Pontifícia Universidade Católica
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Product Variety Management: a Conceptual Framework and empirical studies

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Thesis presented to the Programa de Pós-Graduação em Engenharia de Produção of the Departamento de Engenharia Industrial, PUC-Rio as partial fulfillment of the requirements for the degree of Doutor em Engenharia de Produção.

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For my parents, who have always given me support and security to make my dreams come true.

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Abstract

Reis, Augusto da Cunha; Scavarda do Carmo, Luiz Felipe Roris Rodriguez (Advisor); Scavarda do Carmo, Annibal José Roris Rodriguez (Co-advisor). **Product Variety Management: a Conceptual Framework and empirical studies** Rio de Janeiro, 2013. 128p. Doutoral Thesis – Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

High product variety is a reality in many industries. The automotive and cosmetic industries are among those most affected. Within this context, companies need to manage their product variety to compete and to achieve success in the market. Although product variety is an important issue, the literature lacks models and frameworks that help its management. The main goal of this thesis is the development of a conceptual framework for product variety management (PVM) and its use to analyze this management in the industry. The academic contribution is to offer a framework to the literature that integrates the highly dispersed works on product variety and to indicate how researchers' understanding of this topic has developed. Practitioners can also benefit from the results, as this framework is applied to different cases via empirical studies within the automotive and cosmetic industries.

Keywords

Product Variety Management; Operations Management; Supply Chain; Systematic Literature Review; Automotive Industry; Cosmetic Industry.

Resumo

Reis, Augusto da Cunha; Scavarda do Carmo, Luiz Felipe Roris Rodriguez (Orientador); Scavarda do Carmo, Annibal José Roris Rodriguez (Co-orientador). **Gestão da Variedade de Produtos: um Modelo Conceitual e Estudos Empíricos.** Rio de Janeiro, 2013. 128p. Tese de Doutorado – Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

Esta tese aborda o tema Gestão da Variedade de Produtos (GVP), designado pelo seu correspondente em inglês "Product Variety Management" (PVM). GVP é um campo do conhecimento que é, por essência, multidisciplinar, cujo efeito pode ser sentido nas mais diversas áreas de uma empresa. Se por um lado algumas áreas são mais propensas a sentirem os efeitos benéficos do aumento da variedade de produtos ofertada, outras, por sua vez, tendem a associar o aumento da variedade de produtos como um aspecto negativo. As áreas de marketing e de vendas tendem a ter uma visão positiva em relação ao aumento da variedade de produtos, já que associam uma maior variedade à customização do produto frente às necessidades dos cliente, ao aumento na receita, melhor visibilidade da imagem da marca da empresa, entre outros benefícios. Por outro lado, as áreas de produção, logística, compras e ambiental verificam um aumento na complexidade dos produtos, de seus processos e dos resíduos gerados a partir do aumento do mix de produto oferecido, gerando assim inúmeros desfios. Este episódio leva estas áreas a possuírem um receio em relação ao aumento da variedade de produtos. Neste sentido, a GVP é um conjunto de práticas gerenciais cujo objetivo é coordenar as ações dentro da empresa e ao longo da cadeia de suprimentos, buscando o melhor alinhamento das áreas e elos da cadeia. Esta tese tem por objetivo desenvolver um modelo conceitual (framework) para a GVP e de aplicá-lo por meio de estudos empíricos para analisar o uso desta gestão na indústria. A contribuição acadêmica é a de oferecer à literatura uma integração dos trabalhos dispersos sobre o tema e o de indicar como a compreensão de pesquisadores tem se desenvolvido ao longo do tempo. Membros da indústria também podem se beneficiar deste trabalho com os resultados da aplicação do modelo na indústria automotiva e de cosméticos. Para a construção do modelo conceitual utilizou-se uma revisão sistemática na literatura nas bases de dados Science Direct e Emerald. Nestas, 87 dos 455 artigos selecionados foram utilizados e, a partir daí, chegou-se às dimensões que compõem o modelo conceitual (*input, structure and processing, measures* e *outcomes*). Vale a pena destacar que foi verificada uma ausência de sínteses anteriores na literatura que abordem a GVP. Poucos artigos tratam a GVP de forma holística limitando-se, em geral, a um conjunto restrito de aspectos que compõe a GVP. Outra descoberta interessante é que grande parte dos artigos que abordam GVP o fazem em ambiente de manufatura. A vertente empírica desta tese reside nos estudos realizados em empresas. O objetivo destes estudos é validar empiricamente o modelo conceitual desenvolvido. Para tal foram realizados quatro estudos de caso que estão nos capítulos 5 e 6. No capítulo 5 foram realizados dois estudos em profundidade na indústria automotiva entre empresas contendo um relacionamento cliente-fornecedor em uma cadeia de suprimentos (fabricante de chassis de ônibus e encarroçadora). No capítulo 6 foi realizado um estudo comparativo na indústria automotiva e na de cosméticos, com

o intuito de verificar a validade do modelo conceitual além do contexto vivido dentro da indústria automotiva. A criação de um modelo conceitual para a GVP e sua posterior aplicação empírica trouxe à tona importantes aspectos relacionados à GVP. O primeiro deles é a própria avaliação do modelo com suas dimensões e variáveis. Por se tratar de um dos primeiros esforços em organizar e sistematizar o conhecimento acerca da GVP, sua aplicação demonstrou aderência com a GVP realizada nas empresas (vertente empírica) bem como com a literatura acadêmica (vertente teórica). Por fazer parte do cotidiano de todas as principais áreas de uma organização, o caráter interdisciplinar da GVP foi ratificado. A partir da aplicação percebeu-se que áreas como a de operações e a ambiental buscam mitigar os efeitos negativos oriundos da variedade de produtos. Já as áreas de marketing e comercial focam aspectos positivos, em geral, alinhando a GVP como parte de suas estratégias para aumentar a receita e/ou participação de mercado. O pioneirismo desta tese não a exclui de possuir limitações. Dentre estas limitações a utilização de duas bases de dados (Science Direct e Emerald), um horizonte de sete anos (2005-2011) e duas indústrias (automotiva e de cosméticos) acaba dificultando a generalização dos resultados. Não obstante, estas limitações podem contribuir como ponto de partida para estudos futuros, seja ao ampliar as bases de dados, o horizonte temporal ou número de indústrias pesquisadas.

Palavras-chave

Gestão da Variedade de Produtos; Gestão de Operações; Cadeia de Suprimento; Revisão sistemática da literatura; Indústria Automobilística; Indústria de Cosméticos.

SUMMARY

1 INTRODUCTION 12

2 PRODUCT VARIETY 15
2.1 AN OVERVIEW OF PRODUCT VARIETY 15
2.2 MITIGATION STRATEGIES 24
2.3 MEASURING PRODUCT VARIETY 30

3 RESEARCH METHOD **37**
3.1 FRAMEWORK METHOD 37
3.2 CASE STUDIES METHODOLOGY 39

4 PVM FRAMEWORK 44
4.1 INPUTS 47
4.2 STRUCTURE AND PROCESS 54
4.2.1 Relationships and Participants 54
4.2.2 Business Processes 56
4.2.3 Information Technology 58
4.2.4 Mitigation Strategies 60
4.3 MEASURES 63
4.4 OUTCOMES 66
4.5 FINAL CONSIDERATIONS 67

5 PVM IN THE AUTOMOTIVE INDUSTRY 70
5.1 CONTEXT AND COMPANIES CHARACTERISTICS 70
5.2 INPUTS 71
5.3 STRUCTURE AND PROCESS 77
5.4 MEASURES AND OUTCOMES 90
5.5 FINAL CONSIDERATIONS 91

6 PVM WITHIN THE AUTOMOTIVE AND COSMETIC INDUSTRIES: A COMPARISON 93
6.1 CONTEXT AND COMPANIES CHARACTERISTICS 93
6.2 INPUT 95
6.3 STRUCTURE AND PROCESSING 97
6.4 MEASURES AND OUTCOMES 102
6.5 FINAL CONSIDERATIONS 105

7 CONCLUSION 107

REFERENCES 110

List of Tables

Table 2.1: Product variety in different industries 16

Table 2.2: Attributes and variety variables of manufacturing products 17

Table 4.1: Internal and external pressures that influence PVM 47

Table 4.2: Intra- and inter-organizational perspectives in PVM 54

Table 4.3 Business Processes under PVM 56

Table 4.4: Information Technology under PVM 58

Table 4.5: Product variety mitigation strategies 60

Table 4.6: Measures used to assess PVM 64

Table 4.7: Results sought by companies adopting PVM. 66

Table 5.1: Inputs in the researched companies 76

Table 5.2: Structure and Process 89

Table 6.1: World-wide production numbers of cars and commercial vehicles in 2012 94

Table 6.1: Product Variety for Passenger Cars offered to the Brazilian Market 103

List of Figures

Figure 1.1: Thesis structure 14

Figure 2.1: Dynamic variety at Audi from 1980 to 2003 19

Figure 4.1: The content analysis framework 45

Figure 5.1: Products produced by Assembler 72

Figure 5.2: Products produced by Bus Body Manufacturer 72

1
Introduction

Product variety plays a primary role in manufacturing. Thus, it is associated with operational trade-offs (Hayes and Pisano, 1996; Mapes et al., 1997; da Silveira and Slack, 2001; Trentin et al., 2013). Today, the increasing variety of products offered to customers has emerged as a major trend (Bils and Klenow, 2001, Er and MacCarthy, 2006; Scavarda et al., 2010; Stäblein et al., 2011; Wan et al., 2012; Wang, 2013), and great academic interest has developed in the effects and consequences of product variety on production systems. Balakrishnan and Chakravarty (2008), Vaagen and Wallace (2008), Murthy et al. (2009), and Zhang and Huang (2010) reported that product variety refers to variations in product attributes and/or characteristics that allow for different product configurations. Escobar-Saldívar et al. (2008) characterized product variety as the number of existing product lines and the number of products offered in each line.

Elmaraghy et al. (2009) highlighted the difficulty of balancing customer and company viewpoints on variety, such as offering sufficient variety to the customer while also considering the effect of that variety on production systems. Product variety is an effective strategy for increasing market share because it enables a firm to serve heterogeneous market segments and satisfy the variety-seeking behavior of consumers (Tang, 1996). These varieties can involve differences in product features, packaging, or channels of distribution. These marketing strategies should result in sales growth or higher prices and presumed profit, which are gained by meeting more specialized demands (Berry and Cooper, 1999). However, a proliferation of products is also generally accepted to result in a deterioration of manufacturing / logistics performance (Kim and Chhajed, 2000), which can result in higher forecasting errors, excessive inventory for some products, shortages for others and higher costs (Lee and Billington, 1994).

This problem is especially challenging to firms because of the dearth of models and tools that they can use to achieve an appropriate balance between the positive and negative aspects of product variety. According to Elmaraghy et al. (2009) and Schaffer (2010) this lack of models and tools constitutes a significant

gap in the literature. Elmaraghy et al. (2009) noted that managing variety at all levels of production and support is one of the most important priorities for companies in the current dynamic environment. The management of product variety makes it possible to offer customers a variety of products while simultaneously maintaining high levels of quality, responsiveness, and adaptation to change, thereby generating profits.

Within this context, the following research question has been considered: How has the understanding of academic researchers of the product variety management (PVM) theme developed and how has PVM been conducted in practice? Therefore, the main goal of this doctoral thesis was the development of a conceptual framework for PVM and its use to analyze this management in the industry via empirical studies. The academic contribution is an offer of a framework to the literature that can first indicate researchers' understanding of the development of PVM, which concerning research frameworks is in accordance with Rowley and Slack (2004), and Seuring and Müller (2008) and resulted in a systematic review of the literature in this thesis. This conceptual framework was carefully tailored to address the fundamental aspects of PVM and is useful for academicians interested in the theme. Practitioners can also benefit from the results of this thesis, as this framework is applied to different cases in the automotive and cosmetic industries. Figure 1.1 summarizes the thesis structure.

This thesis is organized into seven chapters, and this chapter serves as the introduction. Chapter 2 reviews the product variety concept from a literature perspective. Chapter 3 describes the applied research method. Chapter 4 offers the PVM framework and develops a systematic review of the literature aided by this framework. Chapters 5 and 6 develop empirical studies; Chapter 5 focuses on a dyadic relationship in the automotive supply chain concerning a truck and bus chassis manufacturer and a bus body manufacturer, and Chapter 6 compares the PVM conducted in two different industries – the automotive (passenger car manufacturer) and cosmetic (shampoo manufacturer) industry. Chapter 7 offers the research conclusions and suggestions for future research.

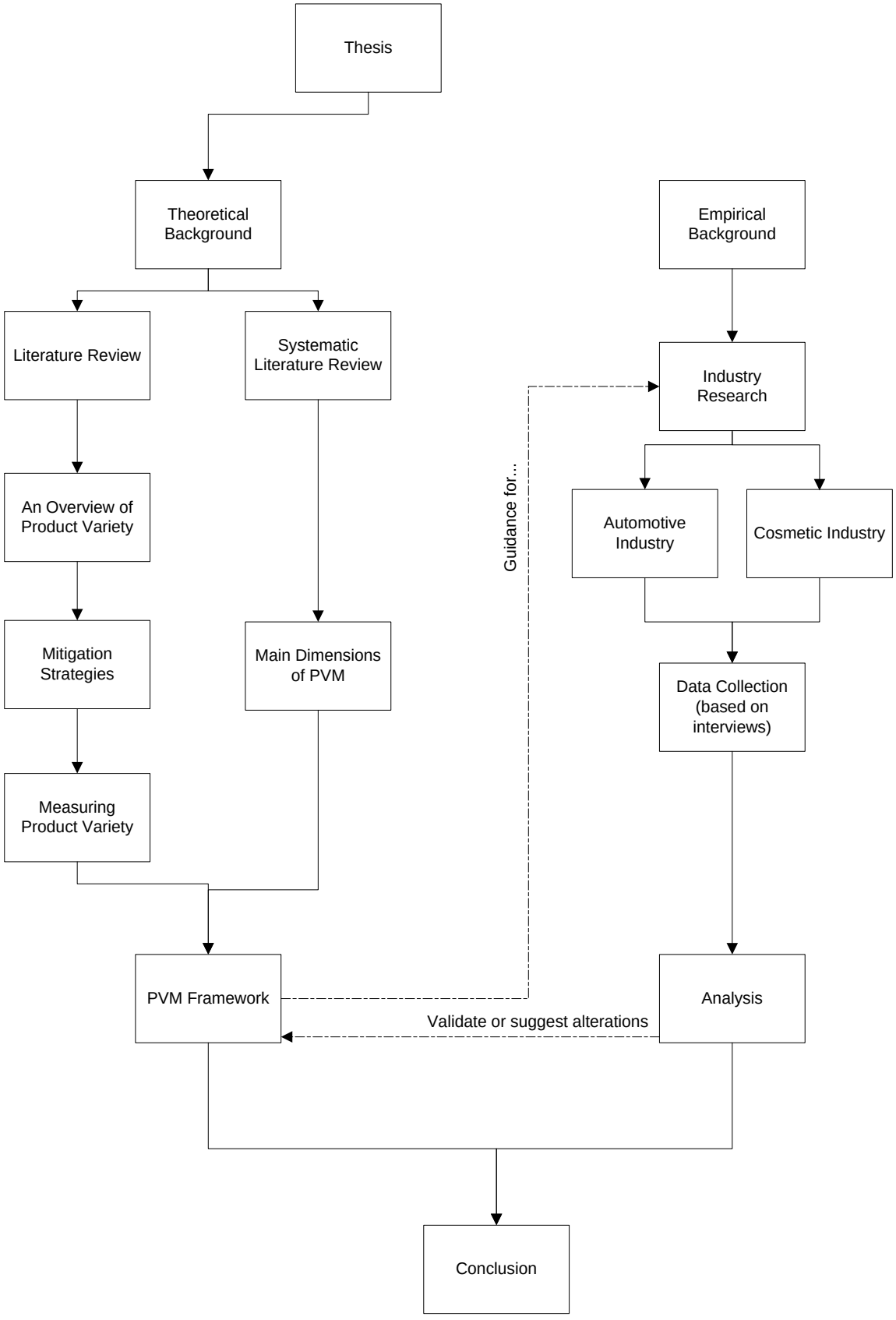

Figure 1.1: Thesis structure

Source: Author

2
Product variety

This chapter presents a panorama of the various aspects of product variety taken from the academic literature on the subject, including definitions, trade-offs, product proliferation, variety and attributes. The end of the chapter offers the measurement of product variety.

2.1
An Overview of Product Variety

First, for establishing some key definitions it is important to avoid ambiguity in further discussions. Product variety can be defined as the number of different versions of a product offered by a firm at a single point in time (Randall and Ulrich, 2001; Rajagopalan and Xia, 2012) and as the number of different product offered to customers (Pine, 1993).

An increasingly demanding market has placed pressure on companies to offer a wider variety of products (Barney, 1986). This fact has forced companies from different industrial sectors to generally respond by augmenting the variety of their products via a combination of attributes (Mapes et al., 1997).

Over the past few decades, product variety has proliferated in a number of industries (Cox and Alm, 1998; Rajagopalan and Xia, 2012). Table 2.1 relates some industries that have been the target of academic research. One of the first of these studies to be carried out concerned the electronics industry (Tang and Yam, 1996). This study analyzed the product variety of the main suppliers of consumer electronics in Southeast Asia. The study concluded that companies in the same sector possess distinct strategies in relation to the variety of products offered. It also emphasized that the companies commonly employ varied strategies for different product lines.

Table 2.1: Product variety in different industries

Industry	References
Computer	Bayus and Putsis (1999); Krishnan and Gupta (2001); Bayus et al. (2003); Hui (2004)
Electronics	Tang and Yam (1996); Appelqvist and Gubi (2005); Rantala and Hilmola (2005)
Automotive	MacDuffie et al. (1996); Fisher and Itterner (1996); Pil and Holweg (2004); Barbosa et al. (2005); Carvalho (2005); Iwaarden et al. (2006); Scavarda et al. (2009); Scavarda et al. (2010); Pero et al. (2010); Stäblein et al. (2011)
Auto Parts	Da Silveira (1998); Fisher et al. (1999)
Bicycle	Randall and Ulrich (2001)
Jellies	Ivengar and Lepper (2000)
Homebuilding	Nahmens and Mullens (2009)
Retail	Chrystopher (1998); Appelqvist and Gubi (2005); Korgaonkar et al. (2006); DiRusso and Schuff (2011)
Mechanical Equipment	Da Silveira (1998)
Plastic Package	Da Silveira (1998); Ruiz et al. (2008)
Wine and Juice	Da Silveira (1998); Ruiz et al. (2008); Krystallis and Chrysochou (2010)
Food / Snack	Pineda and Kleiner (2005); Goyal and Singh (2007)
Books	Brynjolfsson et al. (2003)
Tourism	Weng and Yang (2007)
Watches	Souza et al. (2004)
Yogurt	Draganska and Jain (2005)
Fashion / Clothing	Fisher et al. (1994); Iwaarden et al. (2006); Vaagen and Wallace (2008)

Source: Adapted from Reis (2009)

The attributes that comprise product variety must first be understood before this variety can be analyzed. In other words, a component of variety in one industry may not necessarily be a relevant component in another one. For

example, voltage characteristics are critical and are a component of the attributes that comprise total variety in the electronics industry. Conversely, an attribute like voltage is not important for the bicycle industry, while attributes such as the color and bicycle frame materials (aluminum, steel, alloy, carbon fiber) are. Table 2.2 provides a list of the main attributes and their main features found throughout the literature.

Table 2.2: Attributes and variety variables of manufacturing products

ATTRIBUTES	FEATURES	REFERENCES
Color	Black, blue, white, green, wall paper color, etc…	Fisher and Itterner (1996); Da Silveira (1998); Randall and Ulrich (2001); Pil and Holweg (2004); Scavarda et al. (2005); Appelqvist and Gubi (2005); Pineda and Kleiner (2005); Iwaarden et al. (2006); Scavarda et al. (2009); Nahmens and Mullens (2009)
Flavor	Strawberry, merlot, cabernet, apricot, grape	Da Silveira (1998); Iyengar and Lepper (2000); Pineda and Kleiner (2005); Iwaarden et al. (2006)
Size	Small, medium, large	Da Silveira (1998); Iwaarden et al. (2006); Nahmens and Mullens (2009)
Number of window/door opening	window or door	Nahmens and Mullens (2009)
Technical Features	Memory size, voltage, weight	Berry and Cooper (1999)
Material	Aluminum, wood, steel, leather	Randall and Ulrich (2001)
Design	Geometry	Da Silveira (1998)
Component	Brake, power-train	Fisher et al. (1999)
Model	Market segment	Fisher and Itterner (1996); Tang and Yam (1996); Da Silveira (1998); Pil and Holweg (2004); Scavarda et al. (2005); Iwaarden et al. (2006); Scavarda et al. (2009)
Package	Glass, plastic, metal, local transportation	Da Silveira (1998); Berry and Cooper (1999); Pineda and Kleiner (2005); Weng and Yang (2007)
Distribution Channels	Direct, retailer	Berry and Cooper (1999); Appelqvist and Gubi (2005); Min (2010)

Source: Adapted from Reis (2009)

According to Fischer et al. (1999), product variety can be defined in two dimensions: the range of products that a firm offers during a specific time and the rate at which a firm substitutes its existing products for new ones.

Pil and Holweg (2004) distinguished the dimensions of product variety between static variety and dynamic variety. Static variety is the variety that exists at any point in time. For example, the static variety of the product in question is being identified when the number of possible options for a product offered during a specific year. If the point in time that is employed to characterize the static variety is extended to include the number of possible options offered, such as over the last 20 years, the dynamic variety of a product is being identified (Fischer et al., 1999). Thus, dynamic variety refers to the choices offered over a period of time that result from changes that occur in the number of possibilities offered between the original launch date of a product and its facelift. This variety is well known in the world of marketing, in which the trend toward product proliferation is continuously increasing (Kotler, 2000).

