New Product Development in the Context of Industry 4.0: Insights from the Automotive Components Industry

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1 Introduction

The technological evolution of recent years has allowed automotive component companies to become more competitive by developing innovative and technologically advanced solutions, improving quality and time-to-market and lowering the cost of a product. The growth of these companies in recent years is strongly based on the industrialization of research and development projects what increasingly allows to sustain their growth in differentiation by innovation.

In the automotive components companies there is a focus on quality and technology, which are important principles in developing a culture of innovation that is based on the qualification of their human resources, in new product development (NPD) (at the aesthetic and technical level) and in the continuous improvement of the development and production processes.

The merger between the automotive industry and technology is constantly evolving and the inclusion of technological innovations in automobiles is increasing. The automotive industry is becoming increasingly complex and competitive due to evolving of the nature of the product, increasing numbers of models, and rising development costs. The original equipment manufacturers (OEM) and component suppliers are exploring newer ways to enhance the development process due to increasing competition and pressure to reduce cost and development time [1]. Some examples of

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J. Reis et al. (eds.), *Industrial Engineering and Operations Management II*,
Springer Proceedings in Mathematics & Statistics 281,
https://doi.org/10.1007/978-3-030-14973-4_8

OEM in the automotive industry are Toyota, Volkswagen, General Motors, Hyundai, Ford, Nissan, Fiat, Honda, Suzuki, and Peugeot Citroen.

The automotive industry is one of the most important worldwide drivers of growth, employment, and technological and managerial innovation [2]. The NPD is one of the main ways to gain competitive advantage for a company [3]. Due to an increasingly complex and competitive global marketplace, automotive companies are looking at new ways to improve their operation in order to remain profitable [2]. Cost management in NPD is important and necessary in order to optimize the performance and cost of a product [3]. Indeed, most of the product costs are defined during the development phase and after this phase cannot be influenced significantly anymore [4].

In this sense, NPD has become crucial in the strategies of many companies. The objective of product development is to transform an idea into a product. So, NPD processes comprise several phases, for example, planning, concept design, product design and testing, and production startup [5]. These phases can be performed sequentially (in parallel) or concurrently/overlapping (in this case, design phases occur simultaneously and in a nonlinear manner) [6].

The market has been pushing companies to offer competitive new products simultaneously in quality, functionality, and price, contrary to the traditional trade-off between quality and price [3, 7]. This process occurs in many industries asking for increasingly complex and dynamic production and business models. For example, in the automotive industry, new products are being developed to replace existing products or to add completely new product lines [2] in processes where increased coordination and synchronization is required. Furthermore, modern cars are characterized by having different components (e.g., electronic, mechanical) in which software has gained increasing importance [8].

The automotive component industry is increasingly marked by integrating new technologies into their products and there is a greater need to adapt or evolve cost management in NPD and to optimize processes that were considered “optimized” until now. There is a continuous endeavor by automotive industry for further improvements in the process [1]. OEMs are increasingly involving their suppliers in new developments [9–11] and the collaboration skills in NPD are an important aspect of companies’ ability to access technology and complementary assets [12].

Digital transformation has had a strong connection with the industry since the Third Industrial Revolution. The Industry 4.0 represents the Fourth Industrial Revolution and focuses on the end-to-end digitization of all physical assets and integration into digital ecosystems with value chain partners [13]. The Industry 4.0 is characterized by emerging technologies such as internet of things, mobile internet, wireless sensor networks, big data, cloud computing, embedded systems, nanotechnology, interconnectivity of machines, and artificial intelligence [14]. The intelligent products and machines (driven by real-time data, embedded software, and the internet) are organized as autonomous agents within a pervasive and agile network of value creation [15]. Different technologies are exponentially growing and radically changing industrial processes, accelerating them and making them more flexible and smarter [16].

These concepts such as embedded software, connectivity, and software tools are deeply rooted in industrial processes of automotive components industry. Companies in the automotive components industry are considered a benchmark relative to other industries since the best practices of cost management in NPD are implemented. The optimization of mature development processes is a challenge but Industry 4.0 is changing NPD in the automotive component industry toward new frontiers.

Next section explains the research methodology and in the following one, the main results are presented and discussed. Two dimensions are highlighted: rapid prototyping and manufacturing, and concurrent NPD processes. The main conclusions and opportunities for further research are presented at the end.

