Shortening of Life Cycle and Complexity Impact on the Automotive Industry

Dušan Sabadka [1], Vieroslav Molnár [2], Gabriel Fedorko [3]

[1] *Department of Automobile Production, Technical University of Košice, Faculty of Mechanical Engineering, Mäsiarska 74, Košice, 04001, Slovakia*
[2] *Department of Computer Aided Manufacturing Technologies, Technical University of Košice, Faculty of Manufacturing Technologies, Štúrova 31, Prešov, 08001, Slovakia*
[3] *Logistic Institute, Technical University of Košice, Faculty of Mining, Ecology, Process Control and Geotechnology, Letná 9, Košice, 04200, Slovakia*

***Abstract* – The article is focused on vehicles life cycle and specific phenomena accompanying it. We aimed to review and define factors taken into account in the process of a vehicle development thus we have summarized methodically acquired knowledge of life cycle and complexity of vehicles, analyzed factors that are subject to world automobile production growth and the number of vehicle models selected by well-known manufacturers as well as vehicle generation at the time.**

***Keywords* – innovations, life cycle, complexity.**

1. Introduction

Worldwide competition in the automobile manufacturing sector is the driving force behind the progress of automobile producers. Requirements on suppliers and manufacturers now focus on accelerating of modification and diversification of the production portfolio. Final producers (OEM) are forced to shorten life cycles of their products and expand the configuration of car models. According to different authors [3],[5],[8] Innovation Life Cycle represents the economic and technical life of a product in its particular form.

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Corresponding author: Dušan Sabadka,
Technical University of Košice, Faculty of Mechanical Engineering, Košice, Slovakia
Email: *dusan.sabadka@tuke.sk*

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Life cycle length, depending on the product, is divided into several different phases. Significant changes in product behavior in the market remain during this period such as product demand, its profitability, and so on.

Shortening of Innovation Cycles

In developed countries, the life of an average car model has been shortened by about half (approx. eight to four years) over the last decade. Recently, the average time of a product development (from concept design to start of series) was reduced from an average of 48 months to about 25. Figure 1 presents the essential elements of a car development from the moment of decision on the new product manufacturing, its identity and identification of the target customer, through the process of defining the essential features and design, determination of final price, production volumes and planning the start of its mass production. In Toyota, the initial design product phase takes about 2-3 years while subsequent production planning phase accounts for around 15-20 months. The graph shown in Figure 2 compares actual development times with target times required to develop a new car model by a specific manufacturer. As indicated before, social changes lead to an increase of consumer individualism resulting in their increased expectations and demand for a new product. For as much as the impact of this trend on the automotive production is probably the most important, the following analysis will be mainly limited to this factor [13].

Complexity of the Automotive Industry

The concept of complexity in terms of automobile production can be defined as the variety and complexity of the system, subsystem, or the final product in terms of its organization, management, coordination, respectively resulting structure [1], [10]. Complexity phenomenon in automotive industry most commonly refers to a product development and manufacturing.

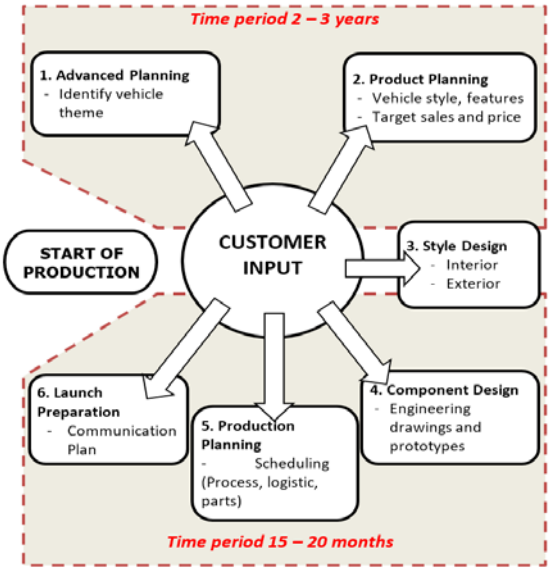

Figure 1. Automobile development time – Toyota example

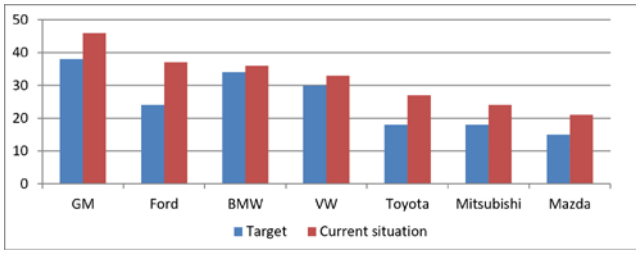

Figure 2. Automobile development times according to manufacturers (in months)

