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Handling Product Variety and its Effects in Automotive Production

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Abstract

Increasing product variety is a matter of fact in many manufacturing organizations. Its qualitative effects on supply chain costs are widely known, while getting quantitative results regarding costs and lead times requires high efforts. Manufacturers often accept the known consequences to increase their market share and acquire additional customers by offering wider product variety. One crucial point is the question how much variety is desired because of its economical efficiency, positive marketing effects etc., and which part of variety is unwanted proliferation that increases cost without delivering adequate benefits. The paper gives an overview regarding the current situation of product variety in the automotive industry in different countries. Trends are analyzed and strategies of variant management related to economical development and other boundary conditions are explained. Methodologies to evaluate the cost effects of variant driven complexity are described and the potential of further research is outlined.

Keywords: Product Variety, Auto Industry, Platforms, Variants

Introduction

Enhancing product variety is a trend in many industries worldwide. The central strategic question in this situation concerns the 'optimum' or 'appropriate' level of variety: on the one hand, offering variety increases cost, on the other hand, offering product variety can provide differentiation in the marketplace (Lancaster, 1990). Many researches have been developed regarding product variety in different industries (Fisher *et al.*, 1994; Fischer and Ittner, 1999; Bayus and Putsis Jr, 1999). The auto industry also offers an interesting arena. Pil and Holweg (2004), Scavarda *et al.* (2005), Scavarda *et al. (*2007) and Schleich *et al.* (2007) analyzed product variety in this industry based fundamentally on the different variants offered by vehicle manufacturers. The goal of this paper is to describe the development of an auto product variety analysis that also embraces the following categories: platform, models and dealer fitted options.

This research is exploratory in nature and includes an empirical comparison considering many significant passenger car models from Ford in major automotive markets. Ford was used as its participation in the world's auto industry is relevant. It has plants in 23 different countries and is the world's 3rd largest vehicle manufacturer with 6.5 millions of units produced in 2005; 9,8% of the world's total production (OICA, 2006). Ford worldwide websites also contain complete information regarding the product variety available for many different countries, what makes a multi-market comparison feasible. Information regarding Ford's world platforms and their resulting models was collected based on information available in world auto data basis. The information regarding the models' variants and the dealer-fitted-options was collected in Ford global websites.

The next two sections offer a review regarding product variety and the results and discussions regarding product variety in a vehicle manufacturer. The last section presents the authors final remarks.

Product Variety

Focusing on automotive product variety, the most aggregated product form is the platform. Platform refers to the upstream variability that represents the potential for combinatorial variety through component sharing (Watanabe and Ane, 2004). Platform strategies have been widely adopted in manufacturing, developing a common technical basis for several models in one project with the intention to obtain benefits from the scale purchases of parts they have in common and save the time and the resources that car development entails (Muffato, 1999).

According to Watanabe and Ane (2004) an automotive model represents a particular technical product, which has been given its own name that reflects the positioning strategy of the company in the marketplace. Vehicle manufacturers have introduced to the market many models towards broadening their product range to penetrate different market segments (Watanabe and Ane, 2004; Pil and Holweg, 2004, Scavarda et al., 2005).

Within one single model it is also possible to increase the vehicle manufacturers' product variety by creating different variants. Pil and Holweg (2004) separate them into four natures: body styles, power trains, paint-trim combinations, and factory-fitted options. Additional options that are installed at dealers are not included in Pil and Holweg (2004), as they do not impact on the manufacturing operations as such. This category could be called dealer-fitted-options and would complete the automotive product variety options group.

