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Cogent Engineering (2017), 4: 1317318
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Abstract: This paper aims to propose a framework to managing the automotive product development process. The framework, named as Automotive-PDP, was developed through a bibliographical survey and through a study of three global automakers from Asia, Europe and America. In order to verify the Automotive-PDP acceptance, interviews involving 75 professionals from automakers, auto parts and automotive design companies were performed. The goal of these interviews was to verify the practice use of the framework (Automotive-PDP) in the automotive sector. The framework development is presented and the findings from interviews are showed. Afterwards, the paper is finished with the relevant conclusions.

Keywords: auto parts; automotive design companies; automotive-PDP; automotive sector; automakers; framework; product development process (PDP)

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PUBLIC INTEREST STATEMENT
The automotive product and process development is composed by activities involving many departments and people from carmakers, auto parts and design companies. This process is internal and exclusive for each carmaker. Despite the current literature bringing some approaches regarding the automotive development, usually only an introduction or some ideas are provided. In this work, we propose a complete framework to managing the automotive product development process (Automotive-PDP). This include: a reference model structured in three main parts and dozens of phases, a hundred and six activities and a functional matrix that shows the relationships between departments, people involved, technical and managerial gates that occurs during the automotive development. In order to verify the proposal acceptance, seventy-five professionals from carmakers, auto parts and automotive design companies were interviewed. A theoretical background is developed, the framework is proposed and results from interviews are presented. The author's expectation is that the framework can assist both professionals and academia to better understand this complex and challenge engineering activity.
1. Introduction
This paper aims to propose a framework for the automotive product development process, named Automotive-PDP.

Although Advanced Product Quality Planning can be considered as a reference model related to the automotive sector, its focus is on the quality strategies and control plans in different time points of the product and process development, in addition to meeting the customers’ expectation (Stamatis, 1998). Therefore, it is not a specific framework for the automotive product and process development.

Another approach about this subject can be found in the book “Automotive development processes: processes for successful customer oriented vehicle development”. It is a reference regarding to the automotive development process; however, as reported by the author “is more a personal report than a manual for the development of vehicles” (Weber, 2009). The author adds describing that “compared to other publications about development automotive, the approach followed in this book reflects more the consumers’ point of view rather than the engineers” (Weber, 2009).

Other researches in relation to different frameworks of Product development process (PDP) show that such models have generic approaches, instead of specific, about the development of the automotive product (Sharafi, Wolfenstetter, Wolf, & Krcmar, 2010).

Thus, the need for this work is based on the lack of a detailed framework for the automotive PDP. This subject is important, and the framework proposed in this work can contribute to a better understanding of such activity.

1.1. Methodology
The methodology shown in Table 1 was used in order to develop the proposed framework.

The following sections describe the theoretical background and the study of automakers’ practices. Subsequently, the framework is developed and presented. Interviews findings are presented and the paper ends with the pertinent conclusions.

| Step                                      | Goal                                                                 | Used means                                      |
|-------------------------------------------|----------------------------------------------------------------------|------------------------------------------------|
| Theoretical background development        | Check approaches presented by the authors regarding to the PDP concepts | Bibliographical and documental research          |
| Analysis of automakers' automotive-PDP    | Analyze three real models existing in global automakers, with different cultures | Bibliographical survey, field study regarding to the current practices |
| Key features for the framework development| Identify concepts, structures and activities                           | Bibliographical and documental research          |
|                                           | Identify characteristics to manage the automotive development process | Field study regarding to the current practices and personal consultations |
| Framework development (Automotive-PDP)     | Develop the Automotive PDP from the key features identified. Obtain practical contributions from professionals and experts in the automotive sector regarding to the Automotive PDP proposed, in order to detail and improve the framework | Consideration, analysis, discussion and proposal |
|                                           | Assess the practice of a set of activities proposed in the Automotive PDP in automakers, auto parts and automotive design companies | Questionnaire                                     |
| Findings                                  | Organize, present and discuss the data obtained from interviews       | Data evaluation                                  |
2. Theoretical background

PDP is a set of activities, involved in a complex network, used by a company in order to conceive, design and commercialize a product, adding value as information is created, and eliminating risks during the development process. Therefore, many of these activities are more intellectual and organizational than physical (Browning, Deyst, Eppinger, & Whitney, 2002; Jun & Suh, 2008; Ulrich & Eppinger, 2012).

Companies must strengthen its focus on innovation that more attractive products, ones that satisfy user’s requirements needs and desires, reach the marketplace earlier than competitors’ products, before new, better technology is available and before the market changes (Welo, 2011).

Interaction is a crucial characteristic of PDP. Through interactions, design problems are solved, difficulties involved are converged into solutions, and design incompatibilities are fixed (Browning et al., 2002; Cho & Eppinger, 2005; Martínez Leon, Farris, & Letens, 2013).

Management portfolio is another strategic and important aspect of PDP. Management portfolio is a dynamic process of decision-making where new projects are prioritized, existing projects can be speeded up or even cancelled, and the resources are allocated according to the needs (Cooper & Edgett, 1999; Martinsuo, 2013; Meskendahl, 2010).

In addition, PDP must be strongly market-oriented, addressing the concern about the development of a product that delivers unique advantages to the customer, along with meeting deadlines and costs that constitute value.

Quality policies must be developed in order to meet or exceed users’ expectations (Cooper, 1983; Durmuşoğlu & Barczak, 2011; Möller, 2006; Schmidt, 1997; Stamatis, 1998).

Product development is not only a design, marketing or manufacturing problem. It is a cross-functional effort, and almost all company functions participate on it. In addition, product development is not just an intra-firm activity (Majava, Haapasalo, Belt, & Mottonen, 2013).

2.1. PDP approaches

Regarding the PDP approaches Evans (1959) presented a design spiral concept. The product and process are detailed in each spiral spin until converge to detailed and final design approval. Latter, Kaminski (2000) presented a similar approach including activities related to cycle of production and consumption, reuse and recycling.

Another approach to PDP is named by Suh (2001) as axiomatic design. In this approach, the design is structured in domains. These domains include the customer’s domain, the functional domain, the physical domain and the process domain.

Despite the approaches proposed by Evans (1959), Kaminski (2000) and Suh (2001) works very well, the approach generally found in PDP literature presents macro-phases and phases, instead of a spiral concept or axiomatic concept (Asimow, 1962; Clark & Fujimoto, 1991; Clark & Wheelwright, 1993; Dieter & Schmidt, 2008; Rozenfeld et al., 2006; Ulrich & Eppinger, 2012; VDI 2221, 1993).