Thus defined, the complexity of the system is induced by certain driving forces, leading to an increase of cost burdens for product or process. Drivers of complexity (e.g. product diversity and variability of the equipment required by the customer) require not only physical modification and variation of the product, but the whole process also requires a wide variety of tangible and intangible logistic flow combinations that attribute to product complexity and process implementation which may lead to an increase in costs. The complexity of products is primarily caused by drivers of the market, especially by changing demand and number of customers [4],[9]. These drivers of complexity are the result of globalization and market dynamics, causing great amount and frequency of offered individual variant changes. In terms of the company, diversification is considered to be the major factor in complexity of products growth. The causes of complexity growth can mainly be identified by customer needs and development of a new situation in the automobile industry market in the early eighties of the last century. The following graph (Figure 3) simply shows how the demands have changed over the time along with customer requirements upon the vehicle.

Development in customer needs is the key reason to model range diversification and increase in variability of assembling an automobile according to customer needs. This is primarily an effort of a company to meet the requirements of the customer, as well as an effort of a company to engage and acquire new customers by expanding its product portfolio. Diversification of model range, equipment variations and the like does not only bring positive results in form of a diverse product portfolio, but also difficulties and various risks associated with the diversity management such as a longer delivery period of the product to the customer, which has a major impact on costs due to complexity growth [2], [10].

2. Material and Methods

The paper focuses on the fact that the trend of shortened life cycle brings out complex management subsystems of production in which the complexity of individual subsystems directly depends on increasing complexity, e. g. increase in production of models and their variations. It includes techniques, recommendations and future trends related to current shortening of the life cycle.

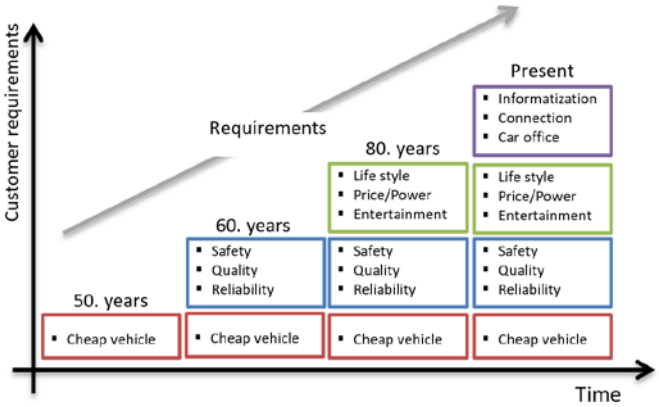

Figure 3: The evolution of customer requirements for vehicle [9]

The paper aims to explore and describe relationship between the development of product differentiation, product life cycle shortening in the automotive industry and complexity phenomenon. The analysis carried out results in a summary of potential solutions for complexity and life cycle in terms of reducing the impact on production systems and solutions to life cycle shortening. The analytical part of the paper deals with the analysis and development of product differentiation in the automotive industry. It describes the consolidation of automobile manufacturers and analyzes the development of product differentiation. Relevant data presented in analytical section has been obtained and compared by the method of comparative analysis and processed then into final graphical results. Data

subject to analysis was drawn from various available sources though its obtaining was difficult due to frequent unavailability and, too often, wide range of information from different sources of various automobile manufacturers.