Winkler (2000) studied the dynamic (from 1980 to 2003) and static (2003) variety of Audi and highlighted that Audi was present in two segments of the European market in 1980 with its Audi 80 and Audi 100 models (segments B and C, respectively), while it operated in five market segments with 23 vehicle models in 2003. This fact is shown in Figure 2.1, which demonstrates the further expansion of the number of body types offered by the factory. Specifically, it only offered a sedan in 1980, while by 2003 the offer had expanded to commercialize vehicles such as the sedan, hatchback, station wagon, and convertible body types.

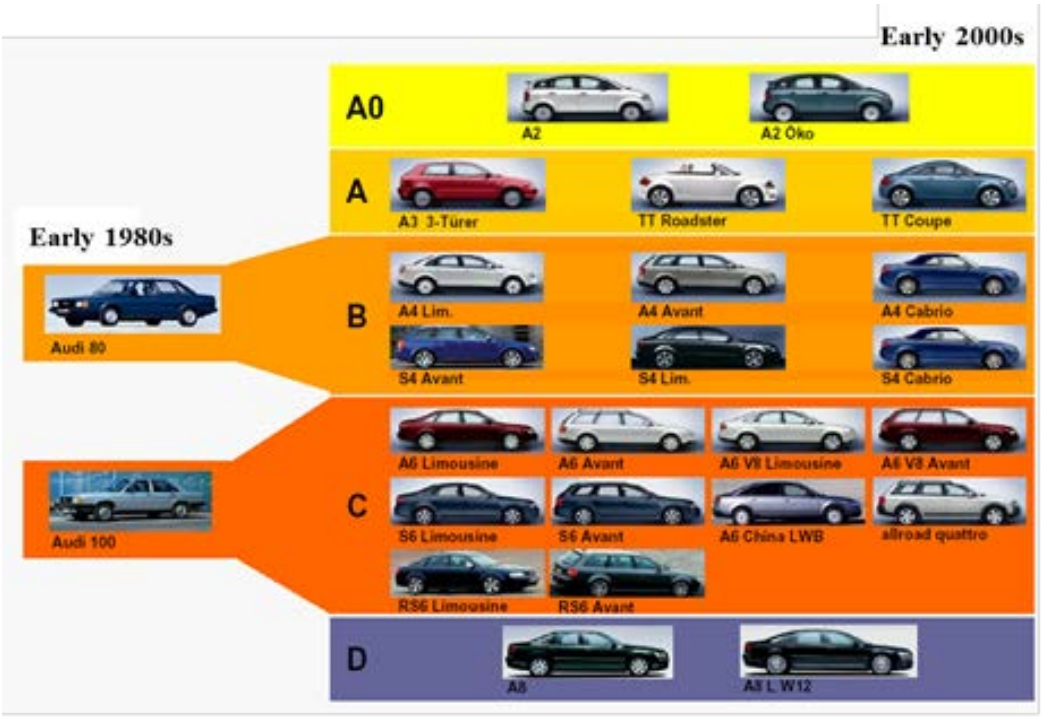

Figure 2.1: Dynamic variety at Audi from 1980 to 2003
Fonte: Winkler (2000)

Models and body styles are not the only thing that vary over time. Winkler (2000) confirmed that factory options, such as interior lighting, also change over time. The author confirmed that the Audi 100, version C, possessed three technical variations and only one color choice in 1983, which means that only three possible options were offered to the consumer. In 1990, the same Audi 100 in the C4 version possessed two technical variations and two color options, which constitutes four possible combinations that were available for purchase.

In general, product variety increases over time. However, Winkler (2000) demonstrates another example of dynamic variety using factory fitted options. The biggest difference between this example and the others lies in the fact that it shows that variety does not necessarily increase over time. This example shows that Audi decided to limit the variety offered to the customer to a single option: internal lighting (dome light). The management of this variety aimed to reduce costs without any perception by the final customer. Indeed, the example shows the decision-making process that resulted in the reduction of this variety. At the end of the project that resulted in the launch of the A6 Audi model, the company planned 12 technical variations and five different colors, totaling 60 combinations.

Just before the model's launch in 1997, four new colors were added, which meant that the total number of final combinations increased from 60 to 108.

In 2003, the total number of combinations of technical variations and colors reached 130. At this point, the company decided to reduce the combinations to 20. After meetings that involved areas such as marketing, production, purchasing, and research and development, a new design for the options was developed that reduced the number of colors offered and created a new layout. Inside the cars, the changes to the new interior lighting module were used in the A6 and C6 models, as well as for the two new models, A4 and B6.

The practice of product proliferation is visible in many different industries (Connor, 1981; Lancaster, 1990; Ratchford and Gupta, 1990; Kekre and Srinivasan, 1990; Fisher et al., 1994; Fisher et al., 1996; Fisher et al., 1997; Putsis, 1997; Bayus and Putsis, 1999; Fisher et al., 1999; Fisher and Ittner, 1999; Powers, 2000; Goldenberg et al., 2001; Ramdas and Sawhney, 2001; Krishnan and Ulrich, 2001; Putsis and Bayus, 2001; Dewan et al., 2003; Bayus et al., 2003; Blecker et al., 2004; Hui, 2004; Perona and Miragliotta, 2004; Souza et al., 2004; Syam et al., 2005; Carvalho, 2005; Bish et al., 2005; Draganska and Jain, 2005; Blecker and Abdelkafi, 2006; Wu et al., 2007; Polo and Chernatony, 2008; Seltene and Brunel, 2008; Vaagen and Wallace, 2008; Mendelson and Parlakturk, 2008; Scavarda et al., 2009; Scavarda et al., 2010; Stablein et al., 2011; Huang and Su, 2013) and has become an important tool employed by companies to improve their competitive strategy (Porter, 1985; Bayus and Putsis, 1999).

Womack et al. (2007) note that the concept of product proliferation is not a new one and that its origin was in the late 1920s when GM developed the strategy of offering a car for every taste and price. Thus, it created a hierarchy of five brands to compete with the Ford Model T, with the cheapest, entry model being the Chevrolet, while the most expensive was the Cadillac. Each brand offered the consumer a range of combinations, such as body style, color, and cosmetic aspects, such as the interior details. This strategy enabled the company to reach consumers of different income levels.

Connor (1981) emphasized that a product proliferation strategy is evident when a company or industry offers a long line of products, and each of these products has a great variety of attributes that differentiate them from each other.

Introducing a new-product variation aims to increase sales and maximize company profit (Tanner et al., 2002). Taken together, product proliferation can increase the complexity of demand forecast activities (Fischer et al., 1997), the purchasing sector (Kotteaku et al., 1995) and production programming (Van Donk and Van Dam, 1996).

In addition to the aforementioned factors, Bayus et al. (1999) considered the number of new-product introductions that a company makes over a specific period of time and concluded that adopting this strategy is important for maintaining the competitiveness of an enterprise.

Increasing the variety of offered products is an important way to attract consumers. The current trend is to offer a very large number of possibilities, commonly more than could conceivably be produced (Pil and Holweg, 2004). For example, Reis (2009) calculated that the total number of possibilities for the German-produced Ford Focus hatchback was more than 1.9×10^{14}. In other words, each of the Earth's seven billion inhabitants must own 27,000 different versions of this vehicle for all of these combinations to be produced.

Starting with this example, a central question regarding variety proliferation emerges: what is the optimum or appropriate variety of products that should be offered to clients? According to Lancaster (1990); MacDuffie et al. (1996); Kahn (1998); Ramdas and Sawhney (2001); Krishnan and Ulrich (2001) and Schaffer (2010), the optimum point of variety that a firm should offer is recognized as a trade-off between satisfying the necessities of a heterogeneous market, which demands a high level of variety, and the economies of scale required by the costs of production.

Bayus and Putsis (1999) defined the strategy of product proliferation as a "double-edged strategy." Although, the development of a new variety tends to create a differentiation in the market, it increases the operational costs associated with this new variety until the marginal revenue generated by that variety exceeds the marginal costs associated with that same variety.

Berry and Cooper (1999) illustrate the drastic reduction in profitability that can result from the introduction of a new-product variety without implementing the necessary changes in investment and production strategies. Wang et al. (2008) conclude that although increased product variety may satisfy a broader range of

customers, it also introduces greater manufacturing complexity (Wang et al., 2008).

Product variety can be studied from the perspective of different areas, which generally include the following: marketing, organizational behavior, engineering (Montoya-Weiss and Calantone, 1994; Tushman and O'Reilly, 1996; Novak and Eppinger, 2001; Goldenberg et al., 2001), and social perspectives (Tang and Yam, 1996). However, the literature can be divided into two main streams areas: marketing (Urban et al., 1986; Griffin and Hauser, 1993; Cooper, 1994; Griffin, 1997; Wind et al., 1997; Bohlmann et al., 2002; Brynjolfsson et al., 2003; Hui, 2004; Shankar,2006) and operations management (Bennet and Forrester, 1994; Tang and Yam, 1996; Fischer and Ittner, 1999; Berry and Cooper, 1999; Jiao and Tseng, 2007a; Randall and Ulrich, 2001; Desai et al., 2001; Christopher and Towill, 2001; Dubelaar et al., 2001; Krishnan and Gupta, 2001; Dewan et al., 2003; Hsu and Wang, 2004; Danese and Romano, 2004; Pil and Holweg, 2004; Holweg and Pil, 2004; Scavarda et al., 2005; Bish et al. 2005; Reisenbeck et al., 2006; Blecker and Abdelkafi, 2006; Thyssen et al., 2006; Vaagen and Wallace, 2008; Xia et al., 2008; Wang et al., 2008; Balakrishnan and Chakravarty, 2008; Scavarda et al., 2009; Scavarda et al. 2010; Stablein et al., 2011)

In the marketing literature, high product variety has been found to enable a firm to satisfy the desires and needs of heterogeneous consumers (Shapiro, 1977; Lancaster, 1990; Connor, 1981; Quelch e Kenny, 1994; Tang and Yam, 1996; Berry and Cooper, 1999; Bayus and Putisis, 1999; Vaagen and Wallace, 2007), increase the probability (Kekre and Srinivasan, 1990; Berry and Cooper, 1999), increase market share (Bagozzi, 1996; Urban et al., 1986; Pine, 1993; Quelch and Kenny, 1994; Tang and Yam, 1996; Bayus and Putsis, 1999; Kotler et al., 2005), increase sales (Bagozzi, 1996; Lancaster, 1990; Pine, 1993; Tang and Yam, 1996; Fisher and Itner, 1999; Berry and Cooper, 1999; Kotler et al., 2000; Shaffer and Zhang, 1995; Bester and Petrakis, 1996; Chen and Iyer, 2002), protect from new competitors (Tang and Yam, 1996; Berry and Cooper, 1999), and maintain or increase competitiveness (Kekre and Srinivasan, 1990; Thyssen et al, 2006, Rajagopalan and Xia, 2012). Conversely, marketing research has also suggested that "excess" product variety may lead to selection confusion for customers, which reduces the marginal benefits from variety (Wan et al., 2008).

However, the operations management literature argues that increasing variety raises general costs (Miller and Vollman, 1985; Yeh and Chu, 1991; Banker et al., 1995; Kaplan and Cooper, 1998; Bayus and Putsis, 1999; Berry and Cooper, 1999; Thonemann, 2002) and inventory cost (Bowersox and Closs, 1996; Fisher et al., 1997; Van Hoek, 2001; Vaagen and Wallace, 2007), reduces operational performance (Miller and Vollman, 1985; Yeh and Chu, 1991; Banker et al., 1995; MacDuffie et al., 1996; Kaplan and Cooper, 1998; Da Silveira, 1998), increases R&D cost (Lancaster, 1990; Bayus and Putsis, 1999) and ultimately undermines sales (Fisher and Ittner, 1999). Higher product variety makes the precise forecasting of demand (Lancaster, 1990; Bennett and Forrester, 1994; MacDuffie et al., 1996; Bayus and Putsis, 1999; Hsu and Wang, 2004) and maintenance of a continuous supply (Thonemann, 2002) more difficult, which results in mismatches between product supply and demand and leads to product stock outs (Bennett and Forrester, 1994).

In industries that feature imperfect product substitutes, such as the automobile and weapons industries, customers might backorder in the case of stock outs (Thyssen et al., 2006). However, in other industries, such as soft drinks and breakfast cereals, products can be easily substituted (Wang et al., 2008). Although sales may not be lost if substitution occurs within a supplier's product offering (Zahorik, 1994), lost sales will transpire when product substitution takes place across suppliers (Souza et al., 2004). Thus, stock outs that result from a high product variety strategy may ultimately hurt sales performance (Wang et al., 2008).

Evidence strongly supports that the competitive advantage predicted by variety proliferation has a close correlation with the proper alignment of the marketing and operational strategies adopted by companies (Richardson et al., 1985; Safizadeh et al., 1996). The addition of product variety may generate unfavorable cost consequences, which negatively impact a product's profit margin (Berry and Cooper, 1999). The failure to align both strategies in terms of the supply chain and manufacturing flexibility in the product mix, which are the key points in these strategies, can result in serious financial consequences for companies (Berry and Cooper, 1999).

Supply chain refers to the sequence of activities conducted within the organization itself, to the group of suppliers which deliver goods and services to

the organization, and to both of them, coupled with the organization's customers (Lamming, 2000). The Global Supply Chain Forum define the Supply Chain Management (SCM) as the integration of key business processes from end user through original suppliers that provide products, services and information that add value for customers and other stakeholders (Lambert and Cooper, 2000). One way that the use of SCM practices has been witnessed is with the recent advent of Efficient Consumer Response (ECR) (Alvarado and Kotzab, 2001). The basic notion underlying ECR is that the whole supply chain is opened up for scrutiny and each linkage is carefully examined with a special emphasis on delivery and stock replenishment, price management and promotions, trade conditions and allowances, as well as communication and information systems for order processing, billing, etc. (Keh and Park, 1997). This SCM approach aims to meet the goal of better fulfillment of consumer needs via the implementation of a four-part process: Efficient Replenishment (maintaining high in-stock levels of required assortment); Efficient Promotion (harmonizing the promotion activities between manufacturer and retailer by communicating benefits and value); Efficient Store Assortment (providing a complete, easy-to-shop, assortment of products wanted by the consumers); and Efficient Product Introduction (developing and introducing new products the consumer really wants by meeting their ultimate needs) (Alvarado and Kotzab, 2001).

2.2
Mitigation Strategies

Product variety and supply chain costs strongly correlate, and a number of studies have been carried out in order to determine how this correlation can be minimized to increase the efficiency of cost allocation for product variety over the entire supply chain. The contributions made by these studies can be divided into three large groups of mitigation strategies:

- Alterations in the product architecture, which entail utilizing component standardization and sharing (especially platforms and modules) that can help to enable the development of product designs that offer great product variety to the market while simultaneously presenting a low complexity level and a reduction in the costs associated with new product development and manufacture.

- Flexibility in manufacturing, which is understood to be a rapid change in tools and a multi-skilled flexible workforce, who can achieve the greatest efficiencies in production costs to enable a reduction in lot size that leads to a greater product variety while maintaining reasonable production costs.

- Postponement (tardy configuration), which refers to decisions that delay assembly. Delaying the distribution system is a strategy that can reduce the impact of demand uncertainty caused by an increase in product variety. This strategy creates varieties that are configured outside the production line or at some point in the distribution channel.

Modularization is understood to be the employment of individual modules to be utilized in a variety of final products. This strategy allows a company to offer greater product variety at a relatively low cost by merely combining different modules that differ very little from each other and simultaneously achieve the benefits of mass production.

Modularization is essentially introduced to reduce costs while shortening a company's reaction time to market demands that require changes in product variety. Cost reduction can take place on three main fronts: economies of scale, stocking cost reduction, and administrative cost reduction.

In relation to stocking costs, Fisher et al. (1999) argue that the introduction of modularization reduces stocking costs because fewer parts need to be stocked. This fact can also be explained by the reduction in safety stock due to the bundling of components in distinct models and delays in differentiation.

Modular products are perceived as a way of enabling economies of scale, which are lost by a great product variety. Modules can be employed in diverse products, which result in increased volume. Nevertheless, the variable cost per module or bundled component is less than the unit variable cost of the specific product that the module substitutes.

When the production is set-up for assemble-to-order-production, few components need to be stocked to meet the demands of a specified service level for a specific lead-time. If the products are fabricated with modules, the same number of modules may be combined to produce different final products. This strategy is known as the risk-pooling phenomenon.

The modularization strategy can be employed in plants independent of their production levels because each plant has standardized some modules that will enable the configuring of the product to the specifications of the client.

Overall, a modularization strategy has various disadvantages even though it positively affects costs. Thyssen et al. (2006) note that any advantages of a modularization strategy are restricted to costs; as more customers perceive the final product variations and their characteristics as the same, the risk of cannibalization among product lines increases.

Component sharing is a product-based strategy that is based on the fact that product families or similar products can use similar components.

All cars have wheels, tires, and a motor. In theory, an assembler that offers one hundred different models could offer one hundred different styles of wheels, one for each model. A more rational solution demands that the number of wheel styles be shared among the various models. A critical point in the adoption of a component sharing strategy is establishing the number of versions that should be offered in a line of existing products and the subgroups in this line of products that will share components. In the 80s, Black & Decker rationalized their product lines by grouping them by motor size. In doing so, the company eliminated the needless proliferation of motor sizes, achieving an almost five-fold reduction variety. In spite of this reduction, the number of final products slightly increased.

The decision to adopt component sharing is linked to the cost, quality and product performance, as well as the organizational structure. Component sharing reduces the investment in new product development, while the performance and the quality of shared components tend to be better than components designed for one purpose. A sharing strategy can lead to an increase or reduction in production costs. On the cost reduction side, a shared component will have a greater volume than one that is designed specifically for one purpose. This approach results in an economy of scale that reduces the unit cost of production. Conversely, each component is developed to operate properly in all the specified functions it must perform. With an increasing number of specified functions to perform, the complexity required for the modules substantially increases over that required for components with a sole function, and an excess of module functions can lead to penalties in unit cost price. Little is known about the popularity of production

concepts in industry and the way this strategy is developed or about the factors that influence the success of such a strategy.

In some cases, the final customer has difficulties in perceiving possible component sharing. Therefore, Degraeve et al. (2005) suggest the terminology “internal sharing” (invisible) and “external sharing” (visible): this concept is of fundamental importance for financial evaluations and later decisions about the level of sharing that a company will adopt. Barbosa (2005) have adopted the term complexity, which is divided into internal or external complexity and defined as follows in the automotive industry:

• External complexity (or market)

This complexity constitutes the final product offered to the clients. It is a result of external variety, which is the real number of combinations of options offered to consumers (i.e., body styles, power train, exterior paint and trim, and interior finishing). The number of combinations most strongly influences the order lead-time, but it also impacts assembly and distribution costs.

• Internal complexity (or technical)

This complexity is the result of internal, i.e., technical features of components and modules involved in the development and fabrication of a vehicle. It is expressed in terms of options in the features of the diverse systems that comprise a vehicle (i.e., motor, doors, transmission, etc.), the main sources of complexity in the development process, component production, assembly and purchasing.

The central cost question for companies that offer product variety over a range of different industrial sectors relates to integrated product development, which, to its credit, reduces complexity and optimizes investments. One of the techniques employed in integration consists of the development of a base platform, which in its most general sense is a component that is shared over a range of products in the same family. This concept has received increasing attention from both industry and academia.

According to Baldwin and Clark (1997), the platform concept is based on the idea of incorporating parts, components, and modules into an integral unit instead of considering components and technologies as separate entities. In addition, a company that can adapt its new products to the needs and expectations

of a group of consumers tends to gain additional market share. In this sense, a platform strategy enables easier adaptation and the creation of new products.

The majority of products that share a platform have a similar use and feature: shared components, modules and systems, a similar manufacturing process, a similar public target, a shared distribution channel, and even brand sharing in some cases. Thus, the platform concept can substantially contribute to cost reduction.

The platform concept can be applied to innumerable fields: automobile design, computer development, airline companies, civil engineering, and the food industry, to name a few.

One example of platform sharing cited is the Boeing 747, whose platform is also the base for the 747-400 and 747-200 models. Another example is the IBM AS400, a computer platform that accepts many hard drives and software configurations, thus enabling the product to be adaptable to the unique circumstances and demands of each client.

The platform concept is well known in many sectors, such as the automobile industry. For example, the Volkswagen Beetle model utilizes the same platform as the one used by the Golf model (VW Golf Platform), which is also shared by the Audi A4 and the VW Passat. The platform concept now encompasses various brands in the group, leading to significant production cost reductions for the Volkswagen group and a consequent increase in profits.

Scavarda et al. (2005) affirmed that a group of assemblers could cover all segments of a market by employing platform strategies to create a family of products with different body types and brand hierarchy, production volumes and pricing, but all sharing a base of internal uniformity.

Nevertheless, the adoption of the platform concept is not unanimous. This group argues that the concept of platform sharing results in products becoming homogenous, which reduces the possibility of choice and differentiation. Products assembled on the same platform often are so similar that consumers cannot easily distinguish one model from another. In addition to this similarity, Griffin and Hauser (1993)confirmed that a platform sharing strategy does not always correlate with the productivity of a product line.

Overall, the use of products that share the same structure (platform), parts or components, or modules tend to be superior in quality because the common

platform has been thoroughly tested with respect to both production and marketing. This testing ensures that the products will satisfy the needs and preferences of dealers and potential clients.

Another advantage accrued by adopting platform-sharing strategies is related to cost savings, especially the costs of complexity. For example, the utilization of the same components or modules can substantially reduce the costs of manufacturing and logistics. Cusumano and Selby (1995) reported that 1.4 million of the 4 million lines of code used in the original Microsoft Windows NT would have new versions on this platform, which has greatly reduced the development costs of future versions. The American airline Southwest is known for its low cost operations, due in part to the fact that all its aircraft are based on the same platform, the Boeing 737, which has low maintenance costs.