In this approach the PDP evolution occurs in each phase, delivering results from many tasks that support the entire forward process, until the launch production and product market.

To monitor and control the evolution of tasks during the PDP, gates are established in order to verify the deliverables. For these activities the stage gate concept are applied (Cooper, 1990).

Lean production is another very important concept, and it is presented in almost all PDP literature. Lean is beyond of production activities and its principles can be applied in whole PDP, from design to
production, passing through simple to complex activities (Holweg, 2007; Khan et al., 2013; León & Farris, 2011; Liker, Sobek, Ward, & Cristiano, 1996; Morgan & Liker, 2006; Shingo & Dillon, 1989; Vamsi, Jasti, & Kodali, 2015; Welo, 2011; Womack, Jones, & Roos, 1990).

The use of virtual and physical prototypes in the automobile's development is also required, as it reduces uncertainties and helps in the conservation of product information flow during the whole PDP (Clark & Wheelwright, 1993; Silva & Kaminski, 2016; Ulrich & Eppinger, 2012).

Under the perspective that products development is a deliberated business process, involving a large amount of decisions (Krishnan & Ulrich, 2001), it is important that the Automotive-PDP has a structure allowing the identification, through its macro-phases, of main departments and personnel in charge involved in decision-making.

Specific concepts regarding the automotive product design and automobile's development phases (press shop, body shop, painting, final assembly and final tests) can be found in Omar (2011), Weber (2009) and Hirz, Dietrich, Gfrerrer, and Lang (2013).

Main approaches used to develop the Automotive PDP are showed in Table 2.

| Main author(s) and year | Title                                                                 | PDP approaches                                          |
|------------------------|----------------------------------------------------------------------|---------------------------------------------------------|
| Evans (1959)           | Basic design concepts                                                | Design spiral                                           |
| Asimow (1962)          | Introduction to design                                               | Production and consumption cycle                        |
| Cooper (1986)          | Winning at new products                                              | Stage gate concept                                      |
| Womack et al. (1990)   | The machine that changed the world: the story of lean production     | Lean production concepts                                |
| Clark and Fujimoto (1991) | Product development performance: strategy, organization and management in the world auto industry | Development of funnel concept                           |
| Clark and Wheelwright (1993) | Managing new product and process development | Development of funnel concept                           |
| VDI 2221 (1993)        | Methodik zum Entwickeln und Konstruieren technischer Systeme und Produkte | Guidelines                                              |
| Krishnan and Ulrich (2001) | Product development decisions: a review of the literature | Perspectives (marketing, organizations, engineering design and operations management) |
| Suh (2001)             | Axiomatic design                                                     | Axiomatic design concept. Domains and subdomains       |
| Rozenfeld et al. (2006) | Gestão do processo de desenvolvimento do produto                     | General reference model and product life cycle management (PLM) |
| Dieter and Schmidt (2008) | Engineering design                                                   | Stage gate concept                                      |
| Weber (2009)           | Automotive development processes                                      | Customer oriented                                       |
| Omar (2011)            | The automotive car body manufacturing systems and processes          | Automotive manufacturing design. Detailed phases and activities |
| Ulrich and Eppinger (2012) | Product design and development                                      | Prototypes concept                                      |
| Hirz et al. (2013)     | Integrated computer-aided design in automotive development. Development processes, geometric fundamentals, methods of CAQ, knowledge-based engineering data management | Automotive product design and data management. Focus on Computer-Aided Design (CAD) |
| Silva and Kaminski (2016) | Selection of virtual and physical prototypes in the product development process | Guidelines to select virtual and physical prototypes in PDP |
3. Automakers selection

Global vehicle production was observed in order to select three examples of automotive PDP. Table 3 shows the distribution of vehicle production by continent (ANFAVEA, 2016).

In Table 3, it is possible to determine the three continents with the greatest vehicle production: Asia (50.4%), Europe (26.4%) and America (22.2%).

For the automotive sector, these three continents represent three different markets. Aiming to verify and analyze the automotive PDP in these three markets, an automaker from each continent was selected: for Asia, Toyota; for Europe, Volkswagen (VW) and for America, General Motors (GM). In order to present the three examples, a bibliographical survey, pertinent documents and interviews with heads of departments, senior engineers and experts coming from these automakers also were done. Information from the examples was classified as: product development concepts; characteristic phases, and main practiced activities. This information will also aid in the creation of the Automotive-PDP proposed in Section 4. Table 4 shows the approach used in the automotive PDP examples.

3.1. Discussion regarding automakers examples

In summary, automotive PDP starts with a strategy for the product that is intended to be developed. Following the design of the strategy comes positioning the product next to the competing products and then the creation of some alternatives for the product development. These alternatives will form the organization’s product portfolio.

Once the portfolio is established, one or more products are selected for development and a process of transformation of qualitative information (desires) into quantitative data (measurable technical information) starts. The product is then developed, as well as the means and plans required to the production.

Development structures of the theoretical framework and the three automotive PDP examples present a similar organization.

Asian configuration shows a difference in itself, i.e. in terms of subsystems and not in terms of macro-phases. However, people, tools and technology subsystems can be understood as the human and technological resources required to the process subsystem. This system presents a structure similar to the theoretical background and to the other examples of automotive PDP. In summary, both in the theoretical background and in the examples of automotive PDP, the structures are initially strategic, latter strategic and technical, and finally are technical and for operational.

Development phases of theoretical background and the three examples of PDP are the discrete elements within the macro-phases. Therefore, this set of discrete elements has specific characteristics that together should characterize the macro-phase and its purpose. The phases in the theoretical background are a summary of the presented models. However, since these are generic models of PDP, they also tend to be generic and comprehensive, in order to offer a holistic view of the process.
### Table 4. Approach for the three examples of automotive PDP

