

# A preliminary proposal to improve the product development process at an engine manufacturing company

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**Abstract:** This paper presents the initial phase of a proposal for improving the product development process of a diesel engines manufacturer. The method used to collect data is field research, where the object of analysis is the product development process of the company under study. The first phase of the research is a diagnosis performed at the company. It consists of a diagnostic of the company's process focused on the structure of the product development process and the organizational structure used to manage the development of new products. The data from this phase serve as a basis for proposed improvements, also outlined in this work.

**Keywords:** product development process, automotive industry.

## 1. Introduction

Competitiveness is one of the main reasons why product variety has increased on the market (MENNE; RECHS, 2002). Calvita (2008) adds that growing competition among companies in the automotive market accelerates not just the race to increase quality and reduce cost, but to reduce product life cycle. Considering all these factors, new products development in the automotive industry has been increasing in importance during last decades.

The automotive industry has yet another factor that contributes to the importance growth new product development: legislation on exhaust gas emissions. Emissions legislation came into effect in Brazil at the end of the 1980s. PROCONVE (Program for Automotive Vehicle Air Pollution Control) was instituted in 1988 (INSTITUTO BRASILEIRO DO MEIO AMBIENTE E DOS RECURSOS NATURAIS RENOVÁVEIS, 2004). Phase 1 was launched in 1988, for light vehicles, and for heavy vehicles in 1989. Since, then periodically more rigorous phases have come into effect. These limits have affected large part of the automotive industry supply chain, especially engine manufacturer and their suppliers.

In this context, the present study attempts to diagnose the situation of the new product development process for an engine manufacturer; based on a literature search and data collected in the field. The study is intended to create a proposal to improve the company's product development process. The specific objective of the article is to diagnose the company, the main unit of analysis, to better understand

the company's product development process with a focus on the product develop process system and organizational structure and then to propose improvements to its product development process.

## 2. Literature review

According to Clark and Fujimoto (2001) and Clausing (1994), survival in the market for many companies depends on their ability to improve the product development process in order to reduce development time, assure quality and reduce the products costs. Rozenfeld et al. (2006) add that product development consists on a set of activities which are based on market needs and technical possibilities and restrictions and take into consideration the company's strategies for completion and for its products. It seeks to arrive at project specifications for a product and its production process, so that manufacturing is able to develop the product. Product development also involves monitoring the product after launch in order to make the necessary changes, allowing for planned discontinuance and incorporating the lessons learned during the product life cycle into the development process.

Further, the product development process has various specificities when compared to other business processes (ROZENFELD et al., 2006); the main ones are:

- High degree of uncertainty and activities and results risks;
- Important decisions should be made at beginning

of the process when the uncertainties are even greater;

- Difficulties in changing initial decisions;
- The basic activities follow a repeating cycle of project-build-test-optimize;
- Generation and processing a high volume of information;
- Information and activities come from different sources, company's areas and supply chain; and
- Multiple requirements to be met by the process, considering all product life cycles' phases and its customers.

When the product development process in the automobile sector is analyzed, one can highlight the fact that the time necessary to complete each cycle of project-build-test-optimize is very high. The main factors that influence the time needed are (MORGAN; LIKER, 2006; CALVITI, 2008):

- Highly complex projects from the technical point of view;
- Building prototypes takes a lot of time, since it normally depends on constructing prototype or low volume tools to be able to produce the parts; and
- Optimization usually requires a separate cycle which involves: analysis of test results or failures that occur during the test to determine the root cause of the failure, implementation of a product improvement, changes of tools or process and only then, production of a new product version.

## 2.1. Organizational structure for product development

In the last thirty years there has been a so-called revolution in the introduction and development of new organizational structures. Top management has realized that organizations need to be dynamic by nature, capable to restructure according with the environmental conditions. These environmental conditions involve increased market competition, technological changes and improvement. There is a wide variety of organizational structures. The exact method chosen depends on the persons in the organization, its product line and management philosophy (KERZNER, 2006).

Projects are within in this context. According to PMI (2004a), even when projects such as joint ventures and partnerships are external to the organization they are influenced by them as well as some of their contents, such as: project management systems, organizational culture, leadership style and the organizational structure. There are three types of organizational structure (PMI, 2004a): functional, matrix (weak, balanced or strong) and projectized.

In the functional structure employees are grouped by function and have a well-defined immediate supervision.

In the projects developed under structures such as this, the scope is restricted to the limits of the function. Thus, the project moves from function to function. At the opposite end is projectized organization, where the members of the project team generally are placed together. In this type of structure the project managers have great autonomy and the specialists of each function report directly to them (PMI, 2004a).