The use of the same platform on a production line enables the reduction of the fixed costs required for developing new versions. In addition, the degree of utilization of a shared platform positively correlates with the availability of time and resources for companies to devote to development and design, which results in enhanced product architecture, optimum component integration and the lowest unit variable cost. Many products that are shared on a platform also possess their own shared components and modules, which intrinsically increases the volume purchased and reduces costs due to economies of scale. A company can respond more quickly to market demands when the creation of a new version or model accelerates, which allows the company to focus on its core business.

Flexibility as a response to an increase in product variety has been extensively studied since the 1980s. Recently, investing in flexible production, such as capacity flexibility, has become attractive, as this approach can allow a plant to produce a variety of products in smaller quantities or to produce each product in diverse plants in an economically viable way. Companies that produce stock (make-to-stock) have used flexibility as a hedge against uncertainties in long-term demand forecasting, utilizing stock as a hedge for short-term variations. However, the effective employment and availability of flexible strategies to mitigate the effects of short-term variability on demand, which impacts companies that produce by order (make-to-order), remains a challenge. To accommodate variation in demand, the production level of each product in each plant requires constant adjustment. This adjustment results in a major change of products on the

production line, which consequently requires maintaining greater component inventory. Outside a company's borders, its entire supply chain must address the problem of variability, which results in an increase in cost across the supply chain of each company.

Da Silveira (1998) divides flexibility into two large groups: strategic flexibility and operational flexibility. Strategic flexibility addresses alterations in the externalities of companies, while operational flexibility addresses their internal changes. In general, strategic flexibility demands a greater effort and a long-term commitment than operational strategy.

According to Da Silveira (1998), the main points that comprise strategic flexibility are as follows:

• Product flexibility: ability to economically introduce or alter products on a production line.

• Product mix flexibility: ability to alter a range of products offered in a specific time period.

• Production flexibility: ability to efficiently produce a range of components and parts.

• Volume flexibility: ability to operate economically at different production levels.

• Expansion flexibility: ability to construct and expand a given system production capacity.

For operational flexibility, Da Silvera (1998) cites the following:

• Delivery flexibility: capability of altering delivery dates.

• Process flexibility: capability of producing with processes that require different sequences or different materials.

• Programming flexibility: capability of making alterations in production programming.

• Machine flexibility: utilization of machines for various purposes.

• Work-force flexibility: workers with a wide range of special skills are able to carry out a greater variety of tasks.

Garvin (1993) defines product flexibility mix as the capacity to produce a large number of products or variations inside a product range. This definition implies that a company can produce a wide range of products or variations with low set-up costs.

High stock levels, especially for finished goods, are one of the greatest challenges faced by industries. In keeping with their traditional way of production, some vehicle manufacturers are adopting a strategy of retarding certain activities over the supply chain based on demand forecasts, thus carrying out final product configuration more closely to the point of sale. Companies use tardy configuration as a strategy to protect the assembly process from undue associated complexity and thus postpone configuration until just before distribution.

Historically, the concept of postponement has been applied by both academia and industry to distribution channels that involve the transfer and movement of stock. For Bowersox and Closs (1996) and Zinn and Bowersox (1998) postponement does not merely pertain to stock relocation but also pertains to various other activities, such as labeling, packaging, adding peripheral components, or even manufacturing these components.

The postponement strategy has become a popular way of reducing production costs while simultaneously being proactive in responding to consumer needs and demands. This strategy aims to determine the point in a chain where only component sharing is employed and also when customization will take place. Thus, this strategy becomes an important tool in the struggle with demand uncertainties. When distribution centers or dealers become responsible for this configuration, the number of final product options that the assembler should possess is reduced.

Battezzati and Magnani (2000) state that a postponement strategy can achieve the highest profit levels when it is adopted as both a physical distribution strategy and as a product customization strategy. In fact, postponement can be applied over the entire length of a supply chain. The following three factors are directly impacted by postponement: the technology and process, the product, and the consumer market characteristics of a product.

2.3
Measuring Product Variety

The heterogeneity of each product variable must be considered to measure product variety (MacDuffie et al., 1996; Koste and Malhotra, 1999; Koste et al., 2004). MacDuffie et al. (1996) and Pil and Holweg (2004) divided product variety into different groups in accordance with the impact they have on the complexity of manufacturing. The groups are defined as follows:

• Fundamental variety – variety significantly impacts production complexity:; it is the structural base of the product. This type of variety rarely occurs outside the factory. The chassis or vehicle platform and the body constitute examples of this type of variety.

• Intermediate variety – this variety has a minor impact on the production process that depends on the characteristics of the variety being added. The motor and painting of a vehicle constitute examples of this type of variety.

• Peripheral variety – this variety minimally impacts the production process, if at all, as it can be configured outside the assembly plant in another point in the production chain, such as at authorized dealers or aftermarket accessory retailers. Alloy wheels or first-aid kits constitute examples of this type of variety.

From the consumer point-of-view, product variety is generally determined by two factors: the first being the model range offered and the second being the external variety of each of the models of the product line. From the industrial point-of-view, internal or technical variety, i.e., the variety involved in the creation and development of product (Pil and Holweg, 2004; Barbosa, 2005) is another variable that impacts the production line.

The following definitions for external variety and internal variety are used in this study:

• External variety is the variety offered to the consumer, which is determined by the total number of real variations (combinations) possessed by each model, in other words, what the consumer can actually order (Pil and Holweg, 2004; Barbosa, 2005). In general, external variety is useful to a company, as long as it does not exceed the variety demanded by the market.

• Internal variety is the variety involved in the creation and development of a product. Its creation is directly based on the external variety offered and thus

converted into necessities for the manufacturing process and value chain (Pil and Holweg, 2004; Scavarda et al., 2005).

Thus, the prime goal of variety management is to minimize internal variety and offer the external variety demanded by the consumer market (Scavarda et al., 2005).

Product variety can be measured by the number of different SKUs (stock keeping units) or the number of configurations available to the final consumer (Pil and Holweg, 2004). Some authors of the academic literature have sought to quantify this variety. Tang and Yam (1996) proposed a simple formula to measure the product variety in the electronics industry with equation 1.

$$V = \sum_{i=1}^{n} m_i \qquad \text{(Equation 1)}$$

Where:

V => Total number of product varieties

i => brands, varying from 1 to n

mi => total number of versions of a category of products for brand i

During the same period, Fisher and Itterner (1999) developed a generic formula to calculate the variety of automobile industry products, which is represented by equation 2.

$$V = n.o.p.2^{a} \qquad \text{(Equation 2)}$$

Where:

V => Total number of product varieties

n => Number of body types

o => Number of motor and power-train combinations

p => Number of paint and trim and interior combinations

a => Number of factory options

Equation 2 has a shortcoming: if all bodies, motors, drive-trains, painting and interior options are assumed to be able to be configured among themselves without any restrictions, but this fact is not empirically verifiable.

Equation 3 (Fisher and Itterner, 1999) is presented as an evolution of equation 2 for two reasons. The first fact to be considered is the inclusion of versions that were not considered in equation 2. The second one is included in the totals: it permits each available version to be able to be configured, such as the

mix of motor, body, paint, and interior, which can be selected by the final customer.

This fact could be supplied with the totals offered in equation 3 to calculate the total number of varieties that have restrictions.

$$V = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{o} \sum_{l=1}^{p} .2^{C_{ijkl}} \qquad \text{(Equation 3)}$$

Where:

V => Total number of product varieties

i => versions, varying from 1 to m

j => body, varying from 1 to n

k => combinations of motor and drive-train, varying from 1 to 0

L => combinations of paint and trim and interior options, varying from 1 to p

c_{ijkl} => factory options

However, the formula proposed by Fischer and Ittner (1999) also does not take into account the restrictions imposed by the factories, such as a convertible model that does not have a solar roof option or option bundling. Thus, the final customer has access to a lower total number of varieties in practice than that proposed by the theory of Fischer and Ittner (1999). In this sense, Pil and Holweg (2004), Barbosa et al. (2005), Scavarda et al. (2009) have included a second portion in equation 3, which yields equation 4.

$$V = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{o} \sum_{l=1}^{p} .2^{a_{ijkl}} - \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{o} \sum_{l=1}^{p} pr_{ijkl} \qquad \text{(Equation 4)}$$

Where:

V => Total number of product varieties

i => versions, varying from 1 to m

j => body, varying from 1 to n

k => combinations of motor and drive-train, varying from 1 to 0

l => combinations of paint and trim and interior options, varying from 1 to p

a_{ijkl} => factory options

p_{rijkl} => potential restriction

This study extended the analysis of product variety in the automotive industry downstream from the vehicle assemblers to include the authorized factory dealers. These members of the supply chain also contribute to the generation of product variety as perceived by the final consumer (e.g., Scavarda et al., 2010). The varieties generated by the dealers (accessories, or dealer-fitted options) contribute exponentially to the total variety (V) as well as to the number of factory options. Reis (2009) reflected these considerations in equation 5.

$$V = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{o} \sum_{l=1}^{p} .2^{a_{ijkl}}.2^{b_{ijkl}} - \sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{o} \sum_{l=1}^{p} pr_{ijkl} \qquad \text{(Equation 5)}$$

Where:

V => Total number of product varieties

i => versions, varying from 1 a m

j => body, varying from 1 a n

k =>combinations of motor and drive-train, varying from 1 to 0

l => combinations of paint and trim and interior, varying from 1 to p

a_{ijkl} => factory options

p_{rijkl} => potential restriction

b_{ijkl} => accessories (authorized dealer)

This evolution of the measurement of product variety was based on the automotive industry. An adaptation of Equation 4 was done in Brafman (2009) to measure the variety of shampoos, as exposed in Equation 6. This variety is composed by the following variables: additional propose (not only to wash but also to treat the hair), focus on hair color, fragrance, special features (e.g. curly hairs and dry hairs), public (female, male or children), and packaging.

$$PV = \sum_{i=1}^{a} \sum_{j=1}^{d} \sum_{k=1}^{e} \sum_{l=1}^{f} \sum_{m=1}^{g} \left(2^{b_{ijklm}+c_{ijklm}} - R_{ijklm}\right) \qquad \text{(Equation 6)}$$

Where:

PV => Total number of product variety for Shampoos

i => number of versions varying from 1 to a

a => total number of versions

j => number of public for each version varying from 1 to d

d => total number of public types

k => number of hair colors for each public varying from 1 to e

e => total number of hair colors

l => number of packages for each color varying from 1 to f

f => total number of packages

m => number of fragrances for each package varying from 1 to g

m => total number of fragrances

b_{ijklm} => total number of additional propose items for each version i, public \aaaj, color k, package l and fragrance m

c_{ijklm} => total number of special features for each version i, public j, color k, package l and fragrance m

R_{ijklm} => Potential number of restrictions of additional propose items and special features for each version i, public j, color k, package l and fragrance m

The next chapter offers the research method adopted in this thesis.

3
Research Method

This chapter presents the research method applied in this thesis. First, the method used in the systematic literature review (bases for chapter 4) is detailed, followed by the methodological approach used in the multi-case study (bases for chapter 5 and 6).

3.1
Framework method

Li and Cavusgil (1995) classified existing literature reviews in an intent to summarize the state of the art in specific areas by distinguishing between reviews that employ the Delphi method, those that use meta-analysis, and those that employ content analysis. The present study used content analysis. According to the GAO (1996), content analysis allows researchers to select, filter, and summarize large volumes of data, which facilitates data analysis. Holsti (1969) suggests that this technique facilitates objective and systematic inference, which allows the identification of the relevant features of a particular subject, especially those isolated by multiple researchers. Moreover, content analysis is a systematic technique that is replicable by other researchers because it is based on explicit rules (Weber, 1990).

The methodological approach adopted in this research was based on Rowley and Slack (2004) and Kirca and Yaprak (2010). First, the criteria for the selection and inclusion of the studies were defined. Then, based on the framework presented in Section 2, the collected data were organized and the results were analyzed. This approach made it possible to draw the conclusions presented at the end of the article.

The data from the review were gathered exclusively from scientific journals. This limitation is justified because academics and professionals generally use such journals to acquire knowledge and disseminate new results. Thus, these journals

represent the highest level of research (Nord and Nord, 1995; Ngai and Wat, 2002, Ngai et al., 2009).

As Rowley and Slack (2004) have indicated, online databases are an important tool in the selection of articles from scientific journals. Science Direct and Emerald were the databases used in this research. Therefore, the present study is non-exhaustive because other databases may contain additional relevant studies on the subject. Furthermore, the only journals included were those that publish articles in the following areas of study: “Business, Management and Accounting”, “Computer Science”, “Decision Sciences”, “Economics, Econometrics and Finance”, “Engineering”, and “Social Sciences”.

To select articles, an advanced search was performed using Boolean expressions ("AND" and "OR") that combined keywords to best approximate specific terms, as advocated in Rowley and Slack (2004). The research procedure included an initial filter that was created by searching for the expression "product AND variety" in the article abstracts, keywords, and titles. In spite of the high number of articles published on this subject, only a small part of the authors conceptualized product variety (e.g., Balakrishnan and Chakravarty, 2008; Vaagen and Wallace, 2008; Murthy et al., 2009; Zhang and Huang, 2010). However, the term “Product Variety” is widely adopted and represents a good expression to cover the vocabulary knowledge in this field. The “AND” Boolean expression was used, as these terms do not always come together. Other keywords, such as variations, variants, and product line, were not used in the inclusion criteria, as they normally accompany the previously mentioned terms. Nevertheless, the expression “managing OR management” was used as a second filter to retrieve several articles that do not directly address keywords in their abstracts and those that include the terms “product” and “variety” in their titles.

In addition, the research analysis has only included articles from 2005 to 2011. Nevertheless, this seven-year scope is sufficient to cover the relevant and current references, thereby making it possible to analyze the current state of the art of PVM.

The first phase yielded 455 articles for possible inclusion in the systematic review. To ensure a focus on the topic of product variety, additional filtering was performed via analyses of the article abstracts, followed by the full articles.

The abstracts were classified in binary form, assigning a value of zero (0) to articles unrelated to PVM and a value of one (1) to related articles. The next step consisted of compiling the values assigned to the abstracts in a Microsoft Excel® spreadsheet. The researchers addressed any instances of disagreement to reach a consensus regarding the inclusion or exclusion of the article in question. After this step had been completed, the number of articles included in the study decreased to 119 (73 from Elsevier and 46 from Emerald).

Next, each of these 119 articles was read in its entirety. Based on this review process, only 87 articles were selected for the systematic literature review (60 from Elsevier and 27 from Emerald). The data from these articles were organized in Microsoft Excel® spreadsheets based on the framework described above. After selection, the units of analysis were sorted. These units included words, sentences, and paragraphs of the text, as recommended by Unerman (2000).

3.2
Case studies methodology

This section presents the method applied to conduct the multi-case studies. The academic literature offers little guidance on a company's operation in a high PV environment and the effects within the main organizational areas. The present thesis aims to fill the gaps in the PVM literature by means of an "explanatory" study. This strategy is preferred when the researcher has little influence over events, and it is a contemporary phenomenon within some real-life context (Yin, 1994; Miguel, 2005). Voss et al. (2002) argued that exploration is needed to develop research ideas and question. This thesis can be classified as an explanatory study because it is the first effort to understand PVM best practices in the business arena.

The research was conducted via a multi-case study approach. The case study is indicated for the investigation of contemporary phenomena within their real life context, particularly when the boundaries between them are not clearly defined. Thus, the current themes and situations are recommended for the researcher to observe the facts and attempt to understand, systematize and analyze them (Yin, 2008; Voss et al., 2002).

The automotive sector was selected due to its economic importance (e.g., the automotive industry represented more than 20% of industrial GDP in Brazil, and the total sales worldwide exceeded 60 million passenger cars in 2012 (ANFAVEA, 2013; OICA, 2013), its operation in a high product variety volume environment (Trentin et al. 2013), its complex and expensive products (Staeblein et al. 2013), and because it has been at the forefront of many managerial and industrial developments throughout the world (Pires, 1998; Thun and Hoenig, 2011). Passenger cars, buses and truck manufacturers represent main segments of this sector, which resulted in the inclusion of a company of each segment in the multi-case study. The details of this inclusion are offered later. Additionally, one company from the cosmetic industry was selected and analyzed. The automotive and cosmetic industries were compared to highlight the similarity and differences in the PVM process. The cosmetic industry was a strategic choice to validate the variables inside the academic framework developed in chapter four; this analysis extended the automotive sectors' perspective and reduced the framework validation limitations. The market for cosmetics, especially for shampoos, has experienced a very large increase in sales as a result of the higher buying power of the Brazilian population and the larger presence of women in the labor market. In addition to these events, the increase in shampoo heterogeneity should also be highlighted, which comprises a unit of analysis within the cosmetic industry in chapter six. This choice is motivated because shampoo has functions than other just washing standard hair types (e.g., treatment) and is adapted to the different customer's needs (e.g., dry hair, colored hair, curly hair). For confidentiality reason and to increase the degree of freedom in the comments and analysis, each company is referred to with randomly generated false names.

All chosen products are also considered to have a high variety in their respective industries (truck, bus, passenger car, and shampoo).

- The first company to be studied is a large multinational automobile company that has a diversified product line (trucks, bus chassis, commercial vehicles and passenger cars). It has been chosen to represent the automotive industry from the truck manufacturing perspective. The company has produced vehicles in Brazil since the 1950s, and its country infrastructure includes two assembly plants, a distribution center and a network of almost 200 dealers. The company is one of the two major

manufacturers that sell most trucks in the South American market. In this thesis, one of its plants dedicated to the production of trucks and the bus chassis is studied.

- The second company to be studied is a Brazilian bus body manufacturer that includes three industrial plants in Brazil and eight foreign ones (China, Egypt, South Africa, Argentina, Colombia, India, and Australia). In Brazil, it features two brands and an independent negotiation unit. It is a market leader and a major shareholder in other body manufacturers. It also holds a stake in some Brazilian suppliers, such as seat makers and upholsterers. This thesis focuses on its main Brazilian manufacturing plant, which supplies parts and components to all its factories in Brazil and worldwide.
- An American multinational OEM that is among the top worldwide vehicle producers with significant sales in Brazil was chosen to represent the automotive industry from the passenger car manufacturing perspective. Its most-produced passenger vehicle in Brazil and one of the best-selling cars in the Brazilian domestic market, a subcompact vehicle model produced in Greenfield, was used as reference.
- A European multinational enterprise that is among the top three producers of cosmetics worldwide and in Brazil was chosen to represent the cosmetic industry. This choice was made because this company is the one that offers most variety of shampoos to the Brazilian market.

In all cases, Brazil contains the production plants that supply all Latin American markets. Furthermore, the Brazilian market is the largest by volume and features the highest product variety (for all products).

This research used a multitude of data sources because any finding or conclusion in a case study is likely to be much more convincing and accurate if based on different sources of information, following a corroboratory mode (Yin, 2008). The triangulation approach was adopted by combining the sources from different pieces of evidence while shifting between analysis and interpretation (Yin, 2008). The data were gathered utilizing interviews with different stakeholders involved in the decision process regarding product variety (each one lasting between two and four hours), *in loco visits* for direct observation and internal documents from both companies.

The interviews began with the production managers of each plant and were followed by a plant visit. The subsequent interviews included the main professionals involved in the decision process related to product variety for each company. The interviews were guided by a questionnaire, and the questionnaires were designed to understand the practices used by the different areas involved in the management of shampoo variety. The questionnaire incorporated the different aspects of PVM based on the research framework, which are offered in chapter four, organized into four dimensions: inputs, structure and processing, measures and outcomes. The questions that were used in the semi-structure questionnaire are the following: 1) What are the main reasons that lead the company to increase product variety? 2) What are the main problems arising from this increased variety in the company? 3) Where are the major costs related to increased product variety? 4) Is there a process for mitigation to minimize problems arising from the expansion of the product range? Cite examples to illustrate. 5) How is the decision making process of determining the range of a product for the Brazilian market? What information is used? What is the role of your area in the definition of the variety? And in the case of export, who defines the variety? 6) Do you think the current suitable range of company's products or should it increase or decrease?

The interview protocol included issues related to the four dimensions, specifically regarding the main advantages and disadvantages of the variety, the main pressures influencing variety creation, the reasons to increase or reduce this variety, the consequences, the related costs, the managing procedures used, the adopted mitigation processes, the existing measures and main desired outcomes. For the Truck OEM, interviews were conducted with six employees: the plant director, marketing manager, production manager, logistics manager and human resources manager, who all directly influenced the decision process regarding the truck variety offered to the market. In the bus-body manufacturing sector, seven employees who work in areas directly impacted by product variety were interviewed. They included a manager from each of the following areas: quality, marketing, commercial, logistics, human resources, and environment. For the passenger car OEM, interviews were conducted with five employees: the chief engineer for product development, production manager, finance manager, sales manager, and marketing manager. For the cosmetic company, interviews were conducted with ten employees from different areas of the company who are

actively involved in the decision process regarding the product variety of shampoos: the marketing director, supply chain director, procurement manager, production manager, marketing manager, imports coordinator, logistics coordinator, transports coordinator, information system coordinator, and shampoo marketing analyst.

Given the key role that the interviewees played in the decision process regarding product variety decisions and their impacts, the relatively low number of interviewees does not pose a major constraint on the validity of the findings, mainly because the findings were triangulated from the interviews with the results from the plant visits. The research further drew upon contextual information obtained from the internal reports and documents of each company.

The members were also verified with the same interviewees to validate the researchers' results and analysis (Bloor, 1997), which was accomplished by presenting the research analysis to allow the interviewees to evaluate and provide feedback about the accuracy of the researchers' understanding.

4
PVM Framework

This chapter aims to offer a conceptual framework for PVM in order to conduct a systematic review of the existing literature by reporting findings from published articles on the research topic, highlighting the state of the art and identifying any gaps that could be addressed in future research.