| Automaker | References                                                                 | PDP approach                                                                                                                                 |
|-----------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Asia      | Shingo and Dillon (1989), Liker et al. (1996), Amasaka (2002), Morgan and Liker (2006), Jayaram, Das, and Nicolae (2010) | Product development concept: concept development; style development; design in CAD systems; prototypes’ manufacturing; tooling construction; product launch; follow-up of the product quality Development systems: process subsystem; people subsystem and tools and technology subsystem. Interdependent and interrelated subsystems. Focus on establishing the value defined by the customer during the whole automobile’s development process. Several phases Main activities: create processes and meet objectives preserving the value defined by the customer during the whole product development process. Standardize as many activities as possible regarding its way of completion. Discuss learned lessons. Carry out daily meetings for continuous improvement of the processes, activities and documents, among other components of the product development process |
| Europe    | Silva (2008), VDA (2011), Interviews with professionals (2012), Form (2010), apud Silva (2013) | Product development concept: product planning; style concepts; model of digital data control; first virtual prototype; physical prototypes; tests and validations; preparation for serial production; pre-series of production and product launch in the market. Supply of car dealers and market review Development phases: three mains macro-phases classified as: concept development; series development and series preparation and support to production. Interdependent and interrelated macro-phases. Focus on product development from the definition of one out of two style models presented. Several phases Main activities: position the product. Create the style model and develop the virtual concept of the product. Develop the virtual concept, develop prototypes, and perform tests and validations. Develop means for the automobile’s production. Train collaborators. Perform final tests, process adjustments and start the pilot production. Launch the automobile in the market. Collect market information for future programs |
| America   | Guiguer Filho (2005), Interviews with professionals (2012), Teske (2016), Donndelinger (2016) | Product development concept: global product development; product planning; program classification; preparation of strategic planning; decision of strategic planning; style development; product and process development; tests and validations of the product and the process; automobiles from pilot production and start of the automobile’s production Development phases: three mains macro-phases classified as: development of product portfolio plan; automobile’s advanced development and global process of automobile development. Interdependent and interrelated macro-phases. Focused on the product development to the definition of one out of three to nine style models presented. Several phases Main activities: define the products portfolio, study the market and competitors. Validate the program to be developed. Develop the automobile’s style. Approve the style and develop the product. Develop the manufacturing process. Test and validate the product and the process. Start the pilot production. Launch the product in the market |

4. Framework proposal: Automotive PDP

Table 5 shows the key features, main references and approaches used in the framework development.

Figure 1 shows the framework representation. The three macro-phases (product strategy, product and process development and production and continuous improvement) are represented in the upper part of the figure. Phases are represented below the macro-phases and are progressively depicted. Outer arrows represent the interaction among the macro-phases.
Table 5. Key features references and approaches used in the framework development

| Key features          | References                                                                 | Approach                                                                 | Framework (automotive PDP)                                                                 |
|-----------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Concept               | Evans (1959), Clark and Fujimoto (1991), VDI 2221 (1993), Krishnan and Ulrich (2001), Rozenfeld et al. (2006) | Sequential and interactive processes                                       | Mnemonic representation (Figure 1): the outer arrows represent the macro-phases interactions. The inner arrows represent the phases and activities interactions |
| Structure             | Womack et al. (1990), VDI 2221 (1993), Liker et al. (1996), Rozenfeld et al. (2006), Morgan and Liker (2006), Guiguer Filho (2005), Weber (2009), Omar (2011), Interviews with professionals (2012), Hirz et al. (2013), Form (2010) apud Silva (2013), Silva and Kaminski (2016) | Macro-phases and phases                                                   | Three macro-phases: (1) product strategy; (2) product and process development; (3) production and continuous improvement |
| Activities            | VDI 2221 (1993), Liker et al. (1996), Guiguer Filho (2005), Morgan and Liker (2006), Weber (2009), Omar (2011), Interviews with professionals (2012), Hirz et al. (2013), Form (2010) apud Silva (2013) | Strategic, technical and managerial activities                           | Strategic, technical and managerial activities                                              |
| Management characteristics | Cooper (1986), Dieter and Schmidt (2008)                              | Technical gates                                                           | Five managerial gates and eighteen technical gates                                        |
|                       |                                                                          | Managerial gates                                                          | 6 gates for the product strategy                                                          |

![Figure 1. Automotive-PDP framework.](image)

Caption:
- Market study (MS)
- Product positioning (PP)
- Market monitoring (MM)
- Product launch (PL)
- Concept development (CD)
- Concept design (SD)
- Planning and preparation of the production system (PP)
- Marketing and sales (MD)
- Modules development (MD)
- Tests and final validation (TF)
- Process technology and automation (TA)
- Process technology and automation (PR)
- Process technology and automation (S)
- Process technology and automation (P)
- Process technology and automation (T)
- Process technology and automation (R)
- Technical review (TR)
Inner arrows represent the interaction among the phases and the convergence to the set of alternatives found. Management gates (Roman numerals) and technical gates (Arabic numerals) are represented in the lower line and are increasingly numbered. Management gates occur in determined time points of the process of macro-phases and or phases. Technical gates occur in different time points of the Automotive-PDP.

In the macro-phase of product strategy, the technical gates occur in the end of the phases. In the macro-phase of product and process development, the technical gates occur both in the end of the phases and in the beginning of them. This variation occurs mainly in phases close to the macro-phase of production and continuous improvement. In the macro-phase of production and continuous improvement, the technical gates occur, mainly, in the beginning of the phases. A generic scale is depicted in the lower line representing the management and technical gates, indicating weeks, months and years.

The macro-phase of product strategy is characterized by the start of the automobile development and consists of the following phases: market study (MS); product positioning (PP), market monitoring (MM) and product launch (PL).

In the macro-phase of product and process development there is the development of the product and means required for its production. Product development occurs in parallel to the process development. The phases of product development are: concept development (CD); style development (SD); modules development (MD); tests and final validation (TV). Phases of process development are: process concept (PC); infrastructure (IE); planning and preparation of the production (PP); concept of the production system (PS); process technology and automation (TA); tests of the facilities (TF); logistics concept (LC); dimensioning and allocation of resources (DR); pre-series production (PS) and start of serial production (SP).

In the macro-phase of production and continuous improvement there is the follow-up of the production and the identification of possible improvements in the product and in the manufacturing process. Monitoring of the product quality occurs through quality indicators. Phases of this macro-phase are: process stability (ST); series stability (SS); cycle time reduction (CR); redimensioning and allocation of resources (RR); series discontinuation (SD) and technical review (TR).

When the development process of a new automobile is started, the guide report for new products is reviewed concomitantly to the phase of market study (MS). This new information set will provide the initial support to the people involved in the development of the new automobile.

The activities in the macro-phases of product strategy, product and process development, and production and continuous improvement are shown in Tables A1, A2 and A3 of the Appendix 1. Decisions that occur in the technical and management gates are demonstrated in Table A4 of the Appendix 1.

5. Interviews
Interviews were performed to verify the acceptability and practical use of the Automotive-PDP. The interviews were structured as: definition and elaboration of the data collection instrument; samples selection; data collection; organization of data collected and presentation and discussion of the results.
5.1. Data collection

The data collection was done personally and directly with the responders involved. The instrument used for the data collection was a questionnaire. Activities described in the questionnaire were obtained from Automotive-PDP's activities in Tables A1, A2 and A3 of the Appendix 1. The questionnaire was structured in sections, according to the macro-phases, phases and activities of the Automotive PDP. For each one of Automotive-PDP's activities two questions (Q1) and (Q2) were made.