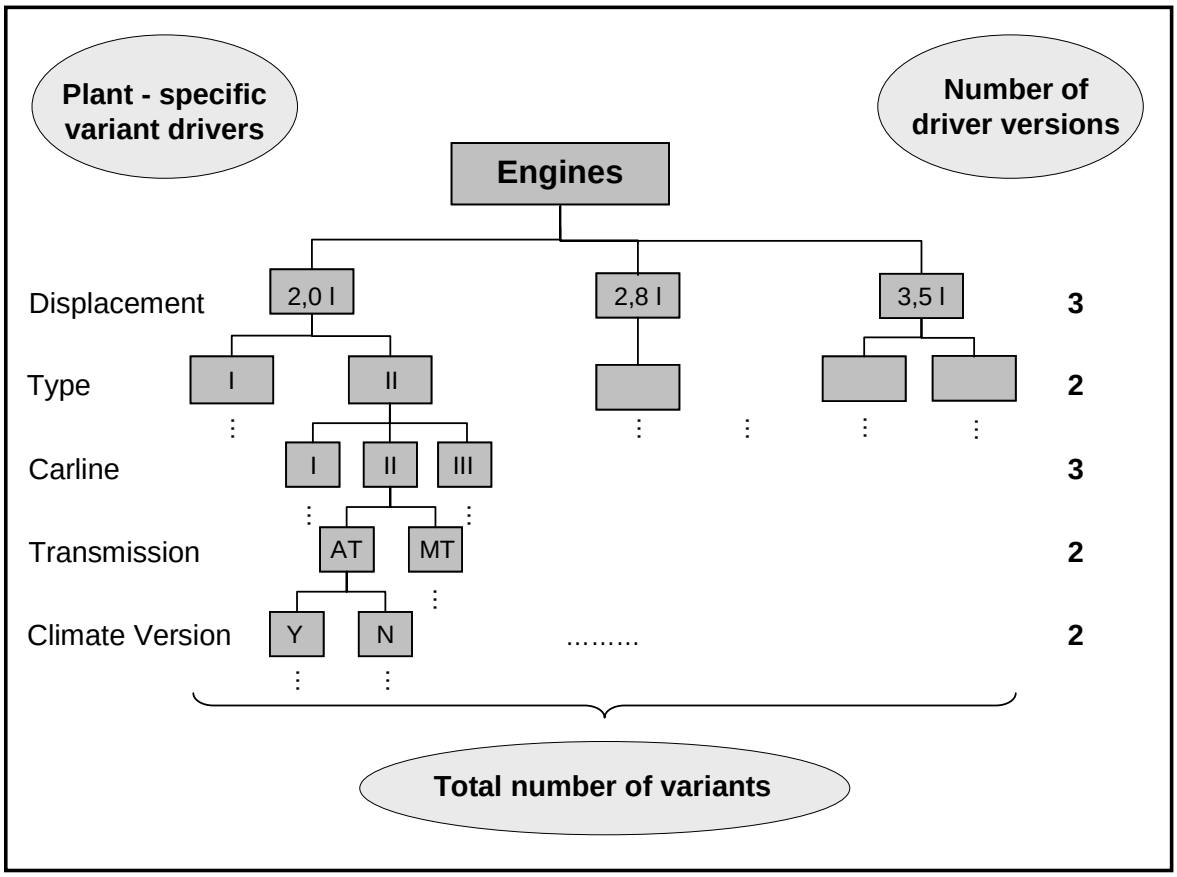
In extension to this categorization there are additional factors that are not directly recognized as product variants by the customer, but have a considerable impact on the production process and the connected costs. The first one is related to increasing globalization and the fact that many products are not in any case manufactured just in and for the region there are sold in. While some technical products can be used in many parts of the world with out any technical differences like USB-Sticks or can be directly configured by the user by choosing the correct language (e.g. MP3 Players) relevant changes in technical details are necessary for other products. Car engines for example often differ in there specifications depending on where they are going to be used. While three cars manufactured for Canada, Germany and Venezuela might be totally identical in their configuration and option packages, they need to be prepared for three different climate regions regarding engine cooling, HVAC and heat or cold resistance of sealings and flexible materials. Other examples are the changes in suspension layout and components considering the available transportation infrastructure and the quality of the road network, speed limits, safety requirements etc.

Automotive interior components like side trim panels are equipped with additional crash pads for US-Versions to fulfill specific crash-test requirements; dynamic suspension control software is improved for high speed reliability on European streets without speed limits. Hoses for cooling fluids are running closer to hot engine blocks in cold climate regions to reach operating temperature faster and minimize wearing. While they run further away from hot parts in tropical climate to prevent overheating at permanent use in high outside temperatures.