2 Research Methodology

This research followed a qualitative approach aiming to address the complexity and detail of the NPD process in this context of Industry 4.0. The data collected was qualitative once the interviews were semi-structured (questions with open answer). The methodology process followed four steps: development of the semi-structured interview, the guide application of the interview, the analysis of data, and sending a personalized report with the most relevant aspects of the interview for validation. So, written informed consent was obtained from the participants for recording the interviews and use of the information collected.

A set of companies of the Portuguese Association of Automotive Suppliers (AFIA) was approached. AFIA is the association that links and represents the automotive suppliers, both at the national and international level, including national manufacturers of components, parts, and accessories. Besides that, AFIA is a member of CLEPA (European Association of Automotive Suppliers) and aims to boost the competitiveness of industries linked to the sector.

The semi-structured interviews were applied in large-sized companies of the automotive components industry with product development in Portugal. The automotive components industry is considered a benchmark industry in relation to the implementation of best cost management practices and plays an important role in the Portuguese economy for several decades.

The semi-structured interviews had a duration between 45 and 120 min. Most of the interviews were tape-recorded and those in which no permission was granted for recording were taken notes. The interviews have been conducted following the interview guide that was previously sent to the interviewee of the company and throughout the interview underwent some changes in its development, such as (1) asking for examples of some project situations that did not go well, (2) how this was overcome, (3) what implications it had for future projects, (4) examples of successful problems and solutions.

Later, interviews and notes were transcribed word-for-word, to digital format for the analysis, which was supported by the qualitative data analysis software NVivo.

Table 1 Study sample

Company	Industry	Interviewees
A	Electric/electronic	Engineering project office team coordinator Development department manager
B	Plastics, rubber, and other composites	Product industrialization manager
C	Metallurgy/metalwork	Project manager
D	Textiles and other trims	Product industrialization and logistics manager
E	Metallurgy/metalwork	Engineering and development supervisor Technical director
F	Textiles and other trims	Research, development, and innovation director
G	Plastics, rubber, and other composites	Product manager

They were realized 9 interviews in 7 firms of the automotive industry components sector. It is estimated that about 10% of the companies of the automotive components industry in Portugal have proper NPD process. Therefore, the sample of this study should represent approximately 30% of the companies with NPD.

In the Portuguese automotive industry components sector, small companies are just production plants and these companies do not develop products because they do not have skills for that. These companies, as they are production companies, control costs in the production phase because they are pressured to find solutions to reduce costs. Therefore, these companies focus only on continuous improvements in production, in order to optimize processes and reduce costs (kaizen costing approach).

In Table 1, the sample of this study is characterized.

Five companies are first-tier suppliers and two are second-tier suppliers. In relation to the activity sector, the companies are classified as follows: electric/electronic (one company), plastics, rubber, and other composites (two), metallurgy/metalwork (two), and textiles and other trims (two).

Rapid prototyping and manufacturing and concurrent NPD process were particularly evidenced as elements of change of NPD in the automotive components industry. Next section focuses on these aspects.

3 Results and Discussion

The automotive components industry concentrates on many multinational groups in Portugal. Multinational companies have an important role in the world economy and trade. In the past, one of the failures of the Portuguese economy was its inability to integrate into the large global value chains, especially in the phases where they have greater capacity for transformation, that is, first in the NPD phase and later in its commercialization. However, in recent years there has been a significant interaction among national companies, universities and research centers, and large multinationals. This strengthening of the interactions and partnerships among the different market players is leading to a paradigm shift in the Portuguese economy, from the paradigm of "made in" to "invented in", "developed in", or "created in".

Automotive component companies sell products to OEM and such components are used in the final product. Small companies in the automotive components sector do not develop new products (focus only on production) and some large companies belong to large international groups (multinational) and have part of NPD (and cost management in this process) outside Portugal, that is, they are manufacturing units of multinational groups. Most of the large companies are production plants and only a few companies develop new products. When companies grow and become very large, entropy increases and companies lose agility. Companies become more formal and process optimization is required.

In the automotive component industry, the product development process may occur on the firm's own initiative but it is mainly at the customer's request. However, product development on its own initiative (innovative products that do not exist in the market) has gained some importance because companies want to be the drivers of the market. The most common development is something that already exists and the client requests new features, more connectivity, a new design (the design is usually customized, for example, the level of mechanics), faster processors, etc. Therefore, in this case, it is also necessary to make the entire development process. The introduction of new functionalities or the change of functional and physical characteristics may also cause changes or adaptations of existing functionalities. The process of launching new products is a cyclical process and due to the pressures of the clients/market, the competition and also the company itself, it is necessary for the company to differentiate through the NPD.