Question (Q1) consisted of identifying the practice of the activity in the company where the responder worked. Question (Q1) was: “Is it your company’s practice?”. The responder had to choose as answer only one out of three possible alternatives: “Yes”, “No” or “Unknown”.

Question (Q2) consisted in evaluate, according to the responder’s opinion, the importance of the activity. Question (Q2) was: “How important is the activity?”, considering its cost/benefit. The responder had to choose as answer only one out of five possible alternatives: “1”, “2”, “3”, “4” and “5”. The alternatives were based on a Likert scale. For grades between 1 and 2, the responder considered the importance of the activity practiced as slightly important. For grade 3, as neutral importance, and for grades between and 5, as very important.

To the Automotive PDP can be considered acceptable, the authors have determined that the percentage averages of “yes” answers from the question (Q1) was equal to or greater than 60%.

For the question (Q2), the weighted global average of “Yes” answers (WY) was equal to or greater than 3.5 on a Likert scale.

In order to identify the lack of possible non-contained activities in the Automotive-PDP, complementary questions were inserted into the end of each section (macro-phase). The complementary question was: “Have you identified the lack of any activity in the macro-phase?”. At the end of each section of the questionnaire a field was available, for the responder to describe in his/her own words the activity he/she suggested.

5.2. Responders selection and data collection

Heads of departments, senior engineers and experts working in automakers, auto parts, automotive design, and other correlated companies constituted the responders selected. There were men and women, i.e. gender difference had no relevance for the interview. Age of the responders was also not considered. From this definition, a total of 75 responders were interviewed. Table 6 shows the data collection, according to the respondent’s subgroup.

| Subgroups  | Qty |
|------------|-----|
| Automakers | 36  |
| Auto parts | 29  |
| Design     | 5   |
| Others     | 5   |
6. Evaluation criteria

Identifying the valid questionnaires was required in order to organize the data. Two criterias for identification of non-valid questionnaires were established: large part of the questionnaire with no answers (more than 30% of the answers), and responders not belonging to the determined subgroup. After setting the criteria, the questionnaires evaluation was performed. From a total of 75 questionnaires, 59 questionnaires were considered valid for the research. The total of the answers were then grouped, according to the alternatives from questions (Q1) and (Q2) chosen by the responders.

In the examples 1 and 2 are described the concept for the grouping and the answers distribution for the questions (Q1) and (Q2) respectively.

Example 1: for the activity (Ia) contained in phase 1 (market study), the 59 answers were grouped and distributed between the alternatives of the question 1 (Q1) “Yes”, “No” and “Unknown”. The results were: 56 answers for the alternative “Yes”, zero answers for the alternative “No”, and 3 answers for the alternative “Unknown”. For this example, there were no Blank answers.

Example 2: for the activity (Ia) contained in phase 1 (market study), the 59 answers were grouped and distributed between the alternatives of the question 2 (Q2) “1”, “2”, “3”, “4” and “5”. The results were: zero answers for the alternative “3”, 12 answers for the alternative “4”, and 47 answers for the alternative “5”. For this example, there were no Blank answers.

Table 7 shows a global view for the organization and distribution of the answers according to examples 1 and 2, for the activity (Ia) contained in phase 1: market study.

In the distribution showed in Table 7, only the total of answers between the alternatives for questions (Q1) and (Q2) are visualized. This distribution does not allow identifying, for a specific alternative from Q1, which was the option chosen by the responders, from the alternatives chosen for Q2.

Based on this situation, a new grouping was done. In this new grouping the grade chosen by the responders was considered, according to the alternatives chosen. In example 3 the concepts of this new grouping and the distribution of the answers for Q1 and Q2 are described.

Example 3: for the activity (Ia) contained in phase 1 (market study), from a total of 56 answers “Yes”, 10 answers had grade “4”, an 46 answers had grade “5”. For the activity (Ia) the was no answers “No”. For the answers “Unknown”, from a total of 3 answers, 2 answers had grade “4” and one answer had grade “5”. For example 3 there were no Blank answers.

Table 7. Global results for examples 1 and 2

| nº | A | Macro-phase of product strategy | Is it your company’s practice? | How important is the activity? |
|----|---|---------------------------------|-------------------------------|------------------------------|
|    |   |                                  | Means                        | Means                        |
|    |   |                                 | Y    | N    | UN   | B    | 1    | 2    | 3    | 4    | 5    | B    |
| 3  | Ia| Check the behavior of the trens for automobile sales market in the next months and years | 56   | 0    | 3    | 0    | 0    | 0    | 0    | 12   | 47   | 0    |
Table 8 shows the answers distribution according to example 3.

Therefore, to the question (Q1), the results obtained for each alternative were converted to percentages (%). To the question (Q2), the results obtained for each alternative were organized and distributed into weighted averages.

Equation (1) shows the calculation for weighted averages.

\[
W = \frac{\sum_{i=1}^{5} q_i \times n_i}{\sum_{i=1}^{5} q_i}
\]  

(1)

W is the weighted average of the grades, \(q_i\) is the number of questionnaires for a determined grade \(n_i\), and \(n_i\) is the grades selected by the responders, with \(i\) from 1 up to 5.

Table 9 shows an example of the results distribution, according to the percentages and weighted averages, for phase 1 activity (Ia): market study (MS).

In order to obtain a global view of the results from the whole Automotive-PDP, weighted averages of activities belonging to a determined phase of the model were added, and an average was calculated, providing a global view of the means for each phase of the model.

Same procedure was adopted for the results obtained with the phases of a determined macro-phase, thus providing a global view of the means for each macro-phase of the model. Finally, the procedure described was also applied to the macro-phases of the model, providing a global view of the means for the whole Automotive-PDP.

| n° | A | Phase 1: market study | Yes | No | Unknown | Blank |
|----|---|-----------------------|-----|----|---------|-------|
| 3  | Ia| Check the behavior of the trends for automobile sales market in the next months and years | 0   | 0  | 10  | 46  |
|    |   |                       | 0   | 0  | 0    | 0    |
|    |   |                       | 0   | 0  | 0    | 0    |
|    |   |                       | 0   | 0  | 0    | 0    |
|    |   |                       | 0   | 0  | 0    | 0    |

Table 9. Distribution of percentages and W of the results for phase 1 activity: market study (MS)

| n° | A | Macro-phase of product strategy | Is it your company’s practice? | How important is the activity? |
|----|---|--------------------------------|-------------------------------|--------------------------------|
|    |   |                                 | Percentage                    | Means                          |
|    |   |                                 | Y (%) | N (%) | UN (%) | B (%) | WG | WY | WN | WUN | WB |
| 3  | Ia| Check the behavior of the trends for automobile sales market in the next months and years | 95   | 0    | 5     | 0    | 4.8 | 4.8 | 0.0 | 4.3 | 0.0 |

Notes: W: Weighted average of the grades; G: global; Y: Yes; N: No; UN: Unknown; B: Blank.
6.1. Findings

Results are presented and discussed in a sequence starting with global results for the whole Automotive-PDP, then, with results from the macro-phases and at last from the phases of the framework.