The matrix structures combine the characteristics of the two previous ones. According to Cleland and Ireland (2002) in a matrix structure there is a division of authority, responsibility and obligations between the project team and the functional departments. The roles relative to and complementary to authority, responsibility and the obligation for expense accounting to the project manager and the functional manager are at the interface between project and function.

Yet Clark and Fujimoto (2001) identify four organizational forms: the traditional functional structure, the structure of the "light-weight" product manager, the "heavy-weight" product manager structure and project-based team. These organizations are similar to those cited earlier, since they have a traditional functional structure, two forms of matrix structure, one less than what the PMI (2004a) presents and a similar structure to the projectized, however with the difference that the functional areas continue to exist and the project team is separated from the functional structure. There are few organizations which use only one type of organizational structure. Most modern organizations have more than one type, if not all the structures shown. Even a functional organization can create a team to develop a specific project (PMI, 2004a).

## 2.2. The stage-gate system of product development

According to Silva (2003), the concept of stage-gates system were originated with NASA (the National Aeronautics and Space Administration) and was popularized by Cooper in the 90s, based on the experience, suggestions and observations of a large number of companies and organizations in addition to the study by Cooper and Kleinschmidt (1999).

The system consists of a model for structuring the new product development processes into phases and revisions of activities carried out during product development.

The process of phase's evaluation has undergone three generations (COOPER, 1994):

- First generation: NASA developed a process called PPP (Phased Project Planning) in the 1960s. It separated product development into discrete phases. There were managerial revisions at each phase to check whether the pre-requisites have been fulfilled in order for the project to continue. This was an engineering-based process. It presented some problems, since the phase revisions were delayed and there were

lines of projects awaiting revision. Further, often the entire project was delayed because a single activity had not been concluded.

- Second generation: the main evolutions were that the process became multifunctional with the involvement of marketing and manufacturing areas, the revisions became broader with the involvement of other functional areas, and there was coverage from the concept development to launching. There were still some problems, since the transition from phase to phase still depended on concluding all the tasks and the phases could not be overlapped.
- Third generation: maintains the same basic concepts, seeking to solve the problems existing in earlier generations. This generation is based on four fundamental points:
  - Flow: the process is fluid and adaptable with phases overlapped to increase speed;
  - Flexible revisions: make decisions about conditional continuity possible, according to each situation;
  - Focus: consider methods to set priorities for the entire portfolio, directing resources to the most important projects; and
  - Flexibility: makes it possible to establish a customized system for each project size.

Some important implications of this third generation are: making the system adaptable to the specific needs of each project, decision making becomes more complex and division into phases is more difficult. The phase revisions are characterized by three deliverable elements: deliverables or phase products, gate criteria or requirements and the results of the revision (COOPER, 1993).

### 3. Methods and techniques adopted

Field research was the method used for data collection, and more specifically a case-based research was employed. The unit of analysis is the product development process used in the autoparts industry. According to Dane (1990), field research is especially indicated for studies of exploratory and descriptive nature, as is the case of this work. As mentioned before, data collection for the diagnosis of the main unit of analysis was done with focus on the product development system and on the organizational structure used to manage new product development.

#### 3.1. Case selection

The choice of the unit of analysis was mainly done as a function of having access to data, since one of the authors work at the organization. Other criteria that complement and justify the choice are:

- Having a structured product development process in place; and

- Developing and manufacturing products, which are considered by the OEM's as complex system and directly involve the aspects discussed in the Introduction.

#### 3.2. Characterization of the principal unit of analysis

The main company unit of analysis is an American multinational which manufactures autoparts. The business focus is diesel engines development and manufacture. Annual company revenues (2007) in Brazil were US\$ 790 million for 120,000 engines produced. The company has 2,600 employees in Brazil and Argentina, distributed in three units; two in Brazil and one in Argentina it is certified according to ISO TS 16949 (2002).

#### 3.3. Data collection

Data collection was done by interviews with those who work in structuring the product development process and with members of the development teams. There were ten meetings in total; four with a senior specialists from the engineering project office who were involved in the process implementation. At these meetings, documents were consulted and evidence about the use of the practices contemplated in the process was analyzed. The other interviews were conducted with six professionals active in the product development, two program coordinators, three engineering project leaders and a project platform manager.

### 4. Empirical findings

This topic includes the diagnostic of the company concerning its product development processes and organizational structure.