Systematic literature reviews are a means of providing an objective theoretical evaluation of a particular topic (Hopayian, 2001). A systematic literature review facilitates the identification, evaluation, and interpretation of studies in a given area by examining existing concepts, practices, and theories and ultimately summarizing the state of the reproducible research in a specific area (Rowley and Slack, 2004; Seuring and Müller, 2008). Thus, the use of literature reviews is necessary for those seeking to better understand the issues associated with a topic of research (Burgess et al., 2006) and provide direction for future studies that can address existing knowledge gaps.

This review was organized with the help of the proposed research framework, as suggested in Rowley and Slack (2004) and Seuring and Müller (2008), which contributed to this thesis. A research framework indicates the development of researchers' understanding of a particular theme (Rowley and Slack, 2004). Research frameworks are carefully tailored to address the fundamental aspects of the studied theme. In other words, these conceptual frameworks must be useful to other researchers interested in the same theme at the end of the research process (Seuring and Müller, 2008).

The chapter is organized according to the key dimensions of the PVM framework depicted in Figure 4.1. The construction of this figure was guided by a review of the existing frameworks used in the literature review content analysis. The framework for the drawing was particularly inspired by and based on Leidecker and Bruno (1984), Danese et al. (2004), Becheik *et al.*, (2006), Marasco (2008), Pokharel and Mutha (2009), and adapted the categories for analysis designated by these authors. The framework includes four dimensions: inputs, structure and processing, measures and outcomes.

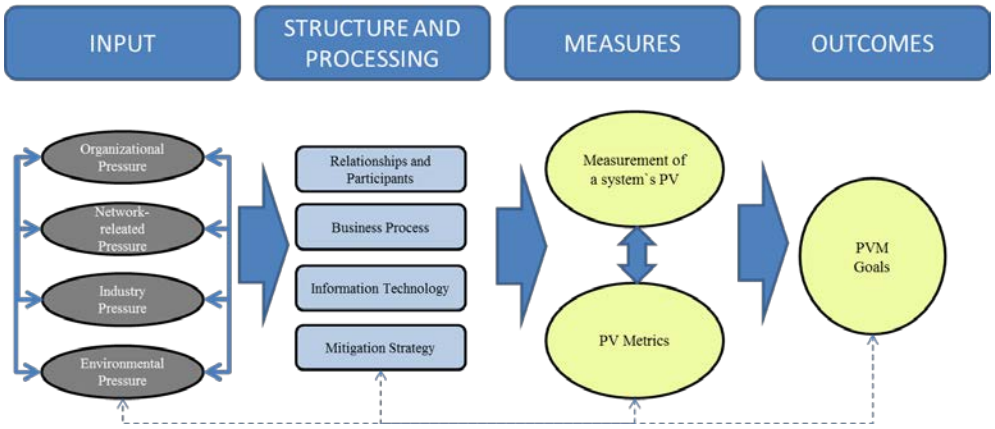

Figure 4.1: The content analysis framework

In this case, inputs are pressures that influence the increase or decrease in the variety of products offered to customers. This dimension was organized into four groups inspired by the classification for supply-risk management adapted from Jüttner et al. (2003), Ritchie and Brindley (2007), Rao and Goldsby (2009) and Ceryno et al. (2012). The four groups are defined as follows: organizational pressure (firm), network-related pressure (supply chain), industry pressure (e.g., automotive industry or cosmetic industry) and environmental pressure (e.g., governmental policies, macroeconomic effects, social and environmental demands). These four main pressures could influence each other and impact the product variety offered in the market.

Organizations use structure and processing characteristics to address these pressures. These resources can be grouped into the following categories: (i) relationships and participants, which can be considered from both the intra-organizational perspective (when the focus is departments or areas internal to departments; Shapiro, 1977; Bowersox et al., 2000; Malhotra and Sharma, 2002) and the inter-organizational viewpoint (when the focus is the various members of a supply chain; Croom et al., 2000; Lambert and Cooper, 2000); (ii) business processes (Davenport, 1990, Lambert and Cooper, 2000, Lambert, 2004); (iii) information technology (Croom et al., 2000); and (iv) mitigation strategies (Pil and Holweg, 2004; Scavarda et al., 2010; Stäblein et al., 2011).

Various articles mention measures that can be used to evaluate the efficiency of production processes, which include analyzing the variety of items produced or the customer service offered, and they can be categorized into two major groups. The first group of measures refers to a measurement of a system's

product variety. Da Silveira (1998) highlighted that the literature may suggest two major approaches. The first may be called the "product line breadth" approach and was used by Kekre and Srinivasan (1990). It consists simply of counting the number of products in a line, in which each product combines distinct characteristics and features. The second approach may be called the "product complexity" approach, in which the variety involves three dimensions (fundamental, intermediate and peripheral). This approach was used by MacDuffie et al. (1996) to measure product variety of automotive plants. The second group of measures refers to product variety metrics that are related to product variety management but have different scopes, such as measuring efficiency in production (Uffmann Sihn, 2006, Bryan et al., 2007; Jiao et al., 2007b), financial aspects (Nepal et al., 2005, Wu et al., 2007; Rabinovich et al., 2010), and consumer perspective (Lin et al. 2010).

Finally, outcomes are the objectives that companies hope to achieve as a result of efficient PVM (Nepal et al., 2005; Morgan and Fathi, 2008; Balakrishnan and Chakravarty, 2008; Hu et al. 2008; Cebeci, 2009).

Before introducing the systematic review organized by the framework key dimensions, a brief introduction regarding the context of the articles is offered. Almost 80.0% of the 87 articles selected are focused on the manufacturing sector in industries such as the automobile, mobile phone, computer, textile, article, and coffee industries. Within the service sector, the retail sector was the most studied, with articles addressing problems such as product variety assortment, shelf allocation (Morales et al., 2005; Chen and Lin, 2007; Hariga et al., 2007), and product recommendation systems for online retailers (Albadvi and Shabazi, 2009). These results suggest that researchers should further explore the nature of the service sector given its increasing importance in industrial engineering.

The data indicate that 65.5% of articles are theoretical: they seek general solutions that may be useful to other companies in the same industry or sector or that may be applicable to more than one type of industry or sector. The remaining articles are purely empirical (22.9%) or both empirical and theoretical (11.4%). These articles propose methodologies and test them empirically. Empirical studies are predominantly focused on manufacturing. However, emerging countries, such as Brazil, are very seldom analyzed (e.g., da Silveira, 1998; Scavarda et al., 2010).

Eighty percent of the articles analyzed are prescriptive, and they mostly propose practices for adoption by companies. Prescriptive and combined descriptive-prescriptive studies together account for 90% of the total articles.

4.1
Inputs

Inputs are factors that drive the adoption of PVM and can be organized into the following: organizational, network-related, environmental and industry. Table 4.1 presents the main inputs identified in the literature review and related references. Although the origins of the inputs in the framework are categorized, in practice, each input may have more than one source. Thus, this research focuses and displays these inputs according to their influence on the management of product variety and not on the source of the input.

Table 4.1: Internal and external pressures that influence PVM

Internal and external pressures that influence PVM	References	Dominant(s) Pressure(s)
Support for and/or responsiveness to the diverse needs of clients (customized)	Hsiao and Liu (2005); Jiao and Zhang (2005); Kim et al. (2005); Lee and Lee (2005); Bramham et al. (2005); Hashmi (2006); Uffmann and Sihn (2006); Fernandes et al. (2006); Brabazon and MacCarthy (2006); Sered and Reich (2006); Sholz-Reiter and Freitag (2007); Bryan et al.(2007); Chen and Li (2007); Wang and Che (2007); Hariga et al. (2007); Jiao et al. (2007); Jiao et al. (2007b); Meredith and Akinc (2007); Weng and Yang (2007); Goyal and Singh (2007); Aramand (2008); Hu et al. (2008); Tseng et al. (2008); Balakrishnan and Chakravarty (2008); Chauhan et al. (2008); Spulber (2008); Vaagen and Wallace (2008); Kucuk and Maddux (2010); Elmaraghy et al. (2009); Johnson and Kirchain (2009); Shiue (2009); Rabinovich	Industry

	et al. (2010); Zhang and Huang (2010); Lim et al. (2010b); Kucuk and Maddux (2010); Xu (2010); Nazarian et al. (2010); Puligada et al. (2010); Lin et al. (2010); Tiwari et al. (2010)	
Miscellaneous costs	Allanson and Montagna (2005); Hsiao and Liu (2005); Jiao and Zhang (2005); Kimura and Nielsen (2005); Nepal et al.(2005); Hashmi (2006); Sered and Reich (2006); Wang and Che (2007); Hariga et al. (2007); Jiao et al. (2007); Jiao et al. (2007b); Meredith and Akinc (2007); Weng and Yang (2007); Wu et al. (2007); Escobar-Saldívar et al. (2008); Balakrishnan and Chakravarty (2008); Sen (2008); Morgan and Fathi (2008); Vaagen and Wallace (2008); Brambilla (2009); Matsubayashi et al. (2009); Johnson and Kirchain (2009); Rabinovich et al. (2010); Lim et al. (2010b); Nazarian et al. (2010); Tiwari et al. (2010)	Organizational, network-related, industry, environmental
Operational complexity	Jiao and Zhang (2005); Kimura and Nielsen (2005); Hashmi (2006); Uffmann and Sihn (2006); Er and MacCarthy (2006); Jiao et al. (2007); Jiao et al. (2007b); Wu et al. (2007); Escobar-Saldívar et al. (2008); Hu et al.(2008); Tseng et al. (2008); Chauhan et al. (2008); Sen(2008); Vaagen and Wallace (2008); Elmaraghy et al.(2009); Shiue (2009); Nahmens and Mullens (2009); Pero et al. (2010); Rabinovich et al.(2010); Lim et al. (2010b); Foubert and Gijsbrechts (2010); Tiwari et al. (2010)	Organizational
Product lifecycle	Nepal et al. (2005); Uffmann and Sihn (2006); Nagarjuna et al. (2006); Iwaarden et al. (2006); Bryan etal. (2007);Wang and Che (2007); Aramand (2008); Tseng et al. (2008); Wang et al. (2008); Sen (2008); Vaagen and Wallace (2008); Shiue (2009); Lim et al. (2010b); Kucuk and Maddux (2010)	Industry

Differentiation from competitors	Hsiao and Liu (2005); Jiao and Zhang (2005); Kim et al. (2005); Bramham et al. (2005); Uffmann and Sihn (2006); Bryan et al.(2007); Erkal(2007); Aramand (2008); Wang et al. (2008); Balakrishnan and Chakravarty (2008); Vaagen and Wallace (2008); Cebeci (2009); Matsubayashi et al. (2009); Elango (2009); Kucuk and Maddux (2010); Scavarda et al. (2009); Scavarda et al. (2010); Krystallis and Chrysochou (2010); Min (2010); Jensen (2011)	Organizational and industry
Customer choice process	Jiao and Zhang (2005); Lee and Lee (2005); Morales et al. (2005); Bramham et al. (2005); Chen and Li (2007); Jiao et al. (2007b); Albadvi and Shahbazi (2009); Matsubayashiet al.(2009); Rabinovich et al.(2010); Kucuk and Maddux (2010); Puligada et al. (2010); Lin et al. (2010)	Network-related
Capacity limitations	Jiao and Zhang (2005); Brabazon and MacCarthy (2006); Bryan et al. (2007); Chen and Li (2007); Hariga et al. (2007); Jiao et al. (2007b); Meredith and Akinc (2007); Escobar-Saldívar et al. (2008); Sen (2008); Elmaraghy et al. (2009)	Organizational
Economies of scale	Allanson and Montagna (2005); Jiao and Zhang (2005); Nagarjuna et al. (2006); Jiao et al. (2007b); Weng and Yang (2007); Elmaraghy et al. (2009); Brambilla (2009); Rabinovich et al. (2010)	Network related, organizational and industry

Resource limitations	Kimura and Nielsen (2005); Wang and Che (2007); Erkal (2007); Tseng et al. (2008); Sen (2008); Elmaraghy et al. (2009); Shiue (2009)	Environmental
Stock levels	Hariga et al. (2007); Jiao et al. (2007b); Escobar-Saldívar et al. (2008); Vaagen and Wallace (2008); Forza et al. (2008); Rabinovich et al. (2010); Kucuk and Maddux (2010)	Network related
Customer quality needs	Nepal et al. (2005); Hashmi (2006); Uffmann and Sihn (2006); Iwaarden et al. (2006); Goyal and Singh (2007); Matsubayashi et al. (2009); Kucuk and Maddux (2010)	Industry, environmental
Management of the number of components that comprise the finished product	Jiao et al. (2007); Erkal (2007); Balakrishnan and Chakravarty (2008); Rabinovich et al. (2010); Puligada et al. (2010)	Organizational, network related
Environmental responsibility	Kimura and Nielsen (2005); Hashmi (2006); Tseng et al. (2008); Cebeci (2009); Elmaraghy et al. (2009)	Environmental
Evolution of technology	Chen and Wu (2005); Uffmann and Sihn (2006); Aramand (2008); Spulber (2008); Hilletofth et al. (2009)	Industry
Time and/or number of setups	Jiao et al. (2007); Escobar-Saldívar et al. (2008); Elmaraghy et al. (2009); Nazarian et al. (2010)	Organizational
Compliance with technical and legal regulations	Hashmi (2006); Sen (2008); Cebeci (2009)	Environmental

The main responsibility of companies is their need to meet and satisfy the diverse needs of customers by increasing the variety of products that they offer, introducing new products (Kim et al., 2005; Aramand, 2008), and adding new features or functions to existing products (Chen and Lin, 2007). Globalization has contributed to the proliferation of variety because geographically dispersed demand increases the need to offer products that are appropriate for different cultures and meet the demands of a diverse customer base. An example of this dispersion is offering tourism packages with a wide range of options of travel

(local transportation, lodging, etc.) due to the ease of access to different geographic areas (Weng and Yang, 2007). Moreover, the fast food industry is pressured by the tastes of global consumers to change and adapt products to a local taste. One example of this trend is the fast food industry in India, which had to adapt products such as the double cheeseburger and onion rings to Indian habits and preferences to attract young consumers (Goyal and Singh, 2007).

Customization can satisfy different consumer needs, but it can also increase the complexity of operations. Nahmens and Mullens (2009) argue that customization can disrupt the entire estimating, production, delivery and management process, which reduces the efficiency of operations. In addition to customization, the needs of both the final customers and the intermediary customers can pressure a company to increase the variety of products. For examples, retailers want greater variety to prevent the transformation of the products offered in its sales outlets in commodities subject to price competition (Johnson and Kirchain, 2009). Another example is the high-technology products industry, which is characterized by products with a short life cycle due to technological developments, such as software products and services. According to Aramand (2008), this industry must meet the demand for variety in accordance with the changing requirements of clients represented by other industries (telecommunications, electronics, etc.) and end users. These intermediate customers of the company who are responsible for producing the variety can be first-tier (direct downstream in the chain) but not necessarily the ultimate customers in the supply chain. They can also be second-tier customers (customers of your client). Bramham et al. (2005) suggest that some key customers have the power to negotiate some product specifications/attributes that are tailored to meet their requirements.

Increased competition may result in the implementation of personalization strategies and in product diversification (Uffmann and Sihn, 2006; Bryan et al., 2007; Wang et al., 2008; Elmaraghy et al., 2009) to achieve market differentiation and thereby to attract more customers. These efforts, in turn, can result in increased product variety. However, product quality may diminish as a result of such increases in variety (Hashmi, 2006; Matsubayashi et al., 2009), thereby generating resistance against the latter.

Market requirements are dynamic, often shortening the product lifecycle (Uffmann and Sihn, 2006; Aramand, 2008). This reduction in the lifecycle may also be affected by technological changes, thereby leading companies to develop new products more rapidly (Bryan et al., 2007). A short product lifecycle creates a greater range of new products offered over time (Uffmann and Sihn, 2006).

Environmental responsibility, regarded as an input that reduces variety, is an issue of increasing focus (Tseng et al., 2008). As discussed in Cebeci (2009), environmental responsibility, with regards to the demand for environmentally friendly products, is often determined by legal and technical regulations, which, in turn, affect the variety of products offered on the market.

To counteract the negative consequences of the proliferation of product variety, companies should ensure that their offerings are not so extensive as to cause confusion in the customer decision-making process, otherwise known as "mass confusion" (Jiao et al., 2007b). In the presence of many options, a customer may take too long to make purchasing decisions, may not be able to determine the best alternative (Matsubayashi et al., 2009), or may even make mistakes during the selection process, which then results in a high rate of product returns (Rabinovich et al., 2010).

Many studies highlight that significant increases in product variety can compromise operational efficiency by complicating manufacturing (Jiao et al., 2007b; Tseng et al., 2008; Chauhan et al., 2008; Elmaraghy et al., 2009), distribution (Jiao et al., 2007; Vaagen and Wallace, 2008), and supply processes in production systems and in the entire supply chain (Hu et al., 2008; Sen, 2008). Moreover, increased product variety can increase the complexity of administrative management (Escobar-Saldívar, 2008).

Increased product variety can also raise costs (Jiao et al., 2007b). The main types of costs include investments made to install production systems and/or increase their efficiency (Wang and Che, 2007; Wu et al., 2007); the costs associated with supplying a greater variety of products in smaller quantities (Sen, 2008; Vaagen and Wallace, 2008); manufacturing costs (Allanson and Montagna, 2005; Hsiao and Liu, 2005; Jiao and Zhang, 2005; Nepal et al., 2005; Meredith and Akinc, 2007; Balakrishnan and Chakravarty, 2008; Morgan and Fathi, 2008; Johnson and Kirchain, 2009); product-specific costs (Hsiao and Liu, 2005; Nepal et al., 2005; Jiao et al., 2007a); market brokerage costs (Wu et al., 2007; Sen,

2008); transport and distribution costs (Weng and Yang, 2007; Allanson and Montagna, 2005; Sen, 2008); set-up costs (Escobar-Saldívar et al., 2008); inventory costs (Hariga et al., 2007; Escobar-Saldívar et al., 2008; Sen, 2008); product storage and display costs (Tseng et al., 2008); and quality requirements and maintenance costs (Wu et al., 2007). The major challenge highlighted in the literature is the requirement that firms offer greater product variety at lower costs. As such, analyses of cost relative to variety should be performed during the product development phase (Johnson and Kirchain, 2009).

Industries characterized by a wide variety of products must work with different production set-ups. The greater the set-up time, the lower the production efficiency (Escobar-Saldívar et al., 2008). Another important consideration is the required stock level as it can cause management problems and require additional warehouse space (Hariga et al., 2007; Escobar-Saldívar et al., 2008) when inventory is too high.

Issues such as limited capacity and resources are also cited as justifications for a decrease in variety. Capacity limitations may include inventory limitations (e.g., available shelf space can restrict the range of products provided by a supplier; Chen and Lin, 2007; Hariga et al., 2007), warehouse limitations with respect to the capacity to allocate space for products (Jiao et al., 2007b), production and/or assembly limitations (Brabazon and MacCarthy, 2006; Bryan et al., 2007; Escobar-Saldívar et al., 2008; Sen, 2008), and labor force capacity limitations (e.g., restrictions related to overtime and subcontracting; Meredith and Akinc, 2007). Even the resources available for production can create limitations, for instance, if natural resources (Tseng et al., 2008) or other types of raw materials (Erkal, 2007) are not sufficiently available.

The last input identified is the production of different (especially smaller) lot sizes due to product proliferation, which can negatively affect economies of scale (Elmaraghy et al., 2009).

Overall, the inputs identified as increasing or decreasing product variety emphasize the importance of PVM in promoting a balance between the positive and negative factors at play. Accordingly, PVM structures and processes are the focus of the next subsection.

4.2
Structure and process

The results in this category are presented and analyzed using the following categories: relationships and participants, business processes, information technology (IT), mitigation strategies.

4.2.1
Relationships and Participants

Table 4.2 summarizes the results related to product variety and the related studies. It is evident that many researchers emphasize both intra- and inter-organizational perspectives.

Table 4.2: Intra- and inter-organizational perspectives in PVM

Intra-organizational	References
Horizontal alignment	Hsiao and Liu (2005); Jiao and Zhang (2005); Kim et al. (2005); Uffmann and Sihn (2006); Hariga et al. (2007); Jiao et al. (2007b); Meredith and Akinc (2007); Elmaraghy et al. (2009); Lim et al. (2010b)
Vertical alignment	Jiao and Zhang (2005); Jiao et al. (2007b); Sen (2008); Cebeci (2009); Pero et al. (2010)
Inter-organizational	References
Supply chain integration	Chen and Wu (2005); Jiao and Zhang (2005);Sholz-Reiter and Freitag (2007); Wang and Che (2007); Erkal (2007); Wu et al. (2007); Aramand (2008); Hu et al.(2008); Balakrishnan and Chakravarty (2008); Sen (2008); Spulber (2008); Vaagen and Wallace (2008); Cebeci (2009); Hilletofth et al. (2009); Pero et al. (2010); Zhang and Huang (2010); Lin et al. (2010)

The results highlight the need for companies to internally coordinate their supply and demand capacity horizontally when seeking product variety to avoid creating conflicts between departments. There should be strong intra-

organizational relationships between the departments involved in the marketing and design of products (Hsiao and Liu, 2005) and between those involved in the marketing, production and/or engineering processes (Jiao and Zhang, 2005; Meredith and Akinc, 2007).

The operational activities that are necessary for product variety should be consistent with the strategic objectives of the firm. Thus, the involvement of top-level management vertical alignment within the firm is a necessity (Jiao and Zhang, 2005; Cebeci, 2009).