At plants that manufacture cars or components which are utilized in versions for different legal, safety, environmental or climate conditions variants have to be created that can not in any case be differentiated by customers. To evaluate the variant driven complexity costs of a production process including all kinds of variants a methodology has been used and described by Schleich and Schaffer (2006) which is based on variant drivers and their characteristics, leading to the total number of variants.

In Figure 1 an illustrative example of a variant tree for engine manufacturing is presented.

Figure 1: The variant tree is structured by drivers and their characteristics



The number of variant drivers given in Figure 1 is represented by the number of different levels (e.g. Displacement, Engine Type, Carline, Transmission, and Climate Version). The number of characteristics each driver has can be determined by the maximum number of new branches on the according level. And the total number of resulting variants can be found on the lowest level of a variant tree. The important point in this investigation is that the same number of drivers and characteristics can lead to a different number of variants and therefore variant driven complexity costs. On the other hand a constant number of variants can be created with a different amount of drivers and characteristics. Especially platform strategies

are one major example for the reduction of variant drivers. The goal of the platform strategy is to create the same amount of product variants with a lower number of drivers by deriving the desired number of variants from one single technical basis which reduces the technical complexity in development and production.

For an evaluation of the cost impact of the number of available variants on different markets created in different production processes at suppliers and vehicle manufacturers it is necessary to analyze the variant tree structure. To gain significant information about the cost impact different variants have, the relation between drivers, characteristics and related production costs has to be determined. The derived information allows manufacturers to decide, which variants are cost-effective and which might cause more additional costs than the profit they return and might be deleted for commercial reasons.

Results and discussions

The main findings are presented and analyzed according the 4 product variety categories adopted in the paper: platform, models, variants, and dealer fitted options.

Product Variety: Platform and Models

The usage of individual platforms is rarely confined to single market regions, and in fact in most cases, existing platforms are merged onto a few global platforms. Therefore the number of platforms adopted by vehicle manufactures has been decreasing since 1990. The expansion of traditional model range with the so-called ‘cross-over’ and niche vehicles (Holweg and Greenwood, 2001; Carvalho, 2005), for instance: SUVs (Sport-Utility Vehicles) and MPVs (Multi-Propose Vehicles), has been another trend in the auto industry. Table 1 presents the results for Ford actual product variety for the platform and model categories offered to significant markets worldwide.

It can be seen in Table 1 that the platform numbers of Ford in Latin America and in Europe are mostly the same: 3 (three). Mexico is an exception, as it produces models not only for its domestic market, but also to export for the American market, that has different characteristics. These differences are shown in the second group of product varieties (Model Range). While in Europe the concentration of models can be found in the sub-compact and compact segments, in the USA there is a concentration in higher segment levels (see the sport segment). In South America the concentration is in the sub-compact segment. It is difficult to extend this comparison to Africa, Asia, and Oceania as Ford with its Ford Brand does not produce significantly in these regions and its market sales is not that high.

Table 1: Platform and models varieties

Market	Platforms	Model Range							
		Super-mini	Sub-compact	Compact	Mid-Size	Full-Size	X Full-Size	Sport	Total
Brazil	3	1	2	1	1	-	-	-	**5**
Argentina	3	1	2	1	1	-	-	-	**5**
Chile	2	1	2	1	-	-	-	-	**4**
Mexico	7	1	3	1	2	1	-	-	**8**
U.S.A.	5	-	-	1	1	2	-	3	**7**
Germany	3	1	2	2	1	-	-	-	**6**
U.K.	3	1	2	2	1	-	-	-	**6**
France	3	1	2	2	1	-	-	-	**6**
Italy	3	1	2	2	1	-	-	-	**6**
Portugal	3	1	2	2	1	-	-	-	**6**
Russian	3	-	2	2	1	-	-	-	**5**
Turkey	3	-	2	2	1	-	-	-	**5**
Japan	4	-	1	2	1	-	-	1	**5**
China	3	-	1	1	1	-	-	-	**3**
India	3	-	3	-	2				**5**
Malaysia	1	-	-	1	-	-	-	-	**1**
Middle East	-	-	-	-	-	-	-	-	**0**
Australia	3	-	1	1	-	2	-	-	**4**
Philippines	1	-	-	1	-	-	-	-	**1**
South Africa	2	1	1	1	-	-	-	-	**3**