NPD at the request of clients has a higher weight than the autonomous NPD, but the tendency is for the autonomous NPD to have an increasing weight. There is greater control on projects at the request of clients than in autonomous projects. Autonomous projects are usually financed by the Government and companies are forced to execute the budget at 100%. Projects at the request of customers are more controlled in terms of bureaucracy, deadlines, costs, and quality.

The advent of Industry 4.0 is imposing several changes and challenges on industrial processes in general and on NPD, in particular. Software embedded and software tools are making the NPD process more and more simultaneous and, consequently, more complex and shorter. Rapid prototyping and manufacturing are emerging approaches in the automotive components industry and are referenced in the literature [e.g., 17].

3.1 Rapid Prototyping and Manufacturing

The prototyping phase is of high importance, mainly in car safety products:

> On average, 3 to 4 prototypes are made for each product. The prototype is tested and if does not meet the requirements back to the initial stage. What changes from one prototype to another are the product specifications (braking in dry or wet conditions, rolling resistance, comfort, tire adhesion, …). There are several characteristics in developing a tire that come into conflict with each other. Often, when a company solves a feature of a product [that] might create negative results to other features. (Interview extract 1; Company B; Product Industrialization Manager)

Tests are very heavy (for example, the product is subjected to vibration and temperature tests due to customer requirements and these requirements have been kept stable) and evaluate the product under extreme conditions.

However, it is the phase where companies in the automotive components industry achieve brutal savings by eliminating unnecessary prototypes. Customers have forced companies (suppliers) to make the process of NPD faster and faster, eliminating steps that were considered to be consecrated in the traditional NPD process, such as prototyping and preproduction.

> In the past, companies prototyped, corrected and then launched industrialization. Now the prototyping phase has almost disappeared, they make the layout very fast, but the prototyping phase no longer exists or there is very little. (Interview extract 2; Company C; Project Manager)

> This firm does not do pre-series. Once the prototype is very important for the firm, from the moment that the prototype is approved by the internal tests and the customer, the company begins the series production. The prototype development is accompanied by the customer. The prototypes are expensive and the development of many prototypes brings high costs. Then there is the involvement of various stakeholders in order to reduce the development stages and costs. The development timing is two years (since the initial phase of requirements identification until to product presentation to the client). (Interview extract 3; Company B; Product Industrialization Manager)

The prototyping phase is losing influence in the NPD process because it takes a long time, consumes lots of resources and is very expensive. On the other hand, new approaches, such as simulation, are emerging that may challenge this validation methodology and can make the process much faster. The validation tests can be replaced by the simulation to simulate a series of conditions to which the product is submitted, reaching the same results in a shorter time.

> Prototyping is very expensive. Prototypes are almost eliminated and only prototypes are made in automotive safety components. Components that are not considered safety pass almost immediately to industrialization. (Interview extract 4; Company C; Project Manager)

The shorter the time-to-market in projects, the greater the frequency of elimination of prototypes and phases of validation and preproduction. In these cases, after the validation of the client, the companies advance to mass production.

Usually, companies develop several prototypes by increasing levels of functionality and the elimination of some of these prototypes becomes a reality to make the process faster and less costly.

> In some cases we cut a sample phase, for example, moving from samples A to C (tool samples) directly. Samples B are developmental samples […] This whole cycle of samples A, B, C and D, with many validations, gives an effective robustness to the product because we are testing the real product. The disadvantage is that it takes a lot of time, it consumes a lot of resources and, moreover, these validations are expensive. Today, new approaches, such as simulation, are emerging. These new approaches may question the traditional methodology and make the process much faster. If we use the simulation instead of doing all tests, we are probably able to achieve the same results in 2 or 3 days because we are simulating a number of conditions to which the product is subjected. (Interview extract 5; Company A; Development Department Manager)

In some cases, we find that from the moment the prototype is approved by the internal tests and customer, the company starts production in series (eliminating the preproduction phase). The prototype is usually accompanied by the customer (more than the start of production) because the more prototypes are made, more costs have companies.