To ensure inter-organizational coordination, the work of individual companies should be synchronized with that of other important members of the supply chain (Wu et al., 2007; Hu et al., 2008; Sen, 2008). Wang and Che (2007), Aramand (2008), and Cebeci (2009) highlight the need for communication channels between buyers and sellers throughout the supply chain to strengthen the relationship between the supply chain links, thus making it possible to control and manage not only the suppliers, but all externally produced items as well. Moreover, Jiao and Zhang (2005) and Wu et al. (2007) add that aligning the information exchanged between companies and their suppliers requires an understanding of the needs of the supply chain endpoint (i.e., the consumer) and of the limitations of the whole chain (i.e., the functional requirements that must be fulfilled to manufacture a variety of products). In particular, Chen and Wu (2005) state that companies must develop key links with distributors and customers.

By linking both the upstream and downstream chains, arrangements may be made in the medium and long term in the form of partnerships between affiliates or between companies from different geographical areas (Sen, 2008; Brambilla, 2009). Such arrangements will allow access to knowledge about specific production processes and lead to greater flexibility in providing the requested range of products. Other types may be mergers and acquisitions, as advocated by Uffmann and Sihn (2006), that can be used to control the competition between the varieties offered in the market. A few companies now offer a wide variety of brands as they seek to compete with each other by acting in different market segments. These closer ties allow you to control the flow of materials, and especially the necessary information to each participant.

Thus, this systematic review indicates that modern companies must now refine their processes at the supply chain level. These efforts require the

integration of participants internal to companies (i.e., intra-organizational integration) as well as participants from outside the companies (i.e., inter-organizational integration).

Hilletofth et al. (2009) stated that companies today usually offer a wide range of products in various types of non-coherent business environments such that there are no supply chain strategies that are applicable to all types of products and markets. This situation affects and concerns the supply, manufacturing and distribution parts of the supply chain strategy. Pero et al. (2010) conclude that to achieve alignment, firms may not only match product features with the supply chain, but may also make long-term decisions regarding, for example, supply chain configuration and coordination, and short-term decisions regarding, for example, supply chain coordination.

4.2.2
Business Processes

PVM may involve business processes. Table 4.3 presents the business processes identified in the review, grouped according to Lambert (2004).

Table 4.3 Business Processes under PVM

Business process	References
Manufacturing flow management	Hashmi (2006); Nagarjuna et al. (2006); Fernandes et al. (2006); Jiao et al. (2007); Hu et al. (2008); Wang et al.(2008); Nahmens and Mullens (2009); Elmaraghy et al. (2009); Shiue (2009); Pero et al. (2010); Kristiano et al. (2010); Nazarian et al. (2010)
Demand management	Brabazon and MacCarthy (2006); Chen and Li (2007); Chauhan et al. (2008); Sen (2008); Foubert and Gijsbrechts (2010)
Product development and commercialization	Nagarjuna et al. (2006); Johnson and Kirchain (2009); Lim et al. (2010); Lim et al. (2010b)
Customer service management	Brabazon and MacCarthy (2006); Kucuk and Maddux (2010); Puligada et al. (2010); Lin et al. (2010)
Order fulfillment	Brabazon and MacCarthy (2006); Morgan and Fathi (2008)
Procurement	Wang and Che (2007); Zhang and Huang (2010)
Customer relationship management	Lin et al. (2010)
Returns	Rabinovich et al. (2010)

Most studies that address the theme of PVM business processes analyze them with a particular emphasis on manufacturing flow management. For example, Hu et al. (2008) address the need to consider the impact of adding variants when planning the assembly sequence in a multi-stage system where complexity spreads from one workstation to another. Fernandes and Carmo-Silva (2006) describe a system for controlling production and the flow of materials to improve performance and reduce delivery time, whereas Jiao et al. (2007a) propose a system for identifying similarities between materials, resources, and processes. It is suggested that firms gain competitive advantage by exploiting these similarities and thereby increasing PVM effectiveness. Nahmens and Mullens (2009) highlight that the increase in product variety has a negative impact on manufacturing flow and that the variations in cycle time make it difficult to establish continuous flow by limiting the possibility of a smooth hands-offs at different stages of the production process.

Chen and Lin (2007) highlight the use of point-of-sale (POS) transactions to collect data on consumers and thus develop demand management that can reduce supply uncertainty while facilitating product sorting and shelf allocation. Sen (2008) states that most large retailers use demand management to analyze and address customer demand with respect to product variety.

Uffmann and Sihn (2006) show that in the process of developing new products, firms must consider failure rates, while Savvopoulos and Virvou (2010) highlight the importance of returning to previous projects to develop new product varieties.

Brabazon and MacCarthy (2006) address customer service management in the automotive industry by monitoring demand through information systems in which customers can access real-time information on product variety. To effectively comply with customer requests, dealers can share information with automakers about the products available so that customers can purchase cars with their desired configuration of features. Kucuk and Maddux (2010) describe this process in their study on electronic retailing.

Wang and Che (2007) highlight the importance of supplier selection when addressing the management of supplier relationships (procurement). Lin et al. (2010) address customer relationship management in electronic retailing, highlighting the importance of one-to-one marketing.

Rabinovich et al. (2010) analyze returns in Internet retail, suggesting that companies experience a large number of returned products resulting from poor choices by the end customers, which, in turn, are theorized to be due to excess product variety.

4.2.3
Information Technology

The use of IT in business can be analyzed from various perspectives. Table 4.4 summarizes IT coverage with respect to the systematic review of the literature on PVM.

Table 4.4: Information Technology under PVM

Information Technology	References
E-Commerce	Brabazon and MacCarthy, (2006); Chen and Li (2007); Aramand (2008); Albadvi and Shahbazi (2009); Savvopoulos and Virvou (2010)
Other software	Jiao and Zhang (2005); Nagarjuna et al. (2006); Iwaarden et al. (2006); Jiao et al. (2007); Escobar-Saldívar et al. (2008)
Product Configurator	Bramham et al. (2005); Walsh and Mitchell (2005); Korgaonkar et al. (2006); Savvopoulos and Virvou (2010); DiRusso and Schuff (2011)
Manufacturing Technologies	Sered and Reich (2006); Sholz-Reiter and Freitag (2007); Sen (2008)
Enterprise Resource Planning - ERP	Sholz-Reiter and Freitag (2007); Cebeci (2009)
Electronic Data Interchange - EDI	Sen (2008)

From the standpoint of the internal organization, IT has a key role in ensuring the fluidity of and control over operations. Sen (2008), Lim et al. (2010a), and Lim et al. (2010b) address product development, suggesting that technologies such as computer-aided design (CAD) can accelerate product development and that technologies that store data can also be used to support future modifications. This is of significant importance in environments that require wide variety and short product lifecycles (Sen, 2008; Lim et al., 2010a). In these types of environments, Nagarjuna et al. (2006) suggest that the material handling systems can be used to facilitate material flow. Component variety may also be better managed using support systems for manufacturing, such as

computer-integrated manufacturing (CIM) (Sered and Reich, 2006; Scholz-Reiter and Freitag, 2007) and computer-aided manufacturing (CAM) (Sen, 2008). Also focusing on production, Jiao et al. (2007a) emphasize the use of data mining and text mining to analyze the historical evolution of product and process variations. It is suggested that this information be used to create processing platforms to efficiently manage the variety and production of customized products. Other areas within businesses that require information technology include purchasing (Escobar-Saldívar et al., 2008; Sen, 2008) and sales (Escobar-Saldívar et al., 2008). More generally, Scholz-Reiter and Freitag (2007) and Cebeci (2009) suggest that enterprise resource planning (ERP) facilitates PVM by integrating information across all company areas and departments.

Within the supply chain, Chen and Lin (2007) and Lin et al. (2010) propose that companies implement systems that collect information about client preferences and use data mining to analyze buying behavior in electronic retail markets, thereby facilitating PVM. Albadvi and Shahbazi (2009), Rabinovich et al. (2010), and Lin et al. (2010) suggest that information systems can also assist clients in searching for and selecting their desired merchandise, particularly when they are faced with an enormous variety of products. Such systems have already been implemented in large electronic retail networks such as Amazon.com and web banking. Virtual-build-to-order systems merge these two perspectives by aligning client demand with available products, for example, by aligning customer demand regarding car colors and options with the cars that are in dealer lots, in transit, or currently being produced by the carmaker (Brabazon and MacCarthy, 2006).

Scholz-Reiter and Freitag (2007) highlight the use of radio frequency identification device (RFID) technology, and Sen (2008) focuses on electronic data interchange (EDI) to assist in the handling of a wide variety of products along the supply chain.

The Internet has made the process of finding and comparing consumer products and prices significantly easier for shoppers (DiRusso and Schuff, 2011). The increase in product development, even in the electronic environment, can result in excessive marketing communications, sophisticated and complex products, and decreased inter-brand differences, thereby causing some consumers to feel overwhelmed when attempting to make a purchase decision (Walsh and

Mitchell, 2005). In this context, intelligent systems have been constructed to help users to choose appropriate services and products, such as product configurator (Savvopoulos and Virvou, 2010). The authors demonstrate that some applications of product configurator help elderly people to use the Internet through their mobile phones. In high-variety environments, product configurator offers support and helps customers select the best product according to their needs by presenting only the requisite information (Bramham et al., 2005). One reason consumers prefer to shop online is that a product configurator makes it is easier to access the specific information they need regarding product attributes (Korgaonkar et al., 2006).

4.2.4
Mitigation Strategies

Mitigation strategies are used to alleviate the negative effects of increased product variety. Table 4.5 lists the main strategies mentioned in the literature.

Table 4.5: Product variety mitigation strategies

Mitigation Strategies	References
Use of common components	Hsiao and Liu (2005); Jiao and Zhang (2005); Du et al. (2005); Kim et al. (2005); Nepal et al. (2005); Rantala and Hilmola (2005); Iwaarden et al. (2006); Sered and Reich (2006); Sholz-Reiter and Freitag (2007); Bryan et al. (2007); Jiao et al. (2007); Erkal (2007); Wu et al. (2007); Aramand (2008); Hu et al. (2008); Tseng et al. (2008); Wang et al. (2008); Balakrishnan and Chakravarty (2008); Sen (2008); Forza et al. (2008); Murthy et al. (2009); Elmaraghy et al. (2009); Johnson and Kirchain (2009); Zhang and Huang (2010); Lim et al. (2010); Lim et al. (2010b); Nazarian et al. (2010); Tretin and Forza (2010)
Mass customization	Jiao and Zhang (2005); Kim et al. (2005); Lee and Lee (2005); Wang and Che (2007); Jiao et al. (2007); Meredith and Akinc (2007); Aramand (2008); Hu et al. (2008); Tseng et al. (2008); Elmaraghy et al. (2009); Nahmens and Mullens (2009); Zhang and Huang (2010); Lim et al. (2010); Lim et al. (2010b); Puligada et al. (2010); Tretin and Forza (2010)
Product families	Hsiao and Liu (2005); Kim et al. (2005); Kimura and Nielsen (2005); Bryan et al. (2007); Jiao et al. (2007); Jiao et al. (2007b); Elmaraghy et al. (2009); Johnson and Kirchain (2009); Lim et al. (2010); Lim et al. (2010b)
Flexible manufacturing	Nagarjuna et al. (2006); Fernandes et al. (2006); Sholz-Reiter and Freitag (2007); Wu et al. (2007); Escobar-Saldívar et al. (2008); Wang et al. (2008); Innes (2008); Nazarian et al. (2010)

Production strategies	Fernandes et al. (2006); Brabazon and MacCarthy (2006); Meredith and Akinc (2007); Chauhan et al. (2008);
Use of common processes	Jiao et al. (2007); Escobar-Saldívar et al. (2008); Balakrishnan and Chakravarty (2008); Pero et al. (2010); Stäblein et al. (2011)
Postponement	Appelqvist and Gubi (2005); Brabazon and MacCarthy (2006); Er and MacCarthy (2006); Meredith and Akinc (2007); Forza et al. (2008); Elmaraghy et al. (2009); Nahmens and Mullens (2009); Tretin and Forza (2010)
Option bundling	Weng and Yang (2007); Foubert and Gijsbrechts (2010); Stäblein et al. (2011)
Lean Manufacturing	Fernandes et al. (2006); Escobar-Saldívar et al. (2008)
Pricing	Jensen (2011); DiRusso and Schuff (2011)
Cellular manufacturing	Sholz-Reiter and Freitag (2007)

The mitigation strategy most often cited is the adoption of common components in the production process. The use of common components to make a variety of products facilitates cost reduction (Balakrishnan and Chakravarty, 2008; Johnson and Kirchain, 2009). For instance, common platforms can be developed for different products, as has commonly occurred in the automotive industry (Erkal, 2007). Common platforms allow companies to reduce their investments in research and development and introduce new products more quickly (Sered and Reich, 2006). Additionally, Kristianto et al. (2010) suggest that platform commonality has a positive impact on product variety by optimizing process and design. Another particular case is that of modularization, which increases the agility of the manufacturing process (Nepal et al., 2005) and allows for increases in product variety through the sharing of modules across different product lines. A third similar strategy is that of organizing products with similar features and attributes into families (Bryan et al., 2007; Jiao et al., 2007a; Jiao et al., 2007b; Elmaraghy et al., 2009; Johnson and Kirchain, 2009), which reduces the complexity associated with producing a variety of products. Elmaraghy et al. (2009), Zhang and Huang (2010), and Lim et al. (2010) suggest that long-term planning for product families be focused on enabling both modularization and the sharing of components and platforms, in order to facilitate PVM. Furthermore, offering products that can be grouped into packages facilitates the management of a large variety of products. Adopting this premise, Weng and Yang (2007) examine the case of tour packages.

Pero et al. (2010) stated that modularity does not necessarily reduce configuration complexity along the supply chain. The authors support their premise referencing two automotive suppliers that produce modules for an OEM (original equipment manufacturer); however, the two suppliers must then manage a complex network of suppliers.

Mass customization is another mitigation strategy that can increase product variety with a low impact on costs (Jiao et al., 2007a). Lee and Lee (2005) demonstrate this strategy in the computer industry where, by offering standard models, the client can customize products by adding other attributes at a relatively low cost.

Jiao et al. (2007a) and Balakrishnan and Chakravarty (2008) see the use of common processes as a mitigation strategy that can help firms avoid dramatic increases in production costs while still offering a significant variety and/or introducing new and different products. Savvopoulos and Virvou (2010) emphasize the need to draw from previous projects when developing new product lines/variations.

The mitigation strategies outlined in these studies also address production processes. The related strategies include lean production (Fernandes and Carmo-Silva, 2006; Escobar-Saldívar et al., 2008) and the use of cellular manufacturing systems (Scholz-Reiter and Freitag, 2007). The use of postponement is also associated with PVM. In postponement, part of the product production is transferred downstream in the supply chain to a point closer to the end consumer, thus allowing the company to adapt more easily to the particular needs of its clients (Meredith and Akinc, 2007; Elmaraghy et al., 2009). The adoption of postponement can also cause additional costs because operating multiple delivery concepts can be complex and costly in terms of information systems support (Appelqvist and Gubi, 2005). The importance of flexible manufacturing systems is widely discussed in the context of PVM. For instance, Fernandes and Carmo-Silva (2006) cite the importance of quick response manufacturing (QRM) as a competitive strategy for companies that work on a make-to-order (MTO) or engineering-to-order (ETO) basis, indicating that such systems enable firms to produce a wide variety of products and meet variable demands. The selection of a production strategy suitable to the level of product variety offered is also discussed in the literature. Meredith and Akinc (2007) and Chauhan et al. (2008)

highlight the MTO and assembly-to-order (ATO) strategies. Savvopoulos and Virvou (2010) underscore the advantages of an ETO strategy compared to MTO and ATO strategies when a firm offers an undefined number of variations (i.e., open product variety). Whereas Brabazon and MacCarthy (2006) analyze virtual build-to-order (VBTO) in the automotive sector, Meredith and Akinc (2007) address make-to-forecast (MTF) systems, which combine the make-to-stock (MTS) and MTO strategies to deliver customized products quickly without increasing costs. Mass customization is another strategy highlighted in the literature (Lee and Lee, 2005; Jiao et al., 2007).

Organizations may produce a variety of generally similar products, or they may practice “scientific pricing” or revenue management whereby the organizations offer similar or somewhat differentiated products in multiple market segments at different prices. Whenever generally similar products are available, the demand for the products is linked through the ability of the customer to substitute one product for another (Kim and Bell, 2011). For example, a customer may substitute a product that is out of stock by buying a similar product or a customer may substitute a less expensive product for a similar higher priced product.

Measures

The measures applied in PVM are intended to quantify the numbers associated with the final products.

4.3
Measures

This section provides a literature overview of the measurements used in PVM and the metric system used for PV.

Various metrics are mentioned in the studies that assess PVM processes adopted by companies. The main metrics are listed in table 4.6.

Table 4.6: Measures used to assess PVM

Metrics	References
Order fulfilment	Brabazon and MacCarthy (2006), Uffmann and Sihn (2006)
Production quality failures	Uffmann and Sihn (2006), Meredith and Akinc (2007)
Production cycle time	Uffmann and Sihn (2006), Jiao et al. (2007b)
Set-up time	Uffmann and Sihn (2006), Bryan et al. (2007)
Production costs	Nepal et al. (2005), Wu et al. (2007)
Rate of reuse	Bryan et al. (2007)
Cycle time for consumer requests	Brabazon and MacCarthy (2006)
Set-up cost	Bryan et al. (2007)
Average rate and net contribution	Meredith and Akinc (2007)
Product return rate	Rabinovich et al. (2010)
Number of components and products	Wu et al. (2007)
Number of products and/or platform variants	Kim et al. (2005)
Number of models or brands offered by the company	Kim et al. (2005)
Customer satisfaction regarding product variety	Puligada et al. (2010)
Relationship between the configuration recommended and the configuration sold	Lin et al. (2010)

Brabazon and MacCarthy (2006) and Meredith and Akinc (2007) suggest using a metric to monitor order fulfillment and to evaluate the production system with respect to the number of product varieties offered.

Different articles mention measures that can be used to evaluate the efficiency of production processes, whether analyzing the variety of items produced or the customer services offered. Toward this end, metrics for different temporal intervals are suggested. These include production cycle time (Jiao et al., 2007b; Uffmann and Sihn, 2006) and set-up time (Uffmann and Sihn, 2006; Bryan et al., 2007). Competitiveness can be achieved by lowering these indices and thus increasing productivity.

Related financial considerations include production costs (Nepal et al., 2005; Wu et al., 2007), set-up costs (Bryan et al., 2007), net product contributions (Meredith and Akinc, 2007), and product returns (Rabinovich et al., 2010).

Wu et al. (2007) and Bryan et al. (2007) refer to measures that assess the complexity of the product variety offered by a company, including the number of components and products. These measures also indicate the rate of reuse for

system elements used for product reconfiguration relative to that of the overall system of elements.

Kim et al. (2005) and Lim et al. (2010a) emphasize the relationship between product variety and product family commonalities. Kim et al. (2005) propose that the number of models and brands that share a common platform be used as an indication of company strategy regarding product variety.

Meredith and Akinc (2007) and Uffmann and Sihn (2006) emphasize concerns regarding possible decreases in product quality due to increased variety, suggesting that firms determine what percentage of units produced have not met quality requirement guidelines.

Puligada et al. (2010) use end customer satisfaction regarding production variety to assess PVM. Lin et al. (2010) present a metric to evaluate variety recommendation systems employed in electronic retail, determining the type of relationship between the configuration recommended by the system and that sold to the customer.

Although measures were highlighted in many articles as being significantly important, none of the articles worked directly with measures aimed at assessing PVM itself. The identified measures have different scopes for examining specific aspects of PVM. As for the description of PVM, measurement issues were highly dispersed and measures varied widely among authors with no common classification. Accordingly, future research on this topic is suggested.

The academic literature suggests two main procedures to measure a product variety system. The first approach is called the “product line breath” approach (Kekre and Srinivasan, 1990). It consists simply of counting the number of products in line, whereby each product combines distinct characteristics and features. According to Da Silveira (1998), this approach was used in a series of studies on the relationships between product variety, performance and competitiveness by Bental and Spiegel (1984), Lindsley et al. (1991) and Yeh and Chu (1991). The second approach is called the “product complexity” approach. This approach was used by MacDuffie et al. (1996) when measuring the product variety of automobile plants. This is a complex approach that may involve three dimensions of product variety (fundamental, intermediate, and peripheral variety). Each dimension refers to a group of parts with a specific level of relationship

associated with the product's core design (Da Silveira, 1998). This thesis considers both approaches for measuring the product variety of a system.

4.4
Outcomes

Outputs are the results sought by companies adopting PVM. Table 4.7 presents the main outputs identified in the literature.

Table 4.7: Results sought by companies adopting PVM.