Product Variety: Variants

Parallel to the number of produced models, the number of body types offered also increased. According to Pil and Holweg (2004), the number of body types produced in Europe doubled between 1990 and 2002, from 88 to 179, thereby corroborating the trend of the automotive market towards diversification and segmentation within this product variety category. These authors also identified a group formed by BMW and Mercedes whose total variations surpassed the order of 10E16, reaching the order of 10E24 for Mercedes' Class E model. It should be considered, however, that these models belong to exclusive segments of the market and that their customers demand an offer of wide variety of attributes (variants) so that their different needs and wishes may be met in a customized vehicle. However, the costs of stocking several different parts and components with a view to meeting such customer needs hinder forecast-driven production. The main solution that the vehicle manufacturers have found in order to minimize this problem is to offer their customers the vehicle they desire on a

build-to-order basis. Table 2 presents the results for Ford actual product variety for the variant category.

Table 2: Number of variants for significant Ford models worldwide

MARKET	FIESTA			FOCUS			
	Hatchback	Sedan	Total	Hatchback	Sedan	Wagon	Total
Brazil	120	152	**272**	64	56	-	**120**
Argentina	96	80	**176**	96	88	-	**184**
Chile	24	24	**48**	10	15	-	**25**
Mexico	24	32	**56**	-	48	-	**48**
U.S.A.	-	-	**0**	42.912	45.504	62.208	**150.624**
Germany	1,16E+11	-	**1,16E+11**	1,95E+14	7,56E+11	4,65E+14	**6,61E+14**
U.K.	45.594.912	-	**45.594.912**	2,36E+10	2,28E+10	3,27E+11	**3,74E+11**
France	68.022.528	-	**68.022.528**	1,65E+11	9,31E+09	5,80E+11	**7,54E+11**
Italy	728.825.856	-	**728.825.856**	-	-	-	**0**
Portugal	1.143.200	-	**1.143.200**	2,40E+10	1,56E+09	1,04E+11	**1,29E+11**
Russia	168.432	-	**168.432**	2,97E+12	1,56E+12	1,56E+12	**6,10E+12**
Turkey	14.144	-	**14.144**	2912	1352	728	**4992**
Japan	14	-	**14**	30	-	-	**30**
China	-	-	**0**	21	28	-	**49**
India	-	64	**64**	-	-	-	**0**
Malaysia	-	-	**0**	3	5	-	**8**
Middle East	15.744	-	**15.744**	2091	2298	828	**5217**
Australia	112	-	**112**	121	63	-	**184**
Philippines	-	-	**0**	5	17	-	**22**
South Africa	560	-	**560**	438	48	-	**486**

The findings presented in Table 2 show that there is a significant difference between the analyzed markets and indicate that in Europe the total number of variants for all models exceeds the one offered in the other regions by far, mainly if Germany is highlighted. For example, the Ford Focus Sedan model is offered in Germany with almost 10 million times the number variants offered in USA and with almost 10 billion times the one offered in China or in Brazil. These differences in the number of variants offered are found in all the analyzed auto segments worldwide. Sales dimensions could initially explain this, but counter examples can be found. For instance, consider the Ford Fiesta Model. This models sale in Brazil is around just ¼ of the total sales in Europe, but the total number of variants is at least 3 (three) orders of magnitudes smaller. As model sales dimension by itself cannot explain the number of product variant offered could factors like the market size of a country, the country's economic development, or the existence or not of an auto plant in the country be an explanation? Based on the information contained in Table 2, it is possible to see that variety is