#### 4.1. Organizational structure

The company has a president and eight directors in Brazil. The directors head product engineering, sales and marketing, parts and services, manufacturing, quality, purchasing, finance and human resources.

#### 4.2. Types of projects

According to Wheelwright and Clark (1992) there are four project classifications:

- Research or advanced development: attempts to invent a new technology or knowledge to be available for application in specific projects later;
- Innovation, radical or breakthrough: involve the creation of a first generation of a process or an entirely new process. The concepts and technologies establish new benchmarks for the organization;
- Platform or generational: establish a new basic architecture for a family of products that follows the

initial project;

- Derivative: this is a project for improvement and refinement to better meet the needs of the market; and
- Alliances: projects in partnership or follow source - the project is done for other units of the group, clients or a technology contract. It does not require significant alterations, local unit adapts to local conditions.

The company adopts a classification of projects that diverges from what is presented in the literature in the sense that it contemplates only the creation of a new product or application of this product, with the following definitions:

- Basic engine project: these are projects in which a new engine is created, i.e., basic product components are developed such as: structural, distribution and fuel systems. Usually, these project are done without there being a specific customer with a view to the market or potential customers; and
- Application project: these are projects that are developed to apply the basic product to a customer vehicle or equipment. The components created in these projects are limited to the interface of the engine with the vehicle, such as: auxiliary, fuel low pressure, cooling, air management and electrical.

Table 1 shows the relationship between the types of projects defined by the company and the classification proposed by Wheelwright and Clark (1992). The table further shows the systems that are usually created or modified for each type of project.

### 4.3. Organization for product development

The company adopts different structures and leadership for basic engine and application projects because they believe that they need to be conducted differently. Basic engine projects have teams with fewer functions, involving only engineering, marketing, manufacture, and purchasing

**Table 1.** Project classification.

Type of project	Classification	New systems
Basic engine	Breakthrough	Structural
	Platform	Lubrication
	Derivative	Power transmission
	Follow source	Fuel low pressure Timing Air management Electrical
Application	Derivative	Auxiliary
	Follow source	Fuel low pressure Cooling Air management Electrical

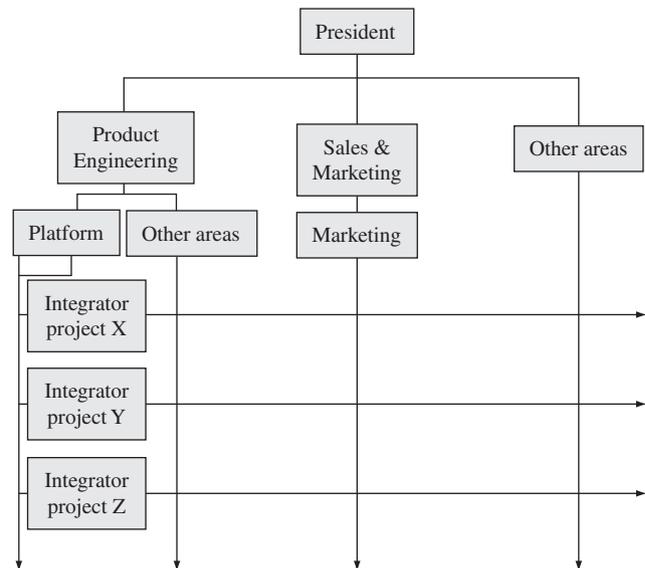
areas. However, they do require great technical depth since they could involve the main engine systems.

All functional areas participate in application projects. There is a defined customer with specific requirements to be met and different organizational culture. Often, the customer has its own development process that needs to be respected and activities to be synchronized between the two organizations.

