In general, researchers need to determine which supply chain links offer the greatest potential absolute savings from better variety management and focus on those links, rather than only on manufacturing.

Organizational capabilities can facilitate or inhibit a firm's variety strategy. For example, while a firm may decide to adopt platform architecture with component sharing, this may be difficult to implement. What form of organization would encourage project teams to share resources? Coordination and communication mechanisms are important here, as are incentives. Yet this area has received little attention.

4.6 *Points of Variegation*

Many researchers have examined the issue of when to variegate generic widgets into different products, primarily from a cost perspective. Revenue gains due to lead time reduction have not been modeled. In some cases, these gains may be needed to justify the costs of delaying variegation. Estimating these gains is largely an empirical question and is a useful research avenue, as is prescriptive modeling that incorporates these gains.

In practice, a firm may have multiple points of variegation. For example, generic products may be variegated first into families and later into individual products. There is scope for more research in this area. A benefit of multiple points of variegation is that a customer order need not be fully specified at one point in time. Customers can be given the option to specify certain details of their order later than others. They would value this option if the later-needed details are about dimensions where they can reduce uncertainty with time—e.g., by learning more about their own markets. The additional revenues that can be extracted for this benefit would need to be estimated and weighed against the additional processing costs of multiple exchanges with a customer to specify a single order, besides other costs. A real options approach would apply to this tradeoff.

In my view, another fruitful and as yet unexplored area of research is the application of the concept of points of variegation in the product development phase. For example, modular product architecture may allow deferral of the time a generic product design takes on the characteristics of specific end-product designs, improving the development team's response time to react to changes in customer specifications.

4.7 *Day-to-Day Decisions*

These decisions often have a narrower scope and involve less complex tradeoffs than strategic decisions and may therefore be more amenable to quantitative modeling. Yet much of the modeling in this area has not been implemented. Raman (1998) suggests two reasons: first, even within the narrower scope of tactical decisions, these models ignore some key interdependencies, e.g., models of day-to-day production planning and inventory control ignore pricing decisions that are closely linked in practice. Second, these models focus on decision-making given a set of parameters such as setup costs, holding costs, etc., without delving into parameter estimation. These are ripe areas for future research. The reader may notice that Table 3 shows no decision interdependencies between day-to-day decisions and the other themes. This is appropriate because day-to-day decisions are made *after* strategic decisions. While modelers sometimes combine strategic and day-to-day decisions in a single model, this can limit model applicability.

5. Conclusion

Rather than starting with the questions addressed in the research on product variety and attempting to make sense of this large body of research, I have found it beneficial in several ways to start instead with the decision themes commonly faced in practical variety management, and to then examine how the research on variety complements these themes. First, it has allowed me to identify research that throws light on the problems that arise within

specific decision themes. Second, it has exposed fruitful avenues for future research that are not incremental to existing research—entire decision themes that have received little attention from the academic community. Finally, examining the interdependencies across themes has uncovered further avenues for future research. Below, I conclude by discussing certain need areas for future research that seem to run through the seven decision themes I examined in this paper.

Better Parameter Estimation

Prescriptive models for variety have had limited practical impact. A necessary input for implementation is parameter estimation, an area that is understudied. I mentioned earlier the need for better estimation of the complex demand and cost interactions between products even when a firm offers ready-made offerings. Of course, these estimation problems are even tougher for firms offering higher degrees of customization.

More Comprehensive Models

Prescriptive models for product variety often focus on narrow tradeoffs within functional silos, ignoring important interdependencies across decisions. This limits their practical use. Yet simply adding on the missing terms to existing models, to expand their scope, will not remedy this problem. As Krishnan and Ulrich (2001) have noted, developing practical models requires moving away from functional stereotypes, by understanding the underlying factors that intertwine different functions, such as product architecture.

Sustainable Advantage

Prescriptive research on variety fails to incorporate the notion of sustainable competitive advantage. For example, attribute-based models may identify a profitable product line. But will competitors easily imitate the particular combination of products identified? Similarly, how should a firm choose points of variegation that are hard to copy? Often sustainable advantage comes from implicit knowledge about linkages among different strategic factors. How can such advantage be gained via variety strategy? Again, I believe the answer will not come from narrowly defined models that analyze pieces of the puzzle, but rather from conceptual or empirical research aimed at understanding the entire puzzle, or modeling techniques that do not compromise complexity.

New Researchable Problems

One can view researchable problems as being either new to a research community or new to the world. Scanning problems faced in practice, and checking to see what issues have been ignored in the literature, can help identify problems new to the community. For example, I find that the primary focus of variety research has been on consumer products. Markets for industrial products operate very differently. Karmarkar (1996) suggests that in such markets customer preferences may be imputed from a customer's production function, rather than from consumption behavior. Better measurement of the inputs into variety decision-making in the business-to-business context, and of the tradeoffs involved, are rich areas for future research. Another way to identify problems new to the community is to examine the interdependencies across decision themes, which have often been ignored. For example, this line of thinking reveals that product architecture, traditionally studied in the domain of engineering design, has many operational implications in variety creation and implementation.

Variety management in services has also received little attention. In fact, a rich area of overlap between two understudied areas—industrial products and services—is business-to-business services, a fast growing segment due to the Internet. This is a problem area that is new to the world, arising due to technological evolution. The Internet presents many challenges to variety management. While variety management has traditionally focused on

managing products within a category, the Internet has broken down boundaries among product categories, so that new products need not belong in the pre-existing physical or attribute space. Research is needed to help make variety-decisions in this situation. The Internet also highlights the need to understand the costs and benefits of increased customization.

As with the Internet, I look to other trends in the business environment to identify researchable problems that are new to the world. Increasingly, firms are examining environmental consequences of their decisions, an area ripe for research from the perspective of variety decisions.

New Research Techniques

As with researchable problems, one can view research techniques used in a research community as either new to the community or new to the world. For example, while firms have faced variety-related problems for a while, researchers in Operations have only recently started to use empirical techniques to examine them. While the techniques used may be relatively new to the Operations community, they have a much longer history. I feel it is important for a research community to be willing to borrow tool sets from other disciplines, as we have done. However I expect that with time researchers in Operations will sharpen their use of econometric tools to include more sophisticated procedures that are standard in other disciplines, for example, rigorous econometric model specification, that would greatly increase the soundness of reported findings. Also, to increase the cumulative knowledge gained from empirical research on variety, researchers must examine and explain why their results are similar to or differ from those of other related studies, rather than focus only on internal consistency.

We should look to apply other established research techniques in the context of variety management. Simulation has proved a useful tool in analyzing inventory policies and supply chain configuration decisions. Simulation may be appropriate for analyzing the impact of moving from off-the-shelf to mass customized products. A necessary input, however, would be good modeling of consumer demand functions. Simulation may also be useful in modeling competitive response in product positioning, a problem that is notoriously difficult to study analytically. Another technique that may be useful to obtain insight on complex problems is systems dynamics modeling. Finally, I also expect research on variety to spur the creation of altogether new research techniques.[2]

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