not essentially related to market size, for instance the variety offered in Brazil compared to a smaller European auto market as Portugal. Neither is the variety essentially connected to economic development, as there is a lower level in Brazil and Malaysia when compared to other emerging countries like Russia or Turkey. The host of a local plant also does not explain the low variety identified in American and Asian markets. See the variety offered in Germany (country that hosts a Fiesta Plant) and the one offered in other European countries that do not have a Fiesta Plant (e.g. France and Italy) and compare to the Brazilian and South African numbers, countries that host Fiesta Plants. The logic can be extended to the Focus, as countries like Germany, Spain, Russia, Mexico, Argentina, USA, and Philippines host a plant and the variant number for the respective domestic market vary a lot.

Product Variety: Dealer-fitted-options

Locating the point of product differentiation as far downstream in the supply chain as possible is also a well known strategy in the area of variant management. But even here the quantitative effects in terms of variant driven complexity costs have to be investigated in depth in many cases to be able to make strategic decisions regarding the desired amount of variants. The execution of final assembly steps at dealerships however is not a common business model in Europe, with the exception of fitting third-party aftermarket parts. Table 3 presents the results of the product variety for the dealers-fitted-options category available in 2006 for two models of Ford in some significant auto markets (Focus and Fiesta).

Table 3: Number of dealer-fitted-options

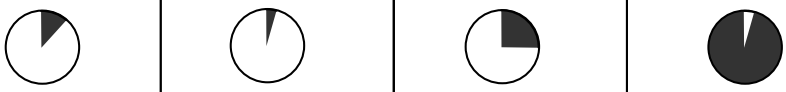
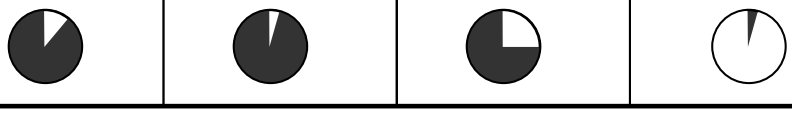
MARKET	Focus Hatch		Fiesta Hatch	
	Accessories	Combinations	Accessories	Combinations
Brazil	28	1.088.640	46	3,36E+10
U.S.A.	30	27.869.184	0	-
U.K.	17	3.360	23	458.752
Spain	22	73.728	14	6.144
Japan	-	-	0	0
Malaysia	5	32	0	-
Australia	26	18.874.368	30	141.557.760
Philippines	9	512	0	-
South Africa	21	786.432	18	262.144

It seems that with late configuration there is a good balance between cost and product variety. There is not a high variety level offered at the plant level in emerging countries, what makes the cost low, but this variety level is increased at the dealers in a way to fulfill additional customer requirements within a low cost perspective.

The cost effects

Another important aspect which's effects can already been seen in the displayed empirical results is the differentiation between the variants available to the customer (build combinations) representing the market complexity and the technical complexity driven by boundary conditions from the production process or technical requirements (an engine with a higher torque needs a stronger transmission) as well as legal (safety, environmental) requirements or conditions of use (climate, infrastructure). While shared part concepts or platform strategies as described above try to reduce the technical complexity of the product and therefore the amount of system variants, late configuration strategies like dealer fitted options in emerging economies often refer to customer choice and build combinations and therefore increase market complexity. The effect on cost related to the product lifecycle is totally different as it can be seen in figure 2.

Figure 2: Cost impact of Build Combinations and System Variants

	Cost Impact on Section of Product Lifecycle			
	Design & Development	Purchasing	Manufacturing	Distribution
Build Combinations				
System variants				

While technical complexity has its main influence on costs in development, component manufacturing and assembly, market complexity influences costs mostly in the area of distribution and assembly and has a main influence on order lead time. This means that for different environments and market requirements the strategies have to be adapted. First steps in this direction have already by taken, as can be seen regarding e.g. the ratio between dealer-fitted options for the Ford Fiesta (see table 3).

Final Remarks

Product variety has a different behavior among auto markets worldwide. Under a platform perspective, markets do have similar varieties as manufacturers adopt world platforms. This similarity is mostly based on the number of platforms. The models offered by vehicle manufacturers that came out from these platforms are not same among the analyzed markets.