From the analysis of results from Table 10, it can be concluded that from a total of 100% of the valid responders, 76% confirmed that, in their companies, there is the practice of a large part of the activities contained in the Automotive-PDP, and they consider the practice of these activities as important or very important.

For the 24% who answered there is no practice or unknown whether the practice of the activities occurs or not in their companies, global grades were neutral (3.0), trending to important, since the grades are between 3.3 and 3.5.

Table 11 shows the global results for the macro-phases and for the technical and management gates of Automotive-PDP.

Table 11 showed that the results obtained with the macro-phases confirmed, with averages greater than 70%, the practice of the activities in the companies contained in the subgroups automaker, auto parts and design.

About the technical and management gates, results showed little variation between them. The variation was 1% for “Yes”, 3% for “No”, and 4% for “Unknown”. The greatest results were attributed to the management gates.

| Table 10. Global results obtained for automotive-PDP |
|----------------------------------------------------|
| **Is it your company’s practice?**                  |
| **How important is the activity?**                  |
| Percentage                                         |
| Y (%)   | N (%)   | UN (%)  | B (%)  |
| W      | G      | Y       | N       | UN      | B       |
| Global means of the model                          |
| 76      | 10     | 14      | 0       |

| Table 11. Global results for the macro-phases and technical and management gates of Automotive-PDP |
|----------------------------------------------------|
| **Macro-phases**                                   |
| **Is it your company’s practice?**                 |
| **How important is the activity?**                 |
| Percentage                                         |
| **Y (%)**  | **N (%)**  | **UN (%)**  | **B (%)**  |
| **WG** | **WY** | **WN** | **WUN** | **WB** |
| Product strategy                                   |
| 84      | 7       | 9        | 0        |
| 4.4    | 4.5     | 2.4      | 3.7      | 0.3    |
| Macro-phase of product and process development     |
| 81      | 7       | 11       | 1        |
| 4.4    | 4.5     | 3.3      | 3.4      | 0.1    |
| Macro-phase of production and continuous improve-  |
|   ment                                           |
| 72      | 9       | 19       | 0        |
| 4.3    | 4.4     | 3.6      | 4.1      | 0.3    |
| Technical gates (TG)                              |
| 70      | 12      | 18       | 0        |
| 4.1    | 4.3     | 3.4      | 3.3      | 0.0    |
| Management gates (MG)                             |
| 71      | 15      | 14       | 0        |
| 4.2    | 4.4     | 3.9      | 3.2      | 0.0    |

Notes: W: Weighted average of the grades; G: global; Y: Yes; N: No; UN: Unknown; B: Blank.
Phases of macro-phase of product strategy were used as example of the results obtained for all the phases contained in the macro-phases of Automotive-PDP. Table 12 shows the results for this macro-phase.

The phase of MS presented the largest result for “Yes” answers (94%), compared to the other results obtained for the whole model.

For “Unknown” answers, this phase obtained a global average of the grades equal to 4.4. The phase of market monitoring (MM) obtained a percentage equal to 17% for “Unknown” answers, this being the largest value between “Unknown” answers, compared to the other phases of macro-phase of product strategy. All results obtained for “Yes” answers of this macro-phase obtained percentages greater than 70%. Analogously, all global averages of the grades obtained were greater than 4.0. Therefore, this macro-phase obtained significant results for both questions (Q1) and (Q2), i.e.: the occurrence of the practice of a large part of the activities contained in the phases, and the importance of the practice of these activities in the companies of the subgroups researched.

Following the analysis of all answers obtained in the field research, it was observed that only one (1) of the activities receiving “Yes” answers obtained a grade lower than 4.0. It was the activity (XVIId), number 74, with grade equal to 3.5.

By observing the general averages of each activity, only six activities were identified as having general grades lower than 4.0. Table 13 shows the activities identified.

| Macro-phase of product strategy | Is it your company’s practice? | How important is the activity? | Percentage | Means |
|---------------------------------|------------------------------|-------------------------------|-----------|-------|
|                                 | Percentage                   |                               |           |       |
|                                 | Y (%) | N (%) | UN (%) | B (%) | WG | WY | WN | WUN | WB |
| Market study (MS)               | 94    | 2     | 4      | 0     | 4.6 | 4.7 | 1.0 | 4.4  | 0.0 |
| Product positioning (PP)        | 89    | 2     | 8      | 1     | 4.4 | 4.4 | 1.7 | 3.6  | 1.3 |
| Market monitoring (MM)          | 75    | 8     | 17     | 0     | 4.3 | 4.4 | 3.4 | 4.1  | 0.0 |
| Product launch (PL)             | 76    | 16    | 8      | 0     | 4.2 | 4.4 | 3.6 | 2.7  | 0.0 |

Notes: W: Weighted average of the grades; G: global; Y: Yes; N: No; UN: Unknown; B: Blank.

Table 13. Activities with general averages lower than 4.0

| nº   | A        | Macro-phase of product strategy                                      | Is it your company’s practice? | How important is the activity? | Summary | Means |
|------|----------|---------------------------------------------------------------------|------------------------------|-------------------------------|---------|-------|
|      |          |                                                                    |                             |                               |         |       |
| 11   | IVa      | Distribute the product in car dealers to be commercialized before the launch | 22                           | 27                            | 10      | 0     | 3.4   | 4.4  | 2.4  | 3.0  | 0.0  |
| 47   | XIIa     | Perform/execute the simulation of facilities and machines in the workstations using improvised materials, or using other resources available in the company | 26                           | 16                            | 16      | 1     | 3.7   | 4.0  | 3.4  | 3.2  | 0.0  |
| 74   | XVIId    | Plan and dimension the workmanship required to protect the company’s assets | 34                           | 9                             | 16      | 0     | 3.5   | 3.5  | 2.9  | 4.1  | 0.0  |
| 77   | XVIIg    | Plan and train all workmanship not directly involved with the automobile manufacturing process | 31                           | 14                            | 13      | 1     | 3.8   | 4.0  | 3.3  | 3.8  | 5.0  |
| 104  | XXVIIIb  | Freeze and do not change the results determined in technical decisions | 35                           | 11                            | 13      | 0     | 3.8   | 4.1  | 2.8  | 3.4  | 0.0  |
| 106  | XXIXb    | Freeze and do not change the results determined in strategic decisions | 33                           | 15                            | 11      | 0     | 3.9   | 4.2  | 3.4  | 3.3  | 0.0  |