The rapid prototyping or elimination of unnecessary prototyping and elimination of preproduction are influenced by the use of advanced materials [17]. The new technologies allow to develop advanced materials with a huge innovative and transformative potential [17]. The use of software tools (for example, 3D CAD software and finite element method simulation and optimization) that can realistically simulate material forming processes enables the elimination of prototype tools in production and testing stages of development process [18, 19].

Rapid prototyping has advantages but a much more radical change can even be considered. Rapid Manufacturing changes the development process through the elimination of prototype and preproduction stages [20, 21]. New technologies allow to construct advanced materials and more sophisticated solutions allowing a more efficient and effective product validation (Fig. 1).

Pressures to lower product cost led to a reduction in the number of tests, in order to reduce the product cost without compromising profit margins.

In addition to rapid manufacturing, the automotive components industry is driven by the philosophy of continuous improvement. For example, the kaizen costing methodology focuses on reducing costs through continuous improvement during the production phase of the product life cycle and involves internal employees of the company and its suppliers [22, 23]. In this process, non-value-added cost activities are reduced or eliminated.

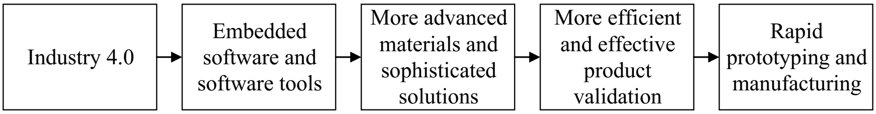

Fig. 1 Contribution of Industry 4.0 to rapid prototyping and manufacturing

3.2 Concurrent NPD Process

In the automotive components industry, the NPD process may occur on the firm's own initiative but it is mainly at the customer's request. However, product development on its own initiative (innovative products that do not exist in the market) has gained some importance because companies want to be the drivers of the market. The most common development is something that already exists and the client requests new features, more connectivity, a new design (the design is usually customized, for example, the level of mechanics), faster processors, etc. Therefore, in this case, it is also necessary to make the entire development process. The introduction of new functionalities or the change of functional and physical characteristics may also cause changes or adaptations of existing functionalities. The process of launching new products is a cyclical process and due to the pressures of the clients/market, the competition and also the company itself, it is necessary for the company to differentiate through the NPD.

NPD at the request of clients has a higher weight than the autonomous NPD, but the tendency is for the autonomous NPD to have an increasing weight. There is greater control over of projects at the request of clients than in autonomous projects. Autonomous projects are usually financed by the Government and companies are forced to execute the budget at 100%. Projects at the request of customers are more controlled in terms of bureaucracy, deadlines, costs, and quality.

An autonomously developed product only passes to the mass production phase if there is a customer for it. For the first-tier suppliers, customers are the OEMs. In another type of business (where customers are individual people), companies do not know how the market will react. In these cases, there is a sales team that studies the market and customer needs but the business model of the automotive components industry is slightly different because they sell to OEMs and there is a contract where it is referenced, for example, price and quantities negotiated.

In addition, NPD can be a sequential or simultaneous (concurrent) process. Most companies use concurrent or simultaneous NPD and the overlapping between phases is evidenced in most companies:

> There is much overlapping. The recursive nature of product development is one thing that no one can say does not exist. It is impossible to say: I have now closed phase 1, now phase 2, … There are always things that come back to the previous phase. The phases are sequential but there is always overlapping between phases, it is impossible to say that there is one that closes for the other to open. There is always a gray area where I have not closed one and I will open the next one, or I have already opened the next one and I have to go back. (Interview extract 6; Company F; Research, Development and Innovation Director)

In the companies studied, the use of simultaneous or concurrent engineering is verified, for example, the product and the process are developed simultaneously. Obviously, there are phases and outputs of the process that are precedent of others. The phases exist, are formal, have outputs and the plan is measured in relation to the outputs.

However, in some cases, the process is more sequential than simultaneous. When the product cannot be made by parts, such as commodities (development of a raw material through the conjunction of various raw materials), the process of product development is always sequential:

> Parallel development at the product level does not exist because it is always the same raw material that is being worked. In these cases, the resolution of a feature creates negative results to another feature because different characteristics require different materials. (Interview extract 7; Company D; Product Industrialization and Logistics Manager)

In fact, this is proven by the literature [24, 25]. Koishi and Shida [25] who mentioned that functions have tradeoffs and, therefore, "understanding the relationship of tradeoffs helps to plan the best design that satisfies the target performance" (p. 173). So, an optimal solution is not unique. When these limitations (e.g., a product cannot be made by parts) do not exist, the use of concurrent or simultaneous NPD was always verified. The use of software tools allows companies to shorten development time, performing simultaneous engineering and accelerating, for example, the prototyping process through advanced tools such as simulation systems.