Development of Product Differentiation

Exploring the development of product differentiation in terms of vehicle life cycle shortening is a considerably complicated process, the reason to it being the high number of aspects influencing and triggering the whole process. The fundamental aspect of a new type of automobile bodywork lies in a more complicated customer behavior and increasing demands on the car. Increase in number of vehicle concepts is a relatively young phenomenon which started in the 1960s. It is therefore clear that at Fordism times (beginning of the 19th century), an automaker had no problems with shortening of innovation and lifecycle of vehicles. The same model had been produced for 30 years (Ford Model T) [7]. However, the graph in Figure 4 makes it clear that the development of cars concept had well advanced since then. Nowadays, car manufacturers not only build their strategy on modern technologies application, but also expand their product portfolio and its different concepts.

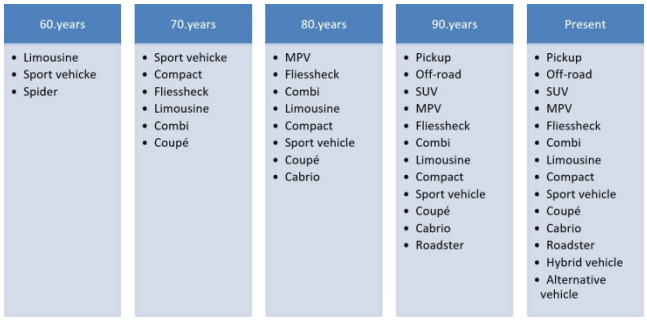

Figure 4: The growth of a car body concepts

Consolidation of Automotive Manufacturers

Global automotive industry, at present, belongs to sectors with the highest degree of globalization. World economy globalization leads to corporate mergers. The situation in automotive industry has significantly changed in a few decades. Automakers began to join groups of companies and create various partnerships or alliances to maintain and stabilize the market. These partnerships have resulted in the reduction of independently operating automakers in half. Such consolidation also shortens automobiles life cycle, when the individual group brands cooperate with each other, for example, to create a common platform used in different brands of concern group automobiles.

A look at evolution of number of independently operating car manufacturers, according to data available, makes it clear that in the 1970s there were 36 independent automobile manufacturers on the market. By gradually consolidating and creating partnerships and alliances, the number decreased in the 1990s to 21, to 14 in late 2000, while there are now 11 conglomerates on the market, owned by several manufacturers. The ownerships and networking are now considerably complicated.

Analysis of the Numbers of Models Development

The analysis in this part of research is focused on development of number of models offered by various car manufacturers, while subject to research being particular global automakers and their models. The term model car is used for a specific brand and type of a car. The same model of car can be sold in different versions and equipment standards, respectively, under different trade names of otherwise identical car which in the analysis do not play a role so as to avoid distortion of research results. From the above definition of the model it is clear that the new-generation vehicles are considered to be new models, but the individual variations in the present generation do not constitute a separate model. Every car manufacturer has been analyzed in the time course since the 1950s up to present in relation to its number of production models.

The analysis has included the whole number of models developed and available on the market since 1950 until present. The research includes the following automobile manufacturers:
European manufacturers:

- Volkswagen, Porsche, Škoda - Volkswagen AG
- BMW — Bayerische Motoren Werke AG
- Peugeot — Grupo PSA
- Ferrari — Fiat Group
- Renault — Renault-Nissan US manufacturers
- Ford — Ford Motor Company Japanese manufacturer
- Toyota — Toyota Motor Corporation

Figure 5 shows the results of analysis of the number of Volkswagen models development. The analysis shows that the automaker has offered two models on the market since the 1950s until now. Specifically, the models named Beetle and Transporter. Carmaker Volkswagen has been, for more than sixty years, continuously expanding its portfolio by an average of three models every decade. At present, the increase represents six times higher number of models offered than in early 1950s. In a similar way, all the above auto manufacturers had been analyzed.