Output	References
Increased profitability	Hsiao and Liu (2005); Kim et al. (2005); Bryan et al. (2007); Chen and Li (2007); Hariga et al. (2007); Meredith and Akinc (2007); Weng and Yang (2007); Wu et al. (2007); Escobar-Saldívar et al. (2008); Balakrishnan and Chakravarty (2008); Chauhan et al. (2008); Vaagen and Wallace (2008); Elmaraghy et al. (2009)
Cost reduction	Chen and Wu (2005); Lee and Lee (2005); Nepal et al. (2005); Hashmi (2006); Sered and Reich (2006); Balakrishnan and Chakravarty (2008); Chauhan et al. (2008); Morgan and Fathi (2008); Lambertini and Mantovani (2008); Cebeci (2009); Nazarian et al. (2010); Nazarian et al. (2010)
Increased market share	Jiao and Zhang (2005); Kim et al. (2005); Nepal et al. (2005); Weng and Yang (2007); Wu et al. (2007); Balakrishnan and Chakravarty (2008); Vaagen and Wallace (2008); Cebeci (2009); Brambilla (2009); Shiue (2009)
Analyses of the optimal level of variety to be offered	Jiao and Zhang (2005); Jiao et al. (2007b); Vaagen and Wallace (2008); Cebeci (2009); Murthy et al. (2009); Rabinovich et al. (2010)
Improved customer service	Morales et al. (2005); Chauhan et al. (2008); Shiue (2009)
Reductions in time-to-market required for product introduction	Sered and Reich (2006); Lambertini and Mantovani (2008); Brambilla (2009)
Increased revenue	Jiao and Zhang (2005); Balakrishnan and Chakravarty (2008); Foubert and Gijsbrechts (2010)
Improved brand image	Cebeci (2009);Brambilla (2009); Foubert and Gijsbrechts (2010)
Reduced production system complexity	Hu et al. (2008); Morgan and Fathi (2008)
Maintenance of customer loyalty	Cebeci (2009)

Increased profitability is the output related to PVM that is most discussed in these studies. This increase can be achieved by highlighting those products

offered in retail outlets that have higher profit margins (Chen and Lin, 2007). According to Vaagen and Wallace (2008), increases in profitability should occur if a firm determines the optimal level of variety for each market (which is itself another output that is widely cited in the literature). Chauhan et al. (2008) note that improving customer service is also a major objective of PVM. Weng and Yang (2007), Balakrishnan and Chakravarty (2008) and Vaagen and Wallace (2008) indicate that increases in both profitability and market share are the main goals of PVM. Nepal et al. (2005) emphasize the importance of offering a wide variety of products to increase market share, while Brambilla (2009) emphasizes that to increase market share, the time needed to introduce new products to the market should be decreased. According to Cebeci (2009) and Brambilla (2009), PVM has improved the brand value of firms and increased their market share by providing them access to new markets.

Cost reduction is yet another output associated with PVM. The main costs to be reduced are those associated with product development projects, purchasing (Balakrishnan and Chakravarty, 2008; Cebeci, 2009); inventory (Chauhan et al., 2008), and production (Nepal et al., 2005; Morgan and Fathi, 2008). In addition to focusing on cost reduction, Balakrishnan and Chakravarty (2008) cite increases in revenue and profitability as PVM outputs.

Finally, Hu et al. (2008) and Morgan and Fathi (2008) cite the minimization of production complexity as goals of PVM. Such a reduction in complexity should influence both assembly lines (Hu et al., 2008) and production systems (Morgan and Fathi, 2008). Another output identified in the review is the improvement or maintenance of customer loyalty (Cebeci, 2009).

4.5
Final considerations

This chapter presents a PVM framework to indicate how researchers understanding of PVM has evolved and to help practitioners understand the main issues related to the gap in the literature (e.g., Elmaraghy et al., 2009; Schaffer, 2010). The framework is used to aid the development of a systematic literature review of PVM research published between 2006 and 2011. The review is based

on a content analysis that integrates the main findings related to this topic and highlights the current state of the art.

PVM is an interdisciplinary topic of interest not only for researchers in the areas of operations and manufacturing management but also for scholars studying finance, economics, and marketing. The interdisciplinary nature of this topic is reflected in the large number of related studies published in journals of different areas.

The results indicate an increased focus of research on manufacturing companies as there are fewer studies on service companies. Therefore, future studies may address the issue of variety in the service sector. It would also be helpful for future studies to draw more heavily on the practical experiences of companies, as such a research strategy would enrich the debates on PVM and increase the impact of empirical PVM research.

PVM should be used to balance the positive and negative effects of increasing product variety. Based on the results of this study, it appears that cost is the most important factor causing decreases in product variety, whereas the greatest positive influence on product variety is customer needs.

The studies examined also emphasize the roles of various actors, both within and outside companies, in implementing PVM. These studies highlight the need for internal integration (e.g., intra-organizational integration). Such integration can occur horizontally across functional areas including research and development (R&D), purchasing, production, distribution, and marketing, and it can also occur vertically across hierarchical levels. In addition, the external integration of a firm with its suppliers and customers in the supply chain (e.g., inter-organizational integration) has also been identified as a pertinent issue.

The topic of integrated business processes has been discussed in some studies. A major concern raised in most of these studies is the management of production flow. Other business processes, such as those related to marketing, are also discussed in the literature, thus corroborating the interdisciplinary nature of PVM. The management and operation of these business processes given a wide variety of inputs and existing products is made possible through IT. IT also helps firms to integrate and share information not only throughout their companies but throughout the entire supply chain, thereby facilitating relationships within and between organizations.

Strategies for mitigating the negative effects of product variety are also discussed in these studies. The most prominent strategy involves the use of common components, including common platforms and modules. In general, mitigation strategies are targeted toward the product, for example, by ensuring that products include common parts across different product categories and production processes through the use of flexible systems, lean manufacturing, or postponed production. The main objective is to offer a wide variety of products to the customer while keeping the production of these products manageable from the company's perspective.

Measures for evaluating PVM are still not widely discussed in the literature, as there are few studies that mention such measures. Moreover, the measures discussed vary, and there is no consensus regarding how they can be adapted for use in different organizations. Thus, future research should focus on indicators and performance measurement systems for environments with high product variety.

Finally, the main objectives of companies that adopt PVM may include improving financial results (e.g., increasing profitability, cost reduction, or revenues) and improving market-related factors (e.g., increasing market share, improving service level and brand value).

Although this chapter is not exhaustive, the 87 selected studies constitute a significant and representative portion of the extant scientific research regarding PVM. Thus, this analysis provides a reliable view of the state-of-the-art with respect to PVM research. Because it is impossible to cover every available study on any given subject, this research has its limitations. As this study involved the exclusive use of one electronic database, relevant studies may have been omitted if they are only indexed in other databases. Additionally, the use of Boolean expressions in the selection process may have caused the researchers to omit studies that address this theme using other words or terms. The six-year period examined also constitutes a limitation because important related concepts could have been disseminated in other years. Thus, future research should address these limitations.

Moreover, the systematic review revealed the need to develop models and tools for PVM, a gap that is highlighted in Elmaraghy et al. (2009).

5
PVM in the automotive industry

This chapter examines the practice of PVM through a comparative study of two companies in the automobile segment that have some characteristics in common and the specificities of the companies researched that affect the administration of product variety. The analyses and results of this chapter are organized based on the PVM framework established in chapter four. A discussion at the end of the chapter develops a comparison between the empirical results obtained.

5.1
Context and companies characteristics

The production of busses and trucks, together with passenger cars, accounts for more than 20% of the net Brazilian industrial-sector revenue. There are nine companies producing trucks and of these, only Hyundai Caoa and Ford do not produce bus chassis (ANFAVEA, 2013). The Brazilian highway cargo transportation sector is responsible for over 60% of the total cargo transported in the country, and 97% of state and interstate passenger travel is by bus (ANTT, 2013). However, inside the automobile industry, the production of trucks and busses possesses distinctive characteristics that differentiate it from the production of passenger cars (the focus of the next chapter). For this reason, two companies have been selected to study the way these particularities affect PVM. The first company to be studied is a large multinational assembler that produces a full range of products for the automotive sector (trucks, bus chassis, commercial vehicles, and passenger cars), as shown in figure 5.1. The second company is a Brazilian bus-body factory with three industrial plants in Brazil and ten industrial plants in seven foreign countries (China, Egypt, Colombia, Mexico, Argentina, India, South Africa). Its products are shown in figure 5.2. Specific information about each of these companies is provided in section 3.2 of this thesis along with a description of the research method employed.

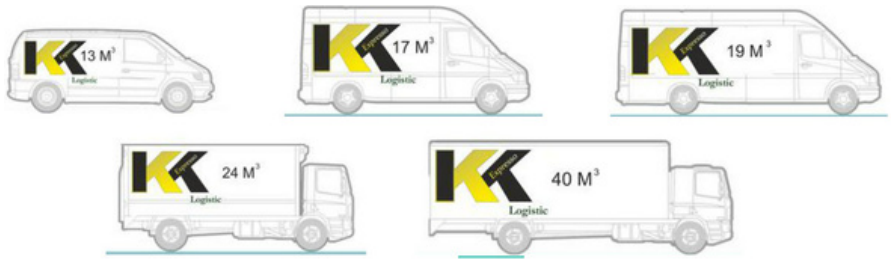

Figure 5.1: Products produced by Assembler

Figure 5.2: Products produced by Bus Body Manufacturer

It is noted that the relationship between an assembler and the bus body manufacturer that it supplies is a long-term partnership. In Mexico, for example, the assembler and the bus body manufacturer run an industrial plant together where some bus models are manufactured, while the chassis is supplied by the assembler.

5.2
Inputs

Both assemblers and bus body manufacturers recognize that PVM is an important topic that has a direct effect on a company's results. The interviews consisted initially of an investigation into what a company's main pressures are with respect to increasing, maintaining or reducing its product variety. The results and analyses of these interviews were compiled and are presented herein.

For the assembler, the support of and/or responsiveness to the diverse needs of clients (customization) and the differentiation from competitors are intimately

linked. This link is exemplified in the statement of the marketing executive. “The difference between our company and our direct competitors is that we can customize items such as color, suspension, traction, and cabin comfort accessories in accordance with the needs of our client, whether he is a fleet owner or an independent operator.” Although a company may offer its clients a range of customization options, pressures to reduce various costs leads the company to provide a relatively low level of customization. A financial manager noted that the cost for customizing a product for an owner-operator is higher than the cost for a fleet owner. For example, the cost incurred for customizing one truck is greater than that incurred for a fleet of 50. “In general, the weekly line revenue is greater when the products are similar to one another, which for us (financial area) is better.” This difference in cost is reflected in the production line where the production manager noted that the majority of the trucks produced have 4X2 or 6X2 traction with a white or silver cab.

Even though a company may be able to customize their products, it was noted by both the production managers and the plant managers that the majority of the buyers of new vehicles (trucks) are fleet managers whose purchasing process is focused on costs and that the great differentiation in price lies in the choice of highway equipment. Highway equipment consists of dump truck bodies, tow truck equipment, cargo-bodies, etc. that are fabricated and installed by specialized companies. Owner-operators, in general, buy used (second-hand) vehicles, and when they buy new vehicles, they usually opt for the cheaper standard models with mainstream combinations that are in stock in the dealer network.

When questioned about the influence of standard purchases on the management of a company’s product variety, because the company supplies a product that is not ready for use, there was a consensus that the pressure for customization is not high. The director of the plant, the logistics manager, and the production manager indicated that their operational complexity is less than that of the production of utility vehicles at one of the company’s other plants. This operational complexity is linked to the fact that the utility vehicles leave the factory ready for use, while this is not true of trucks and busses as they must be sent to companies specialize in special road equipment (trucks) or special bodies (busses) before delivery.

With respect to chassis production for busses, all of the individuals interviewed categorically agreed that the management of product variety is less complex as all of the products are in the catalogue, and it is rarely necessary to perform any type of customization.

According to those interviewed, another pressure that strongly influences the management of product variety is compliance with technical and legal regulations. This pressure can influence the different styles of product management. For example, the new EURO5 legislation forced the companies to alter the engine blocks to comply with regulations, and as a consequence, all of the EURO3 engines had to be changed out. However, such legal aspects and government incentives are not new pressures for the industry, a point explained by a production manager. “In the 1980s, the company developed an alcohol-powered truck because the assemblers were offered incentives through the pro-alcohol program to develop products that could run on alcohol.” The commercial manager added that these incentives might influence the customer choice process, another pressure that affects GVP. “The EURO5, for example, made the consumers anticipate changing their fleets in 2011 (EURO3), which reduced our sales this year (2012) even with the reduction in IPI.”

Legal aspects can also affect the evolution of technologies. The legal requirements for reducing pollution levels forced the industry to develop Arla 32, and today, all vehicles produced leave the factory with this system. Another consequence of this is that the assemblers have had to adapt their current product mix to cover this new system, which means additional pressure to manage the number of components that comprise the finished product.

Regarding the bus body manufacturer and the assembler, the support for and the responsiveness to the diverse demands for client customization were the most mentioned pressures that a company faces. However, a slight difference was cited by the bus body manufacturer in regarding the form this pressure takes and how it influences the functional areas, the company and the PVM.

The first difference is related to product characteristics. This difference is clarified by the marketing manager. “Our product line needs to adapt itself to the needs of each client, that is, the conditions of use and the utility that the client gives the product. An example is a company that exclusively runs highway coach lines. You would think that this company would purchase just one product,

highway coaches. However, its national and international highway coach lines possess distinct characteristics among themselves. It is one thing to set up a bus line that connects south and southeast Brazil and quite another to set up one that connects Brazil to another South American country. The vehicles' needs are going to be different, and we have to understand this to offer the right product to our client. Just to give an example, on some international coach routes, two drivers travel in the vehicle, so a special seat has to be installed for the resting driver." A commercial manager corroborated the marketing manager's comments and added, "In the sales process, the first step is to understand the characteristics of the client's business operation. This is fundamental in defining the sales operation. If we do not understand the operation, we will not be able to offer the proper product and adaptations that suit our client. The thing is that we put the product together with the client guided by his needs and the technical restrictions of the product. This service has differentiated us in the market - from pre-sales to post-sales service - and is reflected in our high levels of client fidelity. We have customers who have been with us for over 50 years!" Starting with the comments of the commercial manager, two pressures are identified - differentiation from competitors and customer choice process.

Pressure related to reduced product life cycle has been highlighted as one of the factors that has had the greatest impact on all areas. The commercial manager commented that reductions in lifecycle have increased the need for sales force training as well as for more frequent upgrading of sales and marketing materials, such as product catalogues. It was noted by the marketing department that the internal administration of information by the company is an important challenge such that once a product line has been changed, the majority of processes must be reviewed. The marketing manager explained the situation. "The actual name of our company came from a successful product that was on the market for more than 20 years. Currently, our products are 'updated' at least once every five years. Obviously, this reduction =/- 80% in market time has had consequences for internal communications and other processes." There was also consensus among managers related to achieving economies of scale as they all agreed that this pressure negatively affects their companies. Overall, in the production area, it was emphasized that the loss of economies of scale coincides with other pressures, namely, miscellaneous costs and customer quality needs. Miscellaneous costs are

impacted once it is impossible to operate on a production scale that permits decreasing unit costs and/or when it becomes more difficult for management to project with a degree of high accuracy the total production cost. The effects of customer quality needs are described with more precision in the words of a production manager. “We know that we will not achieve a gain in scale similar to the XPTO Company, which assembles tractors 2 to 3 km from here. However, for our production line, the primary problem is quality control. Because all the products are different from one another, we have to check each item individually. We do not have lots. This process, in general, takes from three to five working days.” The strategy for mitigating this situation is addressed in the next section.

The effects of stock level pressure are more latent in the logistics area. A characteristic of this area is that an increase in the product variety offered will affect stock levels in two ways. The first is strongly related to the number of components comprised in the finished product, and the second is related to plant location.

Managing the number of components comprised in the final product is related to stocking levels in the sense that any increase in the number of components making up a finished vehicle means a subsequent increase in the number of spare parts that must be stocked and administered, thereby resulting in a higher total stock level. Plant location is another factor that affects stock level as the company is almost 2.000 km from some of its most important suppliers. This distance means that stock levels have a tendency to increase. To avoid stock level increases due to distance, the company has developed a mitigation strategy that is discussed in section 5.3 of this thesis.

The pressure for managing the number of components that make up a finished product is not only felt in the logistics area. The environmental area also suffers from the effects of this pressure, which, combined with the necessities of compliance with technical and legal regulations, the environmental responsibilities exert an additional pressure. This is made clear in the words of an environmental manager. “Environmental legislation is becoming more and more restrictive and with this, the environmental area has to adapt to comply with all municipal, state and federal regulations. If we fail in this, the market will stigmatize us as an environmentally unfriendly company, which will have direct repercussions on our corporate image in Brazil and throughout the world. Aside

the legal aspects, we have to operate with all the certifications that the market requires and an ever-greater number of components for each new product. When the number of components that make up a micro-bus and/or coach increases, there is a consequent increase in the number of packaging materials and residues that need to be properly remanufactured, recycled or disposed of. Another point that draws our attention is that when there is a new technology, many times the old technology continues to be utilized and thus there are two types of residues that must be managed. We are living through this now with our highway coaches, for example, with bulbs for interior illumination. The old bulbs were incandescent, while the new ones are LED." Table 5.1 summarizes all inputs identified in the research companies.

Table 5.1: Inputs in the researched companies

Inputs	Manufacturer	Bus Body Manufacturer
Support and/or respond to the needs of clients (customization)	X	X
Distinguish company from competitors	X	X
Reduce various costs	X	X
Reduce operational complexity.	X	
Comply with technical and legal regulations	X	X
Oversee/regulate customer choice process	X	X
Oversee evolution of technologies	X	
Improve/oversee pre-sales process		X
Reduce product lifecycle		X
Oversee economies of scale		X
Respond to customer quality needs		X
Oversee stock levels		X
Improve/address environmental responsibility		X

Source: Author

5.3
Structure and process

The methods that companies use to address the pressures, structures and processes that enable increasing, reducing, or maintaining levels of product variety vary significantly among the companies studied. In general, the assembler emphasizes problems associated with assembly and some internal company issues. In contrast, the bus body manufacturer emphasizes that the main challenges extend from inside the company to the end user/final client.

The only relationship among participants mentioned by the assembler was that of supply chain integration. Seeking an upstream integration with its main suppliers and a downstream integration with its dealer network, the objective of the assembler is to improve communication between the dealers and the company. This upstream supply chain relationship is exemplified in the comments of the assembler's logistics manager. "We select some key suppliers, and, given their importance, we allocate a space for them inside our plant to enable some minor processes, with the intuition of avoiding an eventual halt in the line for lack of parts, as the number of parts continually rises along with the finished products." In other words, allocating physical space inside the company's plant to its principal suppliers was one way to avoid halts in the production line due to the lack of materials. In addition, the solution also helped to avoid an increase in stock levels, another pressure faced by the company due to the increase in the product variety offered.

The business process (BP) has already been shared and applied to all BP areas including manufacturing flow management, demand management, product development and commercialization, customer service management, order fulfillment, procurement, customer relationship management and returns. However, the relationship between the BP and the pressures previously mentioned has been referenced by the managers interviewed. In general, the BP is a response by the company to pressures from the organization, the hubs of the supply chain, the industry, and the environment.

The first relationship mentioned regarding pressures and the BP was the relationship between compliance with technical and legal regulations and product development and commercialization. The production manager noted that legal

aspects result in product alterations and this frequently leads to modifications in the production process, which in turn causes problems in the production line. One of these problems mentioned by the production manager referred to changes in employees' routines. "When an alteration is made to comply with a law that involves engineering, we have to train our people. This training is fundamental, but often legislation forces a change that was not forecasted in the product's original business plan. The engineering ends up adapting and incorporating these changes, but those of us in HR have to develop training for employees who are used to working in a certain way in their cell and changing an operator is often more of a problem than the product alterations themselves. This ends up, during the initial period of change, impacting line production and the commercialization of the product."

The commercial manager agreed with production that with respect to his area the main effect is delays in delivery. However, he iterated that this was not the only effect on the commercial area or on product development and commercialization. The commercial area experiences two other impacts according to the commercial manager, one in sales force training and the other in alterations to consumption standards. "Late delivery is our main problem when the law changes. We had a delay of five days in the first two weeks of ARLA32. As a manager, I can also confirm that commercialization also suffered with the training of our sales force. It is expensive to train everybody, and in general, a salesperson is not able to stay two days in training, envisioning two fewer available selling days. Gathering the team becomes difficult and expensive as it is not just people from Minas and the southeast, but from all over Brazil. With the changes in the law, EURO3 products were consumed at a greater rate than we expected. Thus at some dealers and in some whole regions, we were left without product to deliver, including the basic configuration of each family. This was good for our sales, as we beat the targets, but two months before the end of the year, we had many lost sales as we didn't have the capacity to deliver, even with production at full speed. We had made a forecast, but the sales were much higher. To compensate, this year (2012) has been difficult because our client has a new car. He (the consumer) anticipated his purchase, which has ruined our forecast. We hope that next year (2013) will be better."

Consistent with the revelations of the production and commercial managers, the marketing manager presents his views on the impact of technical and legal regulation compliance on product development and commercialization in his area, in this case, updating the catalogue. “Our catalogue is of good quality and expensive to make. I have to make them all available to the network (dealers) before the first day the law is enacted. If a potential client comes into the showroom, he has to receive a new catalogue. If not, the company’s image is damaged. As we have various families, each alteration means we must change the whole catalogue, which generates large costs. The more the product development and launch times for new products diminish, the greater the need becomes for vigilance and updating of the catalogues.”

Another link between pressures and the BP is the relationship between the customer choice process and incentives from management. With regard to this relationship, the commercial area cited negative impacts, especially for sales forecasting. “We annually conduct surveys to forecast sales volumes and commercial targets for all the main configurations. We have perfected our method by joining other areas in making a collaborative forecast. But the incentives of an important player in the market, such as the government, influence all forecasting and render the process even more difficult. I say that it is impossible because no area has a way to forecast when the incentive will be given or how long it will last. The incentive causes consumers to change their buying habits, in general, anticipating their purchases. This year (2012), the IPI was reduced, which caused many clients to buy their vehicles this year, especially in the last month before the termination of the incentive. This month, we beat the sales records. However, in the next month, when the IPI was increased, we were bitter about the drop in sales. Our sales have a standard, and we are organized around that standard, which is associated with each product that we offer. With incentives, the market changes and all of our surveys become water under the dam, which generates a shortage of some configurations.”

The last connection between pressures and the BP is that between compliance with technical and legal regulations and environmental responsibility for returns. In this context, the pressure has an equally negative effect on two areas, finance and logistics.

The logistics area is the one responsible for the collection and disposal of solid waste generated by company plants. Therefore, any legal requirements are linked to an increase in the complexity of operations, as recounted by a manager in this area. “Five or ten years ago our job was to control the flow of materials and take it to the end of the line. Now, we don’t only have to do this, but we also have to collect all this material. The problem is that each new vehicle that is added to the catalogue generates a different type of waste, which makes the disposal more difficult. Aside from this, we have to work with companies that we are not used to work with. As the PNRS (National Policy for Solid Waste) came into effect this year (2012), we were obligated to increase the process of returns.”