In recent years, there is a clear tendency to reduce the development time, increase complexity (complexity has been increasing brutally and more and more products have embedded software, incorporation of functions and more complex systems) and make smaller iterations (sprints) to verify if the product is in accordance with what the customer intends.

The way for a company to grow and have a healthy growth is to develop products with greater complexity and more value added. In very simple products, the margins are too tight and, therefore, any deviation that occurs poses a problem for businesses.

> In order to grow and have a healthy growth (up 7%) we must have products with greater complexity and more value added. (Interview extract 8; Company A; Development Department Manager)

The quality targets that are imposed do not depend on the product category (they are usually the same), that is, in simpler products, companies cannot avoid certain control processes that allow them to be more relaxed about quality. Therefore, companies move away from developing products too simple or too cheap.

Growth in the automotive components industry, mainly in the field of electric/electronic, has been greatly boosted by the incorporation of software, and in some cases, it represents for between 60% and 80% of the cost of product development.

> Products increasingly have embedded software… The software represents 60 to 80 percent of the cost of product development, dependent on projects because there are projects with more software than others. (Interview extract 9; Company A; Development Department Manager)

The Scrum methodology focuses on the need to adapt software development to changing customer requirements. A project is divided into cycles, which are called sprints, and the sprint represents a time box in which a set of activities is executed. The functionalities to be implemented are kept in a list called the Product Backlog and then prioritized. At the end of each sprint, there is a meeting with the customer to see if there are any changes to make. This methodology has more validations throughout the process. Then, a new sprint is defined, and there is an iterative approximation in relation to the client's goal. This methodology is widely used in the software industry and as the products of the automotive components industry are increasingly containing embedded software, the development process in these two types of industry will become more similar. That is, Industry 4.0 is changing NPD processes that were considered already very optimized.

Time pressure influences product development, which often forces companies to use prototyping tools:

> If the customer wants the product quickly, we often cannot do it with a definitive tool and then we have to make the product with tools that are called soft tools, which is not a definitive way yet. A definitive tool would delay the normal industrialization time. So we use prototype tools, but product geometry is not a prototype. It is a prototype that is made in a prototype tool but the geometry is already very approximate to the final quality requirements of the product. This happens a lot. (Interview extract 10; Company C; Research, Project Manager)

The inclusion of Industry 4.0 concepts in the automotive components industry allows the development of highly innovative products with higher added value. In addition, Industry 4.0 can be considered the main driver for the future of the manufacturing value chain. In fact, it allows for an evolution of industrial production systems, providing benefits such as developing more complex and innovative products, improving process efficiency, reducing costs, and reducing time-to-market.

4 Conclusions

With Industry 4.0, we are assisting in an evolution of the mature industrial production systems, enabling companies to improve operational and performance ratios and indicators. The combination of low cost, reduced time-to-market, and high quality determines the success of new products and the Industry 4.0 plays an important contribution in this trade-off.

Industry 4.0 contributes to the growing of the complexity of the products, increasing the uncertainty in the business environment and leading to the appearance of methodologies such as rapid prototyping and manufacturing. Customers require suppliers to become the NPD process fastest, less costly, and the best possible quality. Thus, the suppliers of the supply chain are obliged to eliminate some stages of the development process that were considered consecrated in the traditional NPD process.

NPD has more and more embedded software and this process has become increasingly iterative. The integration of software systems in products for certain areas, such as safety and connectivity is increasingly becoming one of the most important differentiating factors for the automotive industry. Digital transformation and incorporation of technology into both products and production processes can contribute to better product performance, business results and greater consumer satisfaction. Automotive components companies are under continuous pressure to reduce costs, improve fuel efficiency, reduce emissions, optimize processes, and develop more complex products, leading to consolidation and new forms of partnerships among business players and partners. Factors such as connectivity, embedded software, and interdependency between companies in global optimized supply chains are influencing NPD in the automotive components industry. This research is an important contribution for companies, especially those that compete with mature companies and with optimized processes.

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