Notes: W: Weighted average of the grades; G: global; Y: Yes; N: No; UN: Unknown; B: Blank.
The italic values indicates the general grades lower than 4.0.
6.1.1. Complementary activities
For the complementary questions of the questionnaire, the responders suggested some activities, also supplementing them with its practice or non-practice, as the importance in practicing or not practicing. Using the analysis of the suggested complementary activity and the identification of its correlation with the activity (ies) of the questionnaire, an analysis of the complementary activities, with no correlation with any activity proposed in the Automotive-PDP, was performed.

The process was repeated for the other complementary activities suggested by the responders for the macro-phases of product and process development and production and continuous improvement. Complementary activities identified as valid for incorporation were inserted in the Automotive-PDP and are identified in Tables A1 and A2 of the Appendix 1 with the symbol (*).

Except the activity (XVIIId), the other activities of this group had global averages for “Yes” answers equal or greater than 4.0.

7. Conclusions
Developing serial products in a structured and concurrent form among automakers, auto parts and automotive design companies is a great challenge.

In this work, we propose a complete framework to managing the automotive product development process (Automotive PDP). The main advantage of this framework is to access a generic automotive reference model that contains a complete set to manage this process. This include: a reference model structured in three main parts and dozens of phases, a hundred of activities and a functional matrix that shows the relationships between departments, people involved, technical and managerial gates that occurs during the automotive development.

The expected results are: a larger interaction among the professionals involved, work standardization, reduction time in function of a defined and known development system, and therefore reduction wastes. A consequent reduction in costs and investments by the organizations can also be expected. In this context, the proposed Automotive-PDP can contribute to the automotive sector.

For the automotive PDP acceptance, global averages of the model showed that 76% of responders replied “Yes” for the practice of the activities suggested in the Automotive-PDP, and only 10% answered “No” practice.

The other 14% replied “Unknown”, i.e. took no position in certain answers. Except the six activities identified and shown in Table 10, all remaining activities of the proposed model obtained general averages of the grades equal or greater than 4.0. i.e. the activities were considered as important or very important by the responders.

Not restricted to the activities proposed in the model, a survey was performed during the research, where the responders were able to suggest complementary activities to the model. These activities were analyzed and incorporated, according to criteria demonstrated during the presentation and discussion of the results.

Based on the global and specific results it can be concluded that the proposed Automotive-PDP presents a significant acceptance with the practices performed in the automakers, auto parts, and automotive design companies. Therefore, it demonstrates its importance for the sector. In addition, it can be concluded that the proposed model also presents a significant compliance to the theoretical background, and the three examples of automotive PDP shown, since the framework proposed was also grounded on them.
Automotive-PDP is expected to be used, among other applications, as a guide for professionals in the automotive sector and for researchers, in the development and helping in the activities pertinent to the automotive products development process.

For future researches is recommended to evaluate the use of the Automotive-PDP considering the next industrial revolution scenario (Industry 4.0). This can start new researches and bring updates to include in the framework, such as: Cyber-Physical Systems (CPS), Internet of Things (IoT), Vertical and Horizontal integrations and Big Data analysis and evaluation.

Funding
The researchers thank CNPq (National Council for Scientific and Technological Development) for the financial support [grant number 141913/2010-0].

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Citation information
Cite this article as: Proposal of framework to managing the automotive product development process, Guilherme Canuto da Silva & Paulo Carlos Kaminski, Cogent Engineering (2017), 4: 1317318.

Cover image
Source: Authors.

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Appendix 1

Table A1

| nº  | A  | Macro-phase of product strategy (main activities)                                                                                       |
|-----|-----|----------------------------------------------------------------------------------------------------------------------------------|
| 3   | Ia  | Check the behavior of the trends for automobile sales market in the next months and years                                         |
| 4   | Ib  | Analyze and investigate the products from competing companies in the market                                                        |
| 5   | Ic  | Perform survey of the clients’ satisfaction                                                                                         |
| 6   | IIa | Clearly define the type of product to be developed by the company, before the start of product development                          |
| 7   | IIb | Characterize the type of product to be developed by the company as a competitor compared to the other products investigated in the market |
|     |     | Estimate costs (*)                                                                                                                 |
|     |     | Determine total costs for the development of the vehicle and manufacturing processes (*)                                              |
| 8   | IIc | Positionate the product in a determined market segment, group of products or line of existing products                             |
| 9   | IIIa| Follow up the changes that might happen in the market during the development of the new product                                   |
|     |     | Perform researches and allow appraisers (potential purchasers) to drive vehicles from the same segment (‘)                           |
|     |     | Perform tests for client’s perception (‘)                                                                                           |
| 10  | IIIb| Identify changes in the clients’ preference and change/modify the design of product under development in the company in order to meet the clients’ expectations |
|     |     | Define strategies to expedite the launch of the vehicle (‘)                                                                             |
| 11  | IVa | Distribute the product in car dealers to be commercialized before the launch                                                        |
| 12  | IVb | Monitor clients’ satisfaction after the purchase of the new product                                                                  |
| 13  | IVc | Transform the information from the purchasing market into new requirements for adequation of the product being manufactured         |
| 14  | IVd | Transform the information from the purchasing market into new requirements for the development of future products                  |

Notes: nº: number; A: activity; (‘): complementary activities.