In the finance area, the main problem is increased costs, as explicated by comments from the financial manager. “There are various aspects of legalization that we are obliged to conform to. The problem is that we have to have an infrastructure that enables the logistics people to collect this material. We have to make a large investment to buy this machinery. If a second line in the plant starts operations with different products, we will have to increase this investment and thus spend even more. I understand this is to benefit the environment, although for the company, it comes at a very high cost.”

With respect to IT needs, the company utilizes certain software and technology manufacturing applications. For example, regarding applied manufacturing technology, ERP and AGV were cited, respectively.

According to the manager of an industrial plant, the greatest benefit accrued from the adoption of ERP lies in the online portraits of all sectors of the company, thus enabling more rapid and accurate decisions. The logistics and supply chain manager noted that the adoption of ERP has had a positive impact on manufacturing flow management. “The utilization of SAP by our area is fundamental as it helps us improve manufacturing flow management with online material requisition order tracking through all areas. Formerly, control was the responsibility of various areas and was accomplished with the help of spreadsheets and non-integrated software. We can now offer a higher service level with little impact on work volume. This means that the impact of an increase in a new product configuration in a family is less for us.”

Other IT used and cited by those interviewed was the use of manufacturing technologies, especially the AGV (automatic guided vehicle). For the area of

production represented by its manager, the great advantage of the adoption of the AGV is the ease of material movement on the production line, which permits a homogenization of speed with a positive impact on manufacturing flow management.

With regard to mitigation strategies, four strategies were adopted - the use of common components, product families, the use of common processes, and lean manufacturing. The areas that were most discussed and that detailed the effects of mitigation were logistics and production.

The use of common components was the strategy perceived by the logistics and production areas as being the most fundamental for mitigating the negative effects of an increase in product variety. The logistics area perceived this strategy as being a way of dealing with the three pressures that occur when product variety increases. These pressures include the management of the number of components that comprise the finished product, miscellaneous costs and stock levels. Details of the relationship among these pressures are addressed in the remarks of the logistics manager. “When we do research and development of suppliers about which items can be included on the production line, we look to increase the number of common components on our lines, consequently reducing the cost. But the cost reduction does not only come from a reduction in items purchased, but also from a reduction in total stock levels and an increase in productivity in selection and manipulation. In addition, for the production area, the number of SKUs that compose the final product is reduced.”

The production area agreed with all the points addressed by the logistics manager, adding that the use of common components, in addition to the benefits mentioned by the logistics department, encourage the use of a common process. The justification for this is that the logistics and production departments are currently conducting a study regarding the use of common components in product families. Accordingly, the two areas can take advantage of this to review processes that both areas have in common. In other words, they can take advantage of the opportunity to deepen the relationship between the two areas through the use of a common process.

Another interesting aspect in the analysis of the production area is the organization of the production line according to product families. For the production manager, the association of a production line to a product family

enables the reduction in the miscellaneous costs of assembling a vehicle. This reduction in costs is achieved through a reduction in time and/or the number of setups and through a decrease in operational complexity, which results from negative pressures associated with an increase in product variety.

Similar to the assembler, the body builder only mentioned supply-chain integration in regard to relationships and participation. Overall, the way in which this supply-chain integration is practiced differs greatly from the way it is used by the assembler. To address an increase in the variety of components from different suppliers, the body builder looks for integration with its main suppliers by offering share participation to these companies. As the body builder operates in a high variety environment, this leads to difficulties in reaching sufficient volume for the suppliers' minimum lot requirements. Buying a lower number than the required minimum causes the product (component) to be too expensive. To avoid this problem, the acquisition of shares in the body builder's company by its key suppliers guarantees the supply of parts and components in whatever quantity is required as it is now the owner who is ordering them. The adoption of this practice means that the addition of an attribute to the final product does not cause restrictions due to price issues.

A practical example of this was given by a marketing manager. "Last month, there was an order from an Argentinian client who wanted each seat to be upholstered in a different pattern of fabrics. Do you know what it is to order 46 seats with different fabrics on each one? Well...if we didn't hold a 40% stake in this supplier, we would have had to pay an absurd amount for each seat, or we would have had to wait for months. This strategy differentiates us in the market (differentiation from competitors), as Busscar, our main competitor, has a longer response time than we do to fill this order. This makes a difference in our business because we manage to fill standard orders as well as 'unexpected' orders like this one without great impact on response time among these products."

For the supply-chain integration manager, supply-chain integration is the most important viability-enabling factor in the company's internationalization strategy. Supply chain integration, in the form that it is carried out by the body builder, enables the adoption of a follow-sourcing strategy by the firm. In this strategy, a company selects its main suppliers and permits them to have installations for assembly and assistance on the grounds of their overseas plants.

In these plants, the suppliers furnish the bus body manufacturer, who benefits through the increase in the reliability of supply. A better relationship with the supplier company, questions related to quality and delivery times, and not having to find new suppliers are some of the other advantages experimented by the body builder.

In addition, as the product project is carried out in Brazil, the cost of product variety offered in the overseas markets can be competitive with the competing local companies. This situation is possible due to the elimination of the need for developing new suppliers. Only adaptations for technical and legal regulation compliance in that market are required. In general, a supplier who is selected for follow-sourcing is involved in developing the product in Brazil. This means that the supplier has more intimate knowledge than anyone about the bus that was developed in partnership with the bus builder, as well as all the possible suppliers of its components. This means that a lean team of supplier employees in a specific market can adapt their component for the final product (buses) in practically any place in the world. Thus, the operation is basically independent of Brazil and can offer the local market essentially the same product variety (bus, microbus or school bus) that is produced in Brazil.

The integration of the bus body manufacturer's employees with those of the supplier outside the country has been noted by the logistics manager as being fundamental to the success of a follow-sourcing strategy and for the integration of Brazilian plants. One of the foundations for this employee integration includes a joint training program promoted by the body builder itself. These programs have provided positive results, which serve led the company to amplify and extend the program to Brazil. This amplification has benefited other company areas, especially in regard to production through a business process (material flow management).

The importance of this training program can be verified by the comments of a production manager. "Different from an automobile, the automation level is low in the assembly of a bus or microbus. In environments that operate with a high product variety such as ours, having adaptable employees is a prerequisite for flexible manufacturing. Because of this, every year, all of our employees receive a minimum of 15 days of training. When a new line is launched, it may take training of up to three months to accomplish everything. Our employee needs to

understand the importance of his job to the whole, understand the cells before and after him, and understand all of the production flow. Such understandings greatly aid material flow management, as the speed of the line becomes more stable and un-programmed stoppages in the line are minimized. As we have our own employees and those of our outsourcers on the same line, it is necessary that everybody speak the same language."

Pressures such as the management of the number of components that comprise a finished product, the product lifecycle, the technical and legal regulation compliances, and the environmental responsibilities when summed up, create huge pressure on business processes, especially with respect to returns. When factoring in ever more rigorous environmental regulations and the pressures from the market to incorporate appropriate environmental practices, the complex situation confronting returns with regard to PVM are observable. Although returns affect the logistics as well as the environmental area, it is the environmental area that must generate disposal solutions for waste generated. This area must address an ever-increasing variety of waste, which is intimately connected to an increase in the variety of products offered. Returns, on their own, cannot address all these pressures. It is at this point that returns must be aligned with other business processes, namely, with product development and commercialization, to jointly resolve these issues.

At first glance, this connection seems a bit out of the ordinary, and it also seems to be quite simple. At the moment the planning stage of a new product is beginning, however, it is not only the aspects linked to the technical issues and to the chain of production that must be considered. Aspects related to the disposal and recycling of a product's components at the end of their lifecycles as well as questions relating to cleaner production must be taken into consideration when a product is being conceived (DFE). This preoccupation with disposal and recycling of components at the end of the useful life of a product minimizes the reverse-stream flow of materials. Thus, product development and commercialization and returns complement each other in the ways that they respond to the pressures created by an increase in product variety as they minimize the amount of waste generated and thereby contribute to better PVM.

However, these two business processes are not always interconnected in the bus body manufacturing organization. The importance of this lack of

interconnection and the negative consequences of a lack of communication between these two business processes is evident in the remarks of an environmental manager. “Until twenty years ago, the development of a product line was carried out uniquely and exclusively by engineering. Marketing helped out with aspects related to the market and competition. Product waste was simply dumped for regular trash collection or, at the most, went to recycling companies. They came to us (the environmental area) and said, ‘take this trash from here.’ The post-consumption was simply not accounted for. Today, the situation is completely different. We are called on to participate and give our opinion at all stages. Logically, the engineering corps has the final word, but they ALWAYS consult us about materials and ecological aspects at all stages of a product’s lifecycle. This new line that was just launched was the project on which we worked together the most. Responding to your question, this allows more items to be customized for our clients without an uncontrolled increase in the volume of waste and effluents as we consider and develop internal solutions together with our suppliers. The bus chain must be green.”

That the bus body manufacturer’s plant located approximately 2,000 km from a number of its key suppliers affects the business plan, particularly procurement. To avoid a reduction in the variety of products offered because of the high cost of transportation, the company has adopted a milk-run strategy. Every day, two tractor-trailers leave the plant to collect components from the supplier. This practice allows the company to stock sufficient parts and components, thereby avoiding an increase in miscellaneous costs and stock levels. This practice prevents the distance from suppliers from restricting the variety of products offered.

The body builder utilizes two IT systems, EDI (electronic data interchange) and ERP (enterprise resource planning). These two systems help PVM in two ways. EDI helps in the integration of management of materials from the company’s primary suppliers. This integration is important in reducing the complexity of supplies, especially in the case of shared components. EDI is utilized for shared components, for which there is a greater demand. EDI orders are more stable and enable increased product variety. ERP contributes to PVM by facilitating and integrating communications among all sectors of the body builder.

In this manner, all the pressures related to PVM can be accessed online from a common base, drastically reducing, the gaps in information related to PVM.

Mitigation strategies are concentrated in the logistics and production areas. The first and most cited mitigation strategy is the process of new-product development, which affects other mitigation strategies as mentioned in the academic literature and in the framework developed in this paper.

Although the academic literature does not consider project development a traditional mitigation strategy, all company areas classify it as being an important mitigation strategy whose effects can be felt in many ways.

The first area in which to note the effect of this mitigation strategy is production. According to a production manager, "As we operate on a global scale we need our products to meet all regulations. One way we can do this is to adopt the strictest set of regulations as a standard for a determined region. For example, Brazil has one of the strictest sets of regulations in South America so when we assemble a bus for another South American country, we use the Brazilian configuration and only make adjustments for the local regulations. This helps us reduce production time and assembly line complexity. Another advantage for us is that when we develop a new product, even before we fabricate a prototype, the engineering already knows the problems we face on that project and thus with this, we have a way of enabling a solution or reducing this time. I am going to give you the example of the double-decker bus. When the engineering called us and showed us the project, we said that it would be impossible to do it without us altering our plant layout, as there were some areas of [the] plant that would not accommodate the height of the bus. So, together with the engineering we made a new layout to facilitate the production of this new product. In this manner, we avoided a problem that would have occurred in prototype production, generating costs and delays in the project."

The environmental sector mentioned that by participating in a project, they could help in the choice of materials, which reduces waste and effluent production and consequently, environmental costs. This is expanded upon by an environmental manager: "When engineering has a new project, and they call us in to collaborate with them on the project with an environmental eye; this brings many benefits for the company. The first one is the application of the DFE (design for environment) concept, or, in other words, thinking of the product as a whole in

all phases of its life cycle. This indicates that the waste and effluent generated in production will be minimized. We have problems with packaging. As some suppliers also take part in the project, we develop solutions together and in this manner avoid costs with disposal for both the suppliers and us. In addition to this, the components that make up the buses are thought out and developed to facilitate the process of recycling and utilization at the termination of the life cycle of the product. This is particularly interesting as our index of product recyclability increased after this project. To exemplify this to you, when engineering called us in for the first time, the index of recyclability was approximately 68%, today we have managed to jump to approximately 82%. The trend is to increase. Furthermore, the volume of packaging disposed of correctly jumped from 89% to 100%, thanks to this interaction between areas." Thus, environmental aspects are examined in light of PVM.

The financial area points to cost reductions as the principal benefit of joint product development. Although this sector had commented that at first, there was an increase in costs, the subsequent alignment of the production, logistics, and environmental areas have enabled a reduction in complexity and a greater return on assets. The best allocation of financial resources, beginning with joint product development, allows maintaining and even increasing the variety of products offered without negatively affecting the company's results.

Yet another highlighted mitigation strategy was the use of common components whose effects are felt in the production and logistics areas. It was emphasized that the use of common components is closely related to the development of products. When a new product project is being thought through, all of its components are developed by the engineering, production and logistics sectors, with the goal of verifying the viability of supplies and dealing with restrictions in production, especially the assembly line. Implementing the use of common components thus supports PVM in two places: the supply area and the production process.

In supplies, help comes in the manner of smaller product flow by inbound logistics. The details and effects of this help can be perceived in greater detail in these remarks by a logistics manager: "As the supplier participated in the product project, all the components that he supplies are already standardized and with our company's required specifications. With this, problems related to not receiving

material because of non-conformity are minimized. To give you a notion, in this class of suppliers the refusal of materials for non-conformity is 92% less than those suppliers who have not participated in a development project for a new bus line."

In the production area, the effect of the use of common components connects with PVM because this mitigation strategy enables another mitigation strategy, the use of a common process. The effects of this interaction can be felt in the business process of manufacturing flow management. The production line has interchangeable components that help the assembly process now that the average speed has increased and the non-programmed stoppages because of problems with materials have been reduced. In this manner, the production line manages to work in a high-variety environment while minimizing negative effects on production.

The milk-run strategy is not embraced in academic literature as a mitigation strategy although it has been cited by the logistics manager as fundamental to mitigating the negative effects of product variety. This consideration of the milk-run as a mitigation strategy could be related to the distance from supply centers. In other words, a company that is close to its supply centers may not use the milk-run as a mitigation strategy. The logistics manager noted that the milk-run is a fundamental strategy to enable access to components that otherwise would be difficult to access. "In my specific area the milk-run has a direct impact on final product variety. We are in a city that is quite far from the suppliers of ABC Paulista. If we don't send there three trailers daily to collect materials and components, our stock levels will greatly increase, or we will have to reduce the final variety. With the milk-run, we have practically any component in the volume we need, as we are collecting the material at the gate of the supplier. If we hadn't adopted the milk-run, we would have had to reduce our components considerably."

The employee training program was designated by the production and logistics managers as another important mitigation strategy. In these areas, training workers enables the production line and its supply to flow more rapidly with fewer stoppages. When a production line is operating with a high degree of customization, its workers must be capable to perform a wide range of activities. Therefore, the yearly training programs established by the company contribute to PVM in that they mitigate the negative effects of a production environment that

must produce a great variety of products for which line speed is high and change is frequent. The production manager concluded that the training programs' beneficial effects are felt by the company in both its Brazilian and overseas plants.

Table 5.2 summarizes all structure and process identified in the interviewed companies.

Table 5.2: Structure and Process

STRUCTURE AND PROCESS	MANUFACTURER	BUS BODY MANUFACTURER
RELATIONSHIP AND PARTICIPANTS	-	-
Supply chain integration	X	X
BUSINESS PROCESS	-	-
Manufacturing flow management	X	X
Demand management	X	X
Product development and commercialization	X	X
Customer service management	X	X
Order fulfillment	X	X
Procurement	X	X
Customer relationship management	X	X
Returns	X	X
IT	-	-
ERP	X	X
EDI		X
AGV	X	
MITIGATION STRATEGIES	-	-
Use of common components	X	X
Product families	X	
Use of common processes	X	X
Lean manufacturing	X	
Milk-Run		X
Training Program		X

5.4
Measures and outcomes

Product variety has long been used to increase firm performance (Wan et al., 2012). Although the measurement of performance is an essential component of the management of product variety, the companies researched do not have in place a means of company measuring system product variety and product variety metrics.

Although it is an important factor in product variety management, neither the assembler nor the body builder presented formulas and metrics to evaluate the variety of products being offered.

The professionals at the assembly plant were indignant regarding the lack of methods of evaluating and quantifying product variety and were unanimous in affirming that these areas do not possess specific methods for measuring product variety systems or product variety metrics.

The finance manager and the industrial plant director argued that the metrics for evaluating the management of product variety can be obtained by translating them from a company's profits. According to this way of thinking, the correct management of product variety is measured by the level of a company's net profits. However, the managers emphasized that they do not understand why there is not a manner of measuring solely for PVM.

A similar situation was encountered at the body builder, where there was are also no metrics to evaluate product variety management. The responses of the managers were similar to those of the assembler, that the correct PVM is measured by analyzing the results of the company as a whole. It was emphasized that because a client can choose and customize an item and generate indicators, product variety is virtually limitless, resulting in low effectiveness.

Finally, the outcomes employed by the companies to manage product variety were financial indicators: TIR, liquid profit, and EBTIDA combined with market share.

5.5
Final Considerations

This chapter has discussed two empirical studies conducted on PVM from the perspectives of two automotive companies, a truck assembler and a bus body manufacturer. The proposal framework developed in this doctoral thesis guided these empirical studies, and the results highlight how PVM occurs in practice.

Nearly all input identified in the systematic literature review was mentioned by at least one manager in the researched companies. Among all inputs. compliance with technical and legal regulations was emphasized. The influence and consequences of every input could also be perceived in all organizational areas and in how companies structure and process inputs. Additionally, pressure to reduce overall costs appears to be one of the most important stimuli to decrease the product variety offered. Other input such as differentiation from competitors and satisfying consumer needs is input that influences product variety positively.

Structure and process promote the balance between the positive and negative factors at PVM. Relations and participant problems are mostly concentrated in the relations between OEM (Original Equipment Manufacturer) and its suppliers. Internally, the engineering department is the key area that determines the level of product variety offered.

All the business processes were cited by the companies. Overall, business process embraces more than just one organizational area. Manufacturing flow management was the most cited process dealing with the negative effects of the assembly line and involves others areas as well, especially logistics. A business process that involves another organizational areas is product returns, which involves the relations among production, logistics and environmental processes.

Mitigation strategies are particularly useful for companies in promoting a balance between the level of variety demanded and the negative effects associated with the variety offered. Both the truck assembler and the bus body manufacturer cited the use of common components as being the most important mitigation strategy. This corroborates the findings in the systematic literature review conducted for this doctoral thesis in which the most prominent strategy involves the use of common components, including common platforms and modules.

IT also helps firms to integrate and share information throughout their companies and throughout the entire supply chain, facilitating relationships within and between organizations. ERP and EDI are the IT used in the researched companies.

Measures for evaluating PVM are still not widely discussed in the literature or by the truck manufacturer and bus body manufacturer. There are no specific measures to evaluate system product variety or any product variety metrics. Finally, the main objectives of companies that adopt PVM are improved financial results and/or market share.

6
PVM within the automotive and cosmetic industries: a comparison

This chapter examines the practice of PVM through a comparative study of two companies from different industries. One of them is a multinational vehicle manufacturer and the other is a multinational cosmetic manufacturer. The analysis of each industry is guided by a product containing a high variety, a passenger car for the vehicle manufacturer and shampoo for the cosmetic manufacturer. Similarly to Chapter five, the analyses and results of this chapter are organized based on the PVM framework offered in chapter four.

6.1
Context and companies characteristics

Since the early twentieth century, the production of cosmetics has been controlled by a handful of multi-national corporations. According to Schultz (2013), the United States is the biggest cosmetic market in the world, with an estimated total sales revenue of about 54.89 billion U.S. dollars and employing about 53,619 people in 2012. Cosmetic sales are estimated to continue to grow in both the United States and other global markets, as many consumers feel that beauty products help in achieving social and economic goals (Schulz, 2013).

Brazil has continued to significantly outstrip global market growth for cosmetics. From 2006 to 2011 the market for beauty in Brazil had grown by a staggering 79% to US$43bn, making it the third biggest market in the world (Pitman, 2012). This growth is driven by factors like the continued economic growth of the country, a larger number of women in the workforce and the considerable growth of the country's retail channels. Hair care remains by far the dominant market category with an estimated market value of US$9bn in 2011 (Pitman, 2012). This is attributed to the fact that many Brazilians wash their hair on a daily basis and use a variety of hair styling products that are specifically designed to cater for Latin hair and its associated hair care issues (Pitman, 2012).

The cosmetic manufacturer considered in this research is among the biggest in Brazil and in the world. In Brazil it has two plants and one distribution center. It attends different kind of customers, from big wholesalers to small beauty shops using different distribution channels.

The other analyzed industry is the automotive one, a key sector of the economy for every major country in the world, including Brazil. The industry continues to grow, registering a 30% increase over the past decade (1995-2005). The world produced more than 60 million vehicles in 2012, what required the employment of about 9 million people directly in making the vehicles and the parts that go into them. This is over 5% of the world's total manufacturing employment. This number grows even more if one considers that each direct auto job supports at least another 5 indirect jobs in the community. Many people are employed in related manufacturing and services. Autos are built using the goods of many industries, including steel, iron, aluminum, glass, plastics, glass, carpeting, textiles, computer chips, rubber and more (OICA, 2013). Table 6.1 presents the production numbers of 2012 of the main world-wide producers. One may notice that this table has changed a lot in the last decade, having now emerging countries playing a significant role. Brazil figures as the seventh biggest producer.