Production in years	1950	1960	1970	1980	1990	2000	2010-present
Volkswagen							Up
							Fox
						Lupo	Polo
						Fox	Beetle
						Polo	Golf
						Beetle	Jetta
						Phaeton	Passat
					Beetle	Sharan	Scirocco
					Transporter	Passat	Tiguan
					Sharan	Golf	Touareg
			Beetle	Transporter	Passat	Touareg	Phaeton
			Transporter	Passat	Golf	Scirocco	Caddy
		Beetle	412	Golf	Polo	Jetta	Touran
		Karmann	Passat	Polo	Scirocco	Tiguan	Sharan
		Transporter	K70	Scirocco	Jetta	Caddy	Transporter
	Beetle	1500	Golf	Jetta	Corrado	Touran	Eos
	Karmann	1600	Derby/Polo	Corrado	Caddy	Transporter	Amarok
	Transporter	411	Scirocco	Caddy	Taro	Eos	XL1
Number of models	3	6	8	8	11	16	18

Figure 5: Volkswagen model portfolio 1950 — present

Analysis of the Car Generations Evolution

One of the ways to interpret shortening of automobile life cycle is to analyze each model generations. Five popular car models had been selected to do so. The analysis examines the evolution of generations of these models:

- Volkswagen Golf — German manufacturer Volkswagen AG,
- Porsche 911 — German manufacturer Porsche AG belonging to the Volkswagen group,
- Ford Fiesta — American manufacturer Ford Motor Company,
- Toyota Corolla — Japanese manufacturer Toyota Motor Corporation,
- Honda Civic — Japanese manufacturer Honda Motor Corporation.

Volkswagen Golf is one of the world's best-known and best-selling vehicles in general, previously produced primarily as a three-door hatchback and five- door respectively, its history dating back to 1974. At present, Volkswagen is already producing and selling its seventh generation of cars. The above model is also sold under other designations such as "Volkswagen Rabbit" (US, Canada), "Volkswagen Caribe" (Mexico) respectively, "City Golf" (Canada, Brazil, Argentina). As far as talking about the life cycle shortening of a vehicle and therefore the sales period of the model in different years, the VW Golf is a typical example. The following table presents each generation Golf model data, such as range of years of production, the number of years having been offered on the market and the number of units produced in millions.

The data in Figure 6 shows that in more than 40 years, the life cycle of Volkswagen reduced to less than a half, from 9 years to 4 years in particular. This significant difference is also reflected in the number of units produced, respectively sold. The first generation of the model had been produced during nine years in the volume of 6,800,000 units, in contrast with the third, fourth and fifth generations produced for only six years each, when the sale was in relative stagnation. In similar way, all featured models had been analyzed.

Volkswagen Golf			
Generation	Year of production	Years	Number of units (in millions)
1.generation	1974-1983	9	6,8
2.generation	1983-1991	8	6,3
3.generation	1991-1997	6	4,8
4.generation	1997-2003	6	4,3
5.generation	2003-2008	6	3,3
6.generation	2008-2012	4	2,9
7.generation	2012 - present	3+	.....

Figure 6: Volkswagen Golf – analysis of generations

3. Results

The results of analysis of models development numbers are summarized and compared in Figure 7. The graph in Figure 8 shows a dramatic increase of products portfolio of all reviewed car manufacturers. The increase indicates that all automakers, due to customer demands and requirements on product, have adopted the idea of increased variety of products. Since individualism seems to be an essential aspect of the development, the reaction of automakers is more than obvious.

Years of production	1950	1960	1970	1980	1990	2000	2010-present
Vlokswagen	3	6	8	8	11	16	18
BMW	6	8	6	6	8	13	15
Ford	5	7	10	11	17	17	21
Peugeot	4	4	8	10	12	14	18
Ferrari	6	7	6	9	8	10	9
Porsche	1	4	6	6	7	6	7
Škoda	3	4	6	7	6	6	8
Renault	5	9	11	13	11	12	18
Toyota	2	3	7	12	16	15	17
Overall	35	52	68	82	96	109	131