Table A2

| nº  | A  | Macro-phase of product and process development (main activities)                                                                    |
|-----|-----|----------------------------------------------------------------------------------------------------------------------------------|
| 15  | VIa | Obtain engineering requirements from the clients’ desires                                                                          |
| 16  | VIb | Obtain engineering requirements from the company’s goal                                                                           |
| 17  | VIc | Transform the qualitative information, obtained from the clients, in quantitative engineering information                           |
| 18  | VId | Use new technologies in the new product design                                                                                    |
| 19  | Vie | Develop new technologies for the new product                                                                                    |
| 20  | VIa | Design the external shape of the automobile                                                                                       |
| 21  | VIb | Design the internal area of the automobile                                                                                        |
| 22  | VIc | Virtually design the parts/components of the automobile                                                                             |
| 23  | VIIa| Virtually design and simulate the chassis of the automobile                                                                         |
| 24  | VIIb| Virtually design and simulate the platform of the automobile                                                                        |
| 25  | VIIc| Virtually design and simulate the body of the automobile                                                                           |
| 26  | VIId| Virtually design and simulate the internal finishing of the automobile                                                           |
| 27  | VIIe| Virtually design and simulate the external finishing of the automobile                                                           |
| 28  | VIIf| Virtually design and simulate the engine of the automobile                                                                          |
| 29  | VIIg| Virtually design and simulate the on-board electronics of the automobile                                                          |
| 30  | VIIh| Create virtual prototypes of the parts/components of the automobile                                                               |

Notes: nº: number; A: activity; (‘): complementary activities.
| n° | A   | Macro-phase of product and process development (main activities)                                                                 |
|----|-----|-----------------------------------------------------------------------------------------------------------------------------|
| 31 | VIIIi | Build physical prototypes of the parts/components of the automobile                                                        |
| 32 | IXa  | Test the parts/components of the automobile, in its final development status                                                 |
| 33 | IXb  | Validate the parts/components of the automobile, in its final development status                                              |
| 34 | IXc  | Characterize the end of the automobile design development, by a framework in the development process                         |
|    |     | Certificate the product (vehicle) with the authorities (*)                                                                 |
| 35 | Xa   | Design the automobile manufacturing processes concomitantly to the automobile design development                               |
| 36 | Xb   | Design and dimension machines and equipments, including robots, for stamping sheet parts of the automobile                    |
| 37 | Xc   | Design and dimension machines and equipments, including robots, for manufacturing the body of the automobile                  |
| 38 | Xd   | Design and dimension machines and equipments, including robots, for painting the body of the automobile                        |
| 39 | Xe   | Design and dimension machines and equipments, including robots, for the final assembly of the automobile                      |
| 40 | Xf   | Design and dimension process areas, including the creation of layouts, for manufacturing processes of the automobile         |
| 41 | Xg   | Design and dimension the resources required for the maintenance of machines and equipments for manufacturing the automobile  |
|    |     | Calculate and determine the consumption of non-productive materials (*)                                                   |
| 42 | Xla  | Plan and implement/adequate the civil infrastructure of the company                                                        |
| 43 | Xlb  | Plan and implement/adequate the electrical infrastructure of the company                                                   |
| 44 | Xlc  | Plan and implement/adequate the mechanical infrastructure of the company                                                   |
| 45 | Xld  | Plan and implement environmental policies specific for each manufacturing process                                           |
| 46 | Xle  | Plan and implement global environmental policies in the company                                                             |
| 47 | XIIa | Perform/execute the simulation of facilities and machines in the workstations using improvised materials, or using other resources available in the company |
| 48 | XIIb | Perform/execute a physical idealization of the workstations, to simulate the production operations                          |
| 49 | XIIc | Physically check the workstations, even before completing the facilities, to check future working conditions for the operators |
| 50 | XIIId| Perform a physical check, before the final installation, of machines and equipments for manufacturing processes, to assure that the design of the workstation meets the needs of the operators |
| 51 | XIIla| Develop the principles required for the conduction of manufacturing activities of the automobile                             |
| 52 | XIIlb| Develop procedures to determine and standardize the methods and ways of performing the activities of producing the automobile |
| 53 | XIIlc| Develop and determine the systems of control and visual management of the manufacturing areas                                |
| 54 | XIIId| Determine and establish countermeasures to identify and track defects that might be generated during the production of the automobile |
| 55 | XIVa | Consolidate the concepts established for the manufacturing processes of the automobile                                     |
| 56 | XIVb | Virtually simulate the manufacturing processes of the automobile                                                          |
| 57 | XIVc | Physically simulate the manufacturing processes of the automobile                                                        |
| 58 | XIVd | Finish the physical facilities required to manufacture the automobile                                                   |
| 59 | XIVe | Automate the manufacturing processes of the automobile                                                                    |
| 60 | Xva  | Test the equipments and other means to produce the automobile                                                            |
| 61 | Xvb  | Produce small batches of subsets of the automobile, to test the manual manufacturing stations                               |

(Continued)
n° | A | Macro-phase of product and process development (main activities)
---|---|---
62 | XVc | Produce small batches of subsets of the automobile, to test the automatic manufacturing stations
63 | XvId | Produce complete automobiles, to test the manufacturing processes of the automobile
64 | XvIe | Train operators during the tests of the manufacturing processes of the automobile
65 | XvIf | Predetermine the indicators and goals, during the test of the manufacturing processes of the automobile
66 | XvIg | Characterize the end of tests in the manufacture processes of the automobile, by using a framework in the development process
67 | XVIa | Determine the systems of receipt, storage and distribution of the materials in the company
68 | XVIb | Determine the amount of workmanship required for the systems of receipt, storage and distribution of the materials in the company
69 | XVIc | Dimension areas for: materials movements, produced automobiles and remaining inputs required to manufacture the automobile
70 | XVIId | Determine the development of a parts supplier park
71 | XVIId | Calculate and determine the amount of workmanship required to perform the operations of manufacturing the automobile
72 | XVIId | Calculate and determine the amount of workmanship required to perform the maintenance operations of the equipments and facilities for manufacturing processes of the automobile
73 | XVIId | Calculate and determine the amount of workmanship required to perform the operations of monitoring the product quality
74 | XVIId | Plan and dimension the workmanship required to protect the company’s assets
75 | XVIId | Plan and dimension the workmanship required to the company’s fire brigade
76 | XVIId | Plan and train all the workmanship involved with the manufacturing process of the automobile
77 | XVIId | Plan and train all the workmanship not directly involved with the manufacturing process of the automobile
78 | XVIIIa | Produce a small batch of automobiles for final validation of the facilities of the manufacturing processes of the automobile
79 | XIXa | Characterize the start of the serial production of automobiles, by using a framework in the development process
80 | XIXb | Program a gradual increase in the amounts of automobiles to be produced

Notes: n°: number; A: activity; (*): complementary activities.