Table 6.1: World-wide production numbers of cars and commercial vehicles in 2012

Country	Cars	Commercial vehicles	Total
Total	**63,074,662**	**21,025,505**	**84,100,167**
China	15,523,658	3,748,150	19,271,808
Japan	8,554,219	1,388,492	9,942,711
Germany	5,388,456	260,813	5,649,269
South Korea	4,167,089	394,677	4,561,766
USA	4,105,853	6,223,031	10,328,884
India	3,285,496	859,698	4,145,194
Brazil	2,623,704	718,913	3,342,617
Russia	1,968,789	262,948	2,231,737
Mexico	1,810,007	1,191,967	3,001,974
France	1,682,814	284,951	1,967,765
Spain	1,539,680	439,499	1,979,179
UK	1,464,906	112,039	1,576,945

Source: OICA (2013)

Since the 1990's many new car plants have been introduced in Brazil due to the potential growth of its domestic market. Vehicle manufacturers already established in the region for decades have been investing in new plants as well as new comers. Despite its continuous growth in recent years, the Brazilian auto industry is undergoing challenging times of extremely important changes. New investments in factory expansion, modernization, and creation, development of new vehicles are increasing energy efficiency and technological content, and location of parts and systems in the production area. New comers as JAC and BMW are still arriving to produce on the domestic market with a resulting increase in competiveness (ANFAVEA, 2013). The vehicle manufacturer considered in this research is an old comer. It is among the biggest passenger cars producers in Brazil and in the world. In Brazil it has been investing in the establishment of new plants and the production capacity increase of its old production sites.

6.2
Input

As mentioned before and confirmed in the empirical findings, the Brazilian market of cosmetics, especially for shampoos, had a huge increase in sales with the growing buying power of the local population and the bigger presence of woman in the labor market. This market also had an increase in the shampoo market heterogeneity as this product can't be considered anymore as a commodity used only to wash standard hair types. Nowadays it needs to have other functions as treatment and beautify. Moreover, it needs to be adapted to the different customer's needs and requirements (e.g., dry hair, painted hairs, and curly hairs).

Besides the market analysis in terms of sales volume and heterogeneity, the empirical findings also point to the market dynamic of the product itself. New launched shampoos tend to be the most sold ones and after approximately eighteen months their sales drop generating the necessity to bring something new. Although the product life cycle is typically of three years, products that do not have a decrease in sales compete with the new products recently introduced.

Additionally, the findings in the cosmetic manufacturer point out under the marketing perspective of the organization that variety proliferation is encouraged and obtains positive results as: increase in market share, more protection against competitors avoiding their market share increase, additional sales, and increase the value perception of customers. All these issues result in pressures to increase the shampoo variety offered to costumers with a greater product mix that needs to be managed by the organization.

In spite of the positive aspect, variety proliferation is questioned from the other corporate areas perspective of the cosmetics organization as the advantages of the variety increase offered can be lower than the disadvantages, resulting in a bad trade-off for the organization. These disadvantages result from: loose of the economies of scale in procurement, production and transport operations; complexity increase in the management of suppliers, contracts, and SKU from raw material acquisition process until the final products distribution until the point-of-sales. The main complexities issues associated to variety are associated to downstream activities of the organization's manufacturing plant. The product has an intensive distribution channel, embracing many wholesalers, distributers and retailers, a challenge for its variety management.

The Brazilian automotive market of passenger cars has also experienced a significant increase in sales, especially for the so called "popular cars" (low cost subcompact vehicle models). This market has also been exposed to a greater variety of vehicle models (locally produced and imported from other regions). Not only are more models being offered to this market, but also a greater variety of options within these models, what is in line to the product variety proliferation trend along the automotive industry worldwide. This means more body types (e.g., sedan/saloon, hatchback, convertible, coupe, and station wagon) and/or these body types' number of doors; more power trains, which describes the combination of both the engine with different cylinder size, horse power and fuel and the type of transmission (e.g., automatic, semi-automatic, manual, and 4WD); more paint-trim combinations, which consist of both the body type color and the car interior trim; more factory-fitted options, which consists options that are offered for the specific model at the plant level, such as ABS, airbags, air-conditioning systems, electric/power windows, etc., and finally more dealer fitted options, which consists of additional options now installed at the car dealer itself.

All the interviewees conducted in the vehicle manufacturer (from the marketing to engineering areas) supported the literature regarding product variety (Lancaster, 1990; 1996; MacDuffie et al., 1996; Kahn, 1998; Ramdas and Sawhney, 2001; Krishnan and Gupta, 2001; and Schaffer 2010), that a firm should offer a trade-off between satisfying the necessities of a heterogeneous market, which demands a high level of variety, and the economies of scale that the costs of production require. At the vehicle manufacturer the notion of a cost-revenue trade-off was clear. However, marketing focus more on customers' requirements demanding more varieties for customization and engineering focus more on cost reduction as customers in the Brazilian market are more price-conscious and seldom demand expensive options, such as satellite navigation systems; at least in the market segment of the analyzed product ("popular cars"). Brazilian government incentives play a key role in the new plants locations, what results in convincing vehicle manufactures to locate the car plants in green-field areas. This is the case of the vehicle manufacturer analyzed in this research. The main complexity issue identified was the product itself with its implications / developments upstream the supply chain with some significant first tier suppliers. Differently from the cosmetic industry, the distribution channel is easy to be managed within a product variety perspective, embracing few hundreds of points-of-sale (official dealerships).

6.3
Structure and processing

The context described in the former section regarding the inputs for PVM highlighted the most significant pressures that influence the increase and the decrease of the variety level offered to the Brazilian Market by both organizations. This brought different implications in their supply chains, both downstream and upstream the products manufacturing plants. To handle this variety both organizations have developed different structure and processing issues for the PVM, as presented in this section.

The decision-making process to define the variety level for both organizations is inter-functional integrating different corporate areas within an process, from marketing (obtaining customer desires and competitors' actions) to

production planning, passing by engineering and finance (assessing the economic viability and technical feasibility of the marketing requirements). However, at the vehicle manufacturer the engineering and production areas do play a more important role in this decision process. From a supply chain perspective, the process is controlled by the vehicle manufacturer with little input from supply chain members downstream the OEM (e.g., dealers and regional sales offices), but with significant integration with some upstream supply chain members as module and system suppliers. This upstream integration is seen in the product development business process and in the manufacturing process for supply chain practices as just-in-time (JIT) and just-in-sequence (JIS). Some of these suppliers are located nearby the vehicle manufacturer assemble plant within a supplier park. This supplier park was a response to maintain an efficient supply of critical parts in a green-field area partially isolated from the main suppliers (more than 1,000 kilometers far away) with a logistic infrastructure that connects them is very bad. At the cosmetic company the main role is played by marketing. From a supply chain perspective, downstream members do play an important role with the some of them included in the ECR program of the cosmetic manufacturer.

Analyzing the vehicle manufacturer, as a major input to determine the appropriate of its variety level offered to the market is the pressure to reduce cost, engineering and production considered seriously this issue during the development of the new plant, its production line and the product to be produced. This was mainly achieved by sharing platforms among different vehicle models (all the models produced by this new plants had the same platform), adopting option bundling, relying on local suppliers and adjusting the manufacturing process. The empirical findings point out that the reasons for offering low level of varieties are the costs associated to Research and Development (R&D), supply, manufacturing and sales and distribution, as discussed next. As the vehicle manufacturer is a global enterprise that develops many product specifications in different countries for markets worldwide (mainly in the parent company's R&D center), it can be expected that little R&D effort is necessary to make these specifications available also in Brazil. However, modifications are often required leading to a number of design changes (i.e. "local adaptations" also called "tropicalization"). Furthermore, the offer of any new specification requires selecting and locating a supplier for the respective components. The vehicle

manufacturer needs also to integrate the new parts into its existing logistics network, which includes transportation for the new component between the supplier and the vehicle manufacturer's assembly plant. With low demand for a particular component the vehicle manufacturer is also unlikely to achieve economies of scale in transportation. Additionally, the possibility of sourcing the respective components from suppliers from abroad is also dismissed due to the high unit cost per part. Employee training is necessary and also adds cost, as training the operators to assemble a car parts with a different variety is needed for any additional option. Additionally, an increase in the number of parts to be handled during final assembly due to a higher variety offered increases the complexity of the manufacturing process.

The vehicle manufacturer adopts the option bundling strategy. The main reason was to bundle options that require similar tasks or parts in the manufacturing process towards mitigating the impact that adding options has on manufacturing complexity and cost. Thus, by bundling them, the vehicle manufacturer can offer combined options at a lower price compared to the individual ones. Although this leads to cost reductions, it restricts the variety offered to customers that may want just one of the options offered in the bundle. However, end-customers are not let down as they can order their specific individualist option at the dealers. This is one of the main reasons for late configuration in the supply chain. For example, the car alarm system is available only in less than 20% of the option combinations offered at the plant level, so many customers require this system at dealers, leading to a large number of cars that are late configured with this option. Other reasons for this mitigation strategy are: dealers aiming to expand their offering beyond the product variety available at the plant level to increase variety providing a competitive offer; dealers wanting to postpone decisions about the final specification of a car until they have a specific customer order for it; and dealers aiming to yield higher margins. While most of the late configuration activities regard to simple peripheral varieties (e.g., radio, speakers, break lights, and allow wheels), more complex peripheral varieties as air-conditioning can also be added at dealers. However, this postponement strategy is limited to peripheral variety and its extent is mainly restricted by technical feasibility and product safety (no ways of installing airbags or ABS systems at dealers). This late configuration in the distribution channel has

created a secondary system for providing product variety. As long as the volume for a specific option is very low, it is more economical to add it in a more flexible environment, such as the dealer's workshop, as opposed to adding it on the rigid vehicle assembly line.

As mentioned before, the most significant arena for PVM within the cosmetic manufacturer is downstream its supply chain. From this downstream perspective, the organization is required to understand better the behavior of the final costumers, now more exigent and looking for customized products for their hair. As a result, the organization seeks integration with this supply chain member in the Customer Relationship Management and Customer Service Management business processes. Different market research techniques that range from interviews in the costumers' residences until the observation of the behavior of these costumers in the point-of-sale are adopted. The distinct and new needs of customers require the development of new products and consequently new formulas in shorter time intervals, requiring from the organization more proximity (e.g., partnership) with some raw material suppliers (chemical products). Therefore, the organization gives priority to the integration of the product development and commercialization business process, this one from raw material suppliers up to corporate customers (e.g., wholesalers, distributors and retails). This process also has implications in the marketing area, as it needs to invest in propagandas, commercials and advertisements of the new products in the media, creation of promotions in retail (e.g., a pack containing a known product and a new product), and distribution of gifts and other marketing actions in loco in the point-of-sale. Sales work force training is also an effort that demands relevant investments.

The product variety increase results also in a loose of scale in packaging transport and complexity increase in the handling, picking and storage processes. As a consequence the logistic costs increase and the service level tend to decrease. The demand forecast becomes more difficult with a more frequent chance of supply disruption. With bigger chances of disruption, marketing pressures logistics and production to guarantee the supply of shampoo, what results in internal conflicts. To minimize problems related to demand forecast, the organization seeks to develop the integration of the demand management business process including the main wholesalers, distributors and retailers. The ones

involved in this process integration do have a close relationship with the cosmetic manufacturer resulting in long term agreements and partnerships. This is seen through the implementation of collaborative forecasts involving representatives from different corporate areas (sales, marketing, production, procurement, and supply chain) and external downstream representatives (significant distributors, wholesalers, and retailers). The organization also uses vendor management inventory (VMI) with some big clients. The development of a collaborative planning forecasting and replenishment (CPFR) with some downstream partners is on the agenda.

The supply chain department faces another challenge in the distribution channel; the management of the shelves at the point-of-sales. The space in these shelves is limited, what means some SKUs (the slow movers) need to be removed to include new products. This reflects in the sell out of some items that need to be informed upstream so that they won't be produced anymore. The existing stocks along the distribution channel still needs to be managed, what means sometimes marketing promotions to push these products to costumers. If there are not sales for these products, the supply chain area is the responsible to remove these slow movers from the points of sale shelves or distributions centres using reverse logistics.

The product variety increase requires more efforts for the purchasing department in selecting suppliers and managing a bigger number of them. Besides this fact, there is a loose in the purchasing scale when there is a need to buy raw material in smaller quantities. In this point the organization centralizes its purchasing in a global scale using global sourcing. In the production level, to deal with smaller production lots the organization invested in new machinery with smaller set up time towards improving its production flexibility. The organization also develops mitigation strategies to face this increased variety. One of the most used is component sharing regarding the packaging of shampoos. The customer packaging does have the same shape, size and colour but peripheral characteristics change from product to product (e.g., stickers). The industrial packaging is standard carrying twelve units each, what facilitates the handling, storage and transport of the products along the distribution channel helping logistics.

Information technologies to support the organization strategies regarding the management of variety is also an important issue. The organization uses EDI

(Electronic Data Interchange), bar codes and ERP (Enterprise Resource Planning) on its operations. It is also studying the implementation of a pilot study to introduce RFID (Radio Frequency Identification) in some of its downstream partners.

6.4
Measures and outcomes

The product variety offered to the Brazilian market by the vehicle manufacturer was calculated using Equation 5 (Section 2.3) and is displayed in Table 6.1. Two vehicle models produced at the Greenfield plant are listed within this table (Model A and Model B).

In spite of having 22 factory fitted options offered for Model A and four for Model B and the exponential impact of this kind of variety has on the total number of end items (See equation 5), there are low number of varieties in fact offered to the Brazilian market. The reason is not the number of options offered, but in the way that the vehicle manufacturer permits customers to combine them. The variety offered is restricted by the option bundling strategy, which was mentioned in the former section. Thus, customers cannot choose freely from all 22 factory fitted options for Model A and 4 for Model B, what would result in 4,164,304 and 16 possibilities respectively, but can only order option packages. This transforms the relatively high number of factory fitted options (mainly for Model A) into a small number of options bundles. In the case of this vehicle manufacturer, just 15 possibilities of bundles for Model A and 19 for Model B. This results in few variety possibilities at the plant level to the market (120 form Model A and 152 for Model B). The number grows impressively when the dealer fitted options are considered. As then can be combined freely, the possibilities offer reach billions. However, one may be aware that this dealer fitted options are peripheral, following MacDuffie et al. (1996) and Pil and Holweg (2004) classification for product variety. There are no fundamental variety offered to the Brazilian market based on these two models (i.e. the factors that lead to a different body in white in the manufacturing process) and few intermediate varieties (power-trains, paint and trim combinations).

Table 6.2: Product Variety for Passenger Cars offered to the Brazilian Market

Model	Body Style	Powertrain			Paint and Trim				Factory fitted options	Total	Dealer fitted options	Total
		Engine	Transmission	Total	Paint	Trim	Versions	Total				
A	1	2	-	1	8	3	2	24	22	120	35	7 billions
B	1	3	1	4	8	5	4	48	4	152	32	6 billions

Fundamental Variety

Intermediate Variety

Peripheral Variety

Table 6.2 presents the variety for Shampoo that was offered to the Brazilian market by the analyzed cosmetic company. This variety was calculated using Equation 6 (subsection 2.3). The four products were offered with different kinds of variety that changed according to their scope. For instance, Product D was for children and what is important for this market segment is fragrance, so this product was offered with seven fragrances possibilities and nothing more regarding the other variety types. Analyzing the variety offered by a dynamic perspective, it should be mentioned that during the early 2000's the cosmetic manufacturer had just three products and the variety for each varied from one to nine, what reinforces the proliferation of product variety seen in the Brazilian domestic market.

Shampoo	Public	Hair color	Packaging	fragrance	additional propose	Special feature	Total
A	1	3	2	1	2	6	18
B	2	2	2	1	2	11	26
C	1	2	1	1	2	8	12
D	1	1	1	7	0	1	7

Although both companies have mentioned the importance of PVM and its impact in their performance, none of them had really formal metrics for Product Variety. This becomes clear with facts as the possibility of providing the number and type of varieties by heart in the cosmetic industry and aided by information systems in the vehicle manufacturer, but the impossibility to answer questions as "how much will it cost to offer one additional fragrance (in the cosmetic industry) or one additional color (in the automotive industry)". Some metrics were mentioned that could give a glue about the effectiveness of the variety offered as set-up times, number of components and variants against the units sold in the vehicle manufacturer and customer satisfaction regarding the sort offered at the point-of-sale in the cosmetic manufacturer, but they were not designed for the propose of PVM. Regarding the main goals for PVM, in the vehicle manufacturer they were mainly financial focusing on revenue and profitability increase and in

the cosmetic manufacturer the outcomes were more customer related focusing in market share, improved brand image, and customer loyalty.

6.5
Final Considerations

The management of the product variety offered by both of the analyzed organizations to their consumer market is an issue that has become critic for their competition success as the variety proliferation trend is a reality in their activities.

This management counts with an integrated view of different corporate areas, where there is a common sense that the proliferation of product variety pushed by marketing needs to be followed by the other areas as production, procurement, supply chain, imports, logistics and information systems. Even though, there are explicit vision divergences among the areas regarding variety, as highlighted in the literature. For instance, when the Supply Chain Director of the cosmetic manufacturer was questioned if the shampoo variety should be increased or decreased, he mentioned: "*The organizations´ catalogue contains too many exaggerations which must be cleaned*". This answer reflexes the negative vision that this area has for product variety that, based on the understanding of its director, there is a huge quantity offered to the market. On the other way around, the Marketing Director comment to this same question was: "*The shampoo variety offered today to the Brazilian market is adequate, but the ideal would be if we could offer an infinite quantity of diversity that could attend to any kind of our costumer's need and desire*". This answer reflexes his positive vision, but with a partial satisfaction of the marketing area regarding the variety level.

Interviewees at the automotive manufacturer emphasized a more cost conscious where they would rather not introduce a new specification with low demand, since the incremental revenues would not cover the initial investments needed to develop and distribute product documentation and to train their staff.

This finding corroborates the literature indicating that PVM indeed is largely based on basic economic trade-offs (Lancaster, 1990). However, the findings show that the actual implementation is contingent upon a much wider range of factors than previously considered. In particular, the importance of taking an holistic approach to analyse product variety that considers all actors in the

supply chain needs to be more emphasized, not just manufacturing. The vehicle manufacturer case illustrates a secondary trade-off with the provision of variety through late configuration in the distribution system. A closer study of PVM and order penetration point should be taken as a future step of this research.

Another interesting finding of this industry comparison is the fact that for the cosmetics manufacturer PVM is more concerned to its downstream connections. It is not a surprise as the complexity seen in its supply chain is located at the many distribution channels.

This is not the case of the vehicle manufacturer, where the distribution channel is simple and limited in terms of size. However, the complexity in the auto industry can be the product itself. R&D and production play an important role to deal with this complexity, so the concerns for PVM are within the vehicle manufacturers' assembly plant and with some of its main suppliers.

7
Conclusion

Managing the product variety offered by an organization to a consumer market is an issue that has currently become critical for success in a competitive market because the variety proliferation trend is a reality. This thesis offers a conceptual framework for PVM and applies it to the industry to obtain empirical findings to understand and analyse how variety management is developed and conducted in different companies.

PVM is an interdisciplinary topic of interest for scholars working not only operations and manufacturing management but also finance, economics, and marketing. The systematic review of the literature aided by the proposed PVM framework reinforces this interdisciplinary aspect and points also to the need to develop models and tools for PVM, a gap that corroborates Elmaraghy et al. (2009) and that highlights one of the academic contributions of this thesis with the proposed framework.

From a marketing perspective, the empirical findings suggest that variety proliferation is encouraged and creates such positive results as an increase in market share; more protection against competitors, deterring their market share increase; additional sales; and increased value perception of customers. In spite of the positive aspects, variety proliferation is questioned from other corporate area perspectives because the advantages of the increased variety offered can be fewer than the disadvantages, resulting in a bad trade-off for the organization. These disadvantages can result from a loss of the economy of scale in procurement, production and transport operations and increased complexity in managing suppliers, contracts, and SKU from the raw material acquisition process to final product distribution to POS. As a result, certain costs of the organization increase, not only in research and development, procurement, production and logistics processes but also processes involved in marketing: already having invested in discovering the customers' wishes, now the organization must spend additional investment to clarify for the customer (for instance, by media advertisement or

promotions in lieu of points of sale) which of the many different available varieties of a product best fits his needs.

The research results also point to the need for integration, both internally among the organization's different corporate areas and externally with the other companies that are part of the supply chain. Different corporate areas are involved; however, some can have more influence than others depending on the industry. For instance, in the automotive industry, engineering plays an important role in the PVM whereas in the cosmetics industry, the most important role is given to marketing. The management of product variety is directly related to the supply chain in which SCM plays an important role that complements the production or marketing vision offered in academic literature. This SCM focus can be emphasized more upstream or downstream. In the cosmetics industry, downstream connections are quite involved in the PVM; for instance, ECR appears as an important and useful concept to support the management of product variety in the distribution channel. In the automotive industry, the focus is more upstream, where the connections between first tier suppliers and OEMs are definitely the most involved relations in the PVM.

In the empirical studies it can be perceived that the inputs are correlated and that it is impossible to select just one as being preponderant. Practically all the inputs mentioned in academic literature are from empirical studies. The inputs vary in accordance to the characteristics of the business such as: position in the supply chain; product characteristics; location of the industrial plant and its territorial reach. Legal and environmental questions are present in all the companies as the factors that most impact PVM. The lack of metrics to gauge PVM is very clear in empirical studies, and this is collaborated in the academic literature. Researches to understand why there are few metrics for PVM within the practitioners view, the main barriers and challenges to implement them, as well as the enablers, is suggested as future research.

Although this thesis provides empirical evidence of two industries with different types of products based on a conceptual framework, the extent to which the findings can be generalized across a wider range of products and industries is limited. Because conceptual frameworks for PVM and comparable empirical studies in the literature are still rare, the results of this thesis cannot claim to be anything more than an initial step toward the study of a topic that is likely to grow

in importance as firms continue to expand their product variety. There remains a lack of tools and models to help companies in their respective management areas. Future studies may want to test and expand on our findings, moving toward the development of other frameworks and the development of new empirical studies. One should highlight also the fact that the study was restricted to manufacturing companies. As services is becoming more relevant for industrial engineering, one may study PVM within the service perspective (e.g., bank portfolios, tourisms, etc). Future research here is also recommended.

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