In South America there is a model concentration in the super mini and sub-compact segments, while in Europe this concentration is in the compact and mid-size segments and in North America in full-size and sports segment. In the model variety category Europe was the region with the highest figures, followed by North America. We also found that in Europe the variety is expanded in terms of the total amount of available product variants, what is done in less intensity in the USA and even less in emerging markets in South America, Africa and Asia. Our findings lead us to believe that customers' desires are not necessarily let down in some of these markets as customization shifts (is postponed) to a different point in the value chain. The variety is enhanced with the large use of late configuration at the dealers' points of sale.

While the examples from empirical research that are presented in this paper already give an overview where and with what methods the variants are created in different regions, the complexity cost methodology based on drivers and characteristics can deliver figures regarding the related variant driven complexity costs. The combination of this information would enable automotive manufacturers to avoid mistakes such as creating massive proliferation meaning just an inefficient amount of variety without an adequate benefit or even creating the wanted and necessary variety with the wrong methods or at the wrong point of the supply chain. Further information can be gained by not only comparing the strategies of one single vehicle manufacturer in different regions and markets but also compare the versatile strategies of different vehicle manufacturers on the markets they compete in by further empirical research and evaluate them by detailed analyses using the complexity cost model.

One advantage of the used complexity cost model at its current stage is that it is highly flexible and adaptable to a large number of processes all over the supply chain. One next step therefore is to interlink research in the field of variant strategies in automotive production with the methodology of complexity cost model as well as finding synergies and adjusting research and evaluation tools. This will lead to comprehensive methodologies for automotive manufacturers helping those making important decisions for automotive development and production in the next decades.

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References

BAYUS, B.L., PUTSIS Jr, W.P., 1999. Product proliferation: An empirical analysis of product line determinants and market outcomes. **Marketing Science** 18 (2), 137-153

FISHER, M.L., HAMMOND, J.H., OBERMEYER, W.R., RAMAN, A., 1994. Making supply meet demand in an uncertain world. **Harvard Business Review** 72 (3), 83-93

FISHER, M., ITTNER, C. (1999), The Impact of Product Variety on Automobile Assembly Operations: Empirical Evidence and Simulation Analysis, **Management Science**, Vol. 45, No. 6, pp. 771-786.

LANCASTER, K. (1990), The economics of product variety: A survey, **Marketing Science**, Vol. 9, No. 3, pp. 189-206.

OICA (2006), **Production Statistics**, Organisation Internationale des Constructeurs d'Automobiles. Available at: http://www.oica.net/htdocs/main.htm. Access: 10/10/2006.

MUFFATO M. (1999), Platform strategies in international new product development, **International Journal of Operations & Production Management**, Vol. 19, No. 5/6, pp. 449-459.

PIL, F., HOLWEG, M. (2004), Linking Product Variety to Order-Fulfillment Strategies, **Interfaces**, Vol. 34, No. 5, pp. 394-403.

SCAVARDA, L.F.; SCHAFFER, J.; SCHLEICH, H.; WINKLER, H.; HAMACHER, S. Complexity in the Auto Industry as a Result of Product Variety. In: **EUROMA** - 15th International Annual European Operations Management Association Conference, 2007, Ankara, Turquia. 2007.

SCAVARDA, L.F.; BARBOSA, T.P.W.; HAMACHER, S. Comparação entre as Tendências e Estratégias da Indústria Automotiva no Brasil e na Europa. **Gestão & Produção**, São Carlos, v. 12, n. 3, p. 361-375, 2005.

SCHLEICH, H.; SCHAFFER, J.; SCAVARDA, L.F. Managing Complexity in Automotive Production. In: **ICPR** - 19TH International Conference On Production Research, 2007, Valparaiso, Chile. 2007.

WATANABE, C.; ANE, B. K. (2004), Constructing a virtuous cycle of manufacturing agility: concurrent roles of modularity in improving agility and reducing lead time, **Technovation**, Vol. 24, No. 7, pp. 573-583.