Table A3 (Continued)

n° | A | Macro-phase of production and continuous improvement (main activities)
---|---|---
81 | XXIa | Check the stability of manufacturing processes
82 | XXIb | Compare the design requirements to the automobiles being produced
83 | XXIc | Identify opportunities of optimization and communication of manual operations of the manufacturing processes of the automobile
84 | XXId | Identify opportunities of optimization and communication of automatic operations of the manufacturing processes of the automobile
85 | XXIe | Determine a maintenance plan for the machines and other equipments used for manufacturing automobiles
86 | XXIIa | Prove the dimensional repeatability of the automobile according to tolerances determined in the product design
87 | XXIIb | Check the dimensional repeatability of the product
88 | XXIIIa | Identify restrictions (bottlenecks) in the automatic manufacturing processes
89 | XXIIIb | Propose and implement improvements to optimize the manufacturing automatic processes
90 | XXIVa | Check the practice/skill developed by the operators after the start of serial production
91 | XXIVb | Optimize the available workmanship in function of the operators’ skill

(Continued)
### Table A3 (Continued)

| n°  | A   | Macro-phase of production and continuous improvement (main activities)                                                                 |
|-----|-----|-------------------------------------------------------------------------------------------------------------------------------------|
| 92  | XXIVc | Communize activities originally performed in different workstations                                                               |
| 93  | XXVa | Characterize the serial production of automobiles, by using a framework in the development process                                  |
| 94  | XXVb | Authorize the serial production (mass production) of automobiles                                                                   |
| 95  | XXVc | Produce automobiles according to the variations of increase or fall in the sales in the market                                      |
| 96  | XXVIa| Discontinue the serial production of automobiles                                                                                |
| 97  | XXVIb| Determine the time required to end the serial production of automobiles                                                           |
| 98  | XXVIIa| Consolidate the information generated during the period of production of the automobile                                            |
| 99  | XXVIIb| Perform practices as learned lessons, based on information generated during the period of production of the automobile             |
| 100 | XXVIIc| Evaluate facilities and machines of the manufacturing processes, to identify the need or not for purchase/adequation of the facilities, for manufacturing new automobile models |
| 101 | XXVIIId| Collect information with the operators working directly in the manufacture of the automobile, for guidance to future processes of products development |
| 102 | XXVIIe| Create a documentation from the information obtained during the period of production of the automobile                              |
| 103 | XXVIIIa| Make technical decisions at known and pre-determined time points, during the process of products development in the company where you work |
| 104 | XXVIIIb| Freeze and do not change the results determined in technical decisions                                                            |
| 105 | XXIXa | Make strategic decisions at known and pre-determined time points, during the process of products development in the company where you work |
| 106 | XXIXb | Freeze and do not change the results determined in strategic decisions                                                            |

Notes: n°: number; A: activity.
| Macro-phase | Gates | Departments | Involved | Main decisions |
|-------------|-------|-------------|----------|----------------|
| Product strategy | | | | |
| I | X | X X X X X X X X | X | X X |
| 1 | X | X X X X X X X | | Development of a new automobile |
| II | X X X X X X X X | X | X |
| III | X X X X X X X X | X | X |
| Product and process development | | | | |
| 4 | X X | X X X X X X X X X | | Approval of the concept of production system. Release of workmanship and financial resources |
| 5 | X X X X X X X | | Approval of chassis, platform, car body, internal and external finishing, engine and on-board electronics modules |
| 6 | | X X X X X X X X | | Approval of process concept. Approval of logistics concept. Release of workmanship and financial resources |

(Continued)
| Macro-phase | Gates | Departments | Involved | Main decisions |
|-------------|-------|-------------|----------|----------------|
| MG TG FN HR MS PE EE CE PE BE FE TV PT IE RD LG EP PS BS PA FA PR VP DR FM SP EN AN SL TC OP |
| 7 | X X X X X X X X | X X X X X X | ● X X X X | End of tests and validations of the product |
| 8 | X X X X X X X X | X X X X X X | ● X X X | Approval of dimensioning of the workmanship required for production and maintenance of subprocesses |
| 9 | X X X X X X X X | X X X X X X | ● X X X X | Approval of process layout. Approval of results from simulations of the subprocesses |
| 10 | X X | X X | ● X X | End of civil, electrical, mechanical and environmental infrastructures |
| 11 | X X X X X X X X X | X X | ● X X | Start of pre-series of the automobile |
| 12 | X X X X X X X X | X X | ● X X | Approval of the process facilities. Definition of indicators of the process and quality for the automobile |
| 13 | X X X X X X X X | X X | ● X X | Start of serial production of the automobile |
| IV | X | X X X X X X | ● X X | Launch the product in the market |
| 14 | X X X X X | X | ● X X | Confirmation of process stability |

(Continued)
### Table A4 (Continued)

**Characteristics of the management and technical frameworks in the process of automotive products development**

| Macro-phase | Gates | Departments | Involved | Main decisions |
|-------------|-------|-------------|----------|----------------|
| **Production and continuous improvement** | MG | | | |
| | TG | | | |
| | FN | | | |
| | HR | | | |
| | MS | | | |
| | PE | | | |
| | EE | | | |
| | CE | | | |
| | PE | | | |
| | BE | | | |
| | FE | | | |
| | TV | | | |
| | PT | | | |
| | IE | | | |
| | RD | | | |
| | LG | | | |
| | EP | | | |
| | PS | | | |
| | BS | | | |
| | PA | | | |
| | FA | | | |
| | PR | | | |
| | VP | | | |
| | DR | | | |
| | FM | | | |
| | SP | | | |
| | EN | | | |
| | AN | | | |
| | SL | | | |
| | TC | | | |
| | OP | | | |
| 15 | X | X | X | X | X | ● | X | X | X | X | Confirmation of series stability |
| 16 | X | X | X | X | X | X | ● | X | X | X | X | Start of reduction of cycle times in automatic and manual workstations |
| 17 | X | X | X | X | X | X | ● | X | X | X | X | Redimensioning the equipments and workmanship of the production |
| V | X | X | X | X | X | X | ● | X | X | X | X | Discontinuation of the series and retirement planning of the product from the market |
| 18 | X | X | X | X | X | X | X | X | X | X | X | Technical review of the product, process and production. Elaboration of the guide report for future products |

**Notes:** MG: management gates; TG: technical gates; PR: president; VP: vice-president; DR: directors; FM: functional manager; SP: supervisors; EN: engineers; AN: analysts; SL: sector leaders; TC: technicians; OP: operators; FN: finances; HR: human resources; MS: market and sales analysis; PE: powertrain engineering; EE: electrical engineering; CE: chassis engineering; PE: platform engineering; BE: body shop engineering; FE: finishing engineering; TV: tests and validations; PT: process technology; IE: infrastructure; RD: resources dimensioning; LG: logistics; EP: environmental processes; PS: press shop; BS: body shop; PA: paint shop; FA: final assembly; X: participation; ●: in charge of the decision.