Figure 7: Production models by brands -summary of results

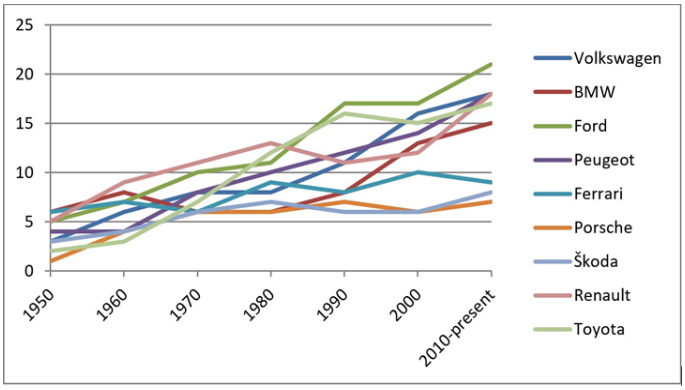

Figure 8: Production chart of models by brands – Summary

Conclusions

- Among the producers that have most expanded their models portfolio during the period, Ford, Volkswagen, Toyota, Renault, Peugeot and BMW can be included. The automakers have been significantly increasing and expanding their portfolio since the 1990s as a result of market changes, customer demand change, introduction

of new techniques and methods of production, increasing globalization, standardization of products, etc. At the moment, they are offering 17 to 25 models on the market.

- The second group, Porsche and Ferrari, represents the automakers whose business strategy is different in terms of number of models. Since this is a luxury premium brand, the number of models in different decades has not changed significantly. However, Ferrari assigns various models of special versions and limited editions to be manufactured, e.g. F12tdf edition of Ferrari will only produce 799 copies. It should be emphasized that the sales volumes are different from traditional manufacturers.
- A special case in terms of the number of development models and sales volumes is Škoda. Its product portfolio over the decades has expanded only at a moderate pace (Figure 7). In the years 1950 – 1960, only three models were offered the number of which rose to 8 models nowadays. With the number of its models, Škoda ranks into the second group, but targets itself to market segment belonging to the first group of traditional producers. Škoda portfolio has significantly been marked with the historical development when restructuring in the 1990s brought Volkswagen AG as its shareholder. Restructuring period required a certain amount of time to consolidate and reengineer the production.

From the examination of automobile generations development (Figure 9, Figure 10) it can be concluded that in terms of life cycle shortening, Golf model has been the best developed strategy of Volkswagen. Within the period reviewed, its life cycle was getting shorter. Based on the analysis, Japanese Automobile Manufacturers Toyota and Honda continue their strategy of introducing new generations every 4 or 5 years. American manufacturer Ford, according to model Fiesta analysis, tends to extend the period of new generation vehicles introduction, which can be due to increasing complexity of its new vehicles. The results for some models are a bit in conflict with the trend of life cycle shortening, but it should be noted that the analysis did not include the data of the model facelift, which prolongs the saturation phase and increases the level of diversification.

The idea of examination of product life cycle shortening is a very complex issue that requires research in many areas of car development and production. Our analysis shows the development of design of selected model generations. Automakers are continually trying to design and modernize their vehicles so that the vehicle design is up to date and attractive to future customers. Many car companies often change the basic features of their model car beyond customer recognition. On the other hand, for luxury vehicle types such as Porsche, maintaining its essential features is of utmost importance. Like this, the brands keep their prestige and changes in design are implemented only to minimum extent and detail.

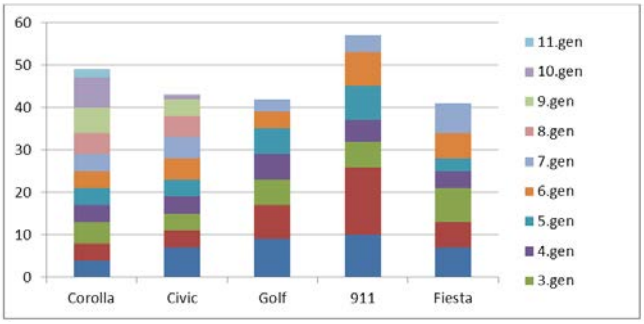

Figure 9: The results of analysis of the automobile generation evolution — summary in years

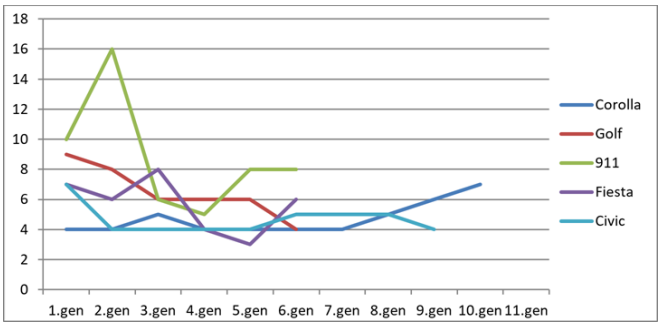

Figure 10: The results of analysis of the automobile generation evolution – summary in years

4. Discussion

Current trend in the automotive industry sector is shortening of products life cycle and increase of their complexity [3],[5],[8]. The phenomenon accompanying the trend also includes: consolidation and centralization of vehicle manufacturers, increased car production and product diversification, growth of model variants, etc. [11],[14]. The paper presents and analyzes various types of specifics of shortening development and product cycles in automotive production. The analysis of development in the number of models under each brand pointed out that the final automobile producers - OEMs are trying to maintain the increase of their market share by the number of models. Having examined generations of models of selected manufacturers, we assume that automakers use different strategies to attract customers. Using the example of generations of Volkswagen Golf and Toyota Corolla models, the tendency of life cycle shortening had been proven. The conclusion of our paper summarizes future trends in product life cycle shortening in the automobile production along with recommendations for complexity management.

Examining the issue of life cycle shortening can be a time consuming activity. Pointing out the specifics of the individual cycle shortening helps to understand its various aspects and context more precisely and helps to design a proper strategy to achieve the highest sales of product resulting in highest possible profits.

Nowadays, the identification of optimal level of product complexity in the car manufacturing industry is of crucial importance. The optimal degree of complexity is based on mutual relationships of costs, revenues and profits (Figure 11). Examination of this level is therefore an important challenge for many automakers. Generally speaking, process optimization stems from the economy coupled with the creation of the product and its diversity [3], [4], [12]. The options to optimize the complexity and products in automobile manufacturing are currently being paid a great deal of attention. In particular, various techniques of products life cycle shortening and their proper use in different stages of development. Basic techniques to shorten the life cycle are simultaneous engineering, virtual testing, platform management, modular strategy, the use of rapid prototyping technology and so on [6], [14].

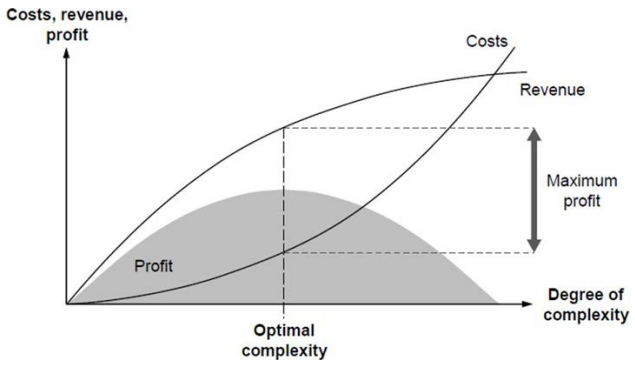

Figure 11: Relationship between revenues and costs to define optimal variety [11]

Effective methods of complexity cost management in automotive production should deal with finding solutions to control and reduce costly aspects the increasing share of which is triggered by complexity. There are several different management tools to complexity as required by types of actions.

The example in terms of organizational measures may include two areas:

- Construction: e.g. simultaneous engineering
- Logistics: reduction of manufacturing width and manufacturing depth and global sourcing.

Possible solutions in the field of technical measures include: standardization, platform strategies, modules, focusing on quality. In terms of marketing measures for effective management these are included: sales promotion of niche models, segmentation by price, focusing on environment and quality.

The most fundamental potential to reducing and controlling product costs and the entire system is in the area of product development, as has already been mentioned. The use of appropriate techniques and tools in the early stage of value chain significantly contributes to complexity management and optimization.

5. Conclusion

The theory of innovation is based on an assumption that a product, throughout its life cycle, is upgraded several times. Individual innovative solutions to each product should be followed with no loss in products. Thanks to the implementation of new variants, the companies maintain their current product portfolio and thereby prevent the obsolescence. Good estimate and timing of the product launch as well as its withdrawal from the market, product competition comparison, analysis of marketing products and services, all together affect the success or failure of the product and help companies to a proper understanding of the life cycle.

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