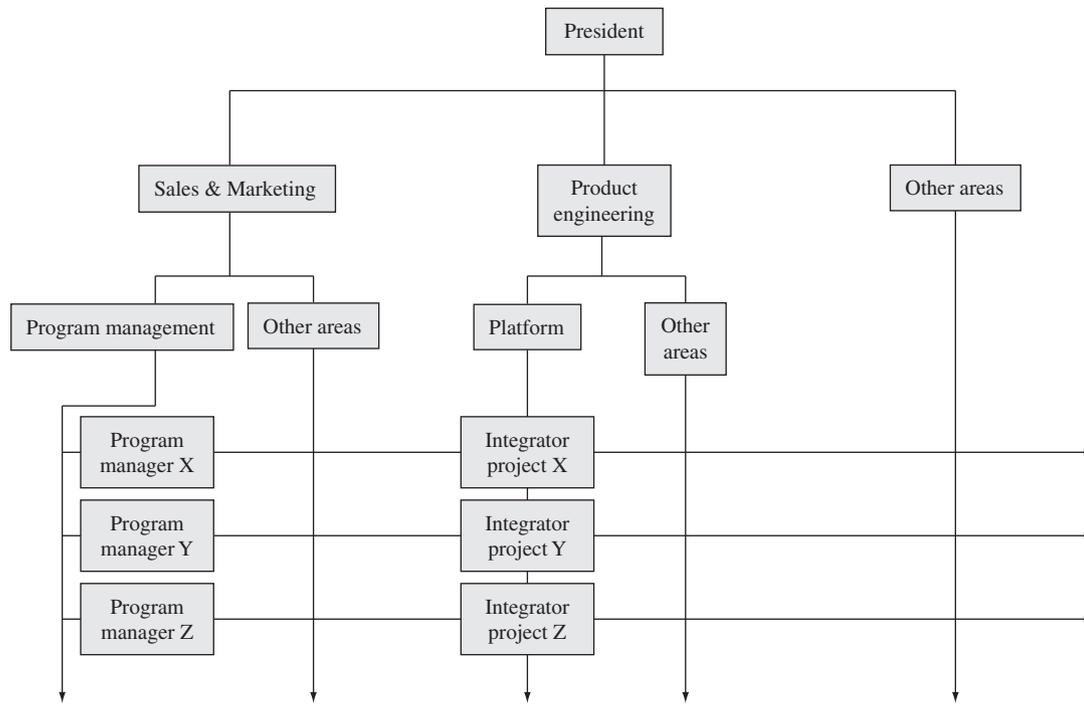
The leadership of basic engines development is carried out by the head of product engineering through the area of product creation, where the designated project leaders coordinate the team made up of representatives of the other areas of organization, as shown in Figure 1. In application projects, leadership is exercised by personnel from program management, which is subordinate to the sales department. In these projects, the product engineering areas acts as part of the project team, as shown in Figure 2.

According to Kerzner (2006) this type of structure can be used when the project becomes large and the project manager, in this specific case called the program manager, is not able to deal with both the management aspects and engineering techniques. In these cases, an engineering leader is designated for each project, but remains functionally linked to the product engineering director.

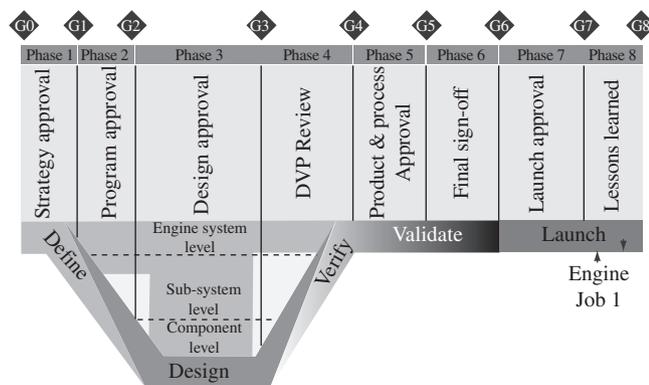
There is great similarity between the structure adopted by the company and that proposed by Kerzner (2006). In both, there is a project leader from the engineering area who becomes responsible for integrating the other technical functions within his area. One important difference is the non-existence of a so-called project office in the company.



**Figure 1.** Structural organization of the basic engine projects.



**Figure 2.** Structural organization of the application projects.



**Figure 3.** QVP Model (source: company studied).

#### 4.4. The product development process model

The company adopted a model for the process composed of phases and gates (eight phases and nine gates, shown in Figure 3). This model is called QVP (Quality Value Planning), in this sense its structure is very similar to the stage-gate model studied by Cooper (1993). There is a committee that analyzes projects at the end of each phase and approves or rejects the transition to the next phase.

This committee is composed of the company's president in Brazil and all members of the board of directors. It meets monthly and projects are put on the agenda with at least fifteen days in advance and are presented in a standard format which contains all the necessary information for

decision taking. The results of the phase and the decision about project continuity are recorded in a document signed by all committee members.

Goals are established for each phase in the process. At the end of each phase there is a project progress presentation to demonstrate whether it has achieved its objective. At that time a decision is made about whether to continue to the next phase, remain in the present phase until resolving some problem or completing some specific activity, or to abort the project. The possibility of aborting the project exists, but according to the reports of those interviewed, this decision would normally occur at the initial phases of planning and research, prior to approval of the complete project.

Figure 3 illustrates the product development process which was adopted, its division into phases and their names. Note that the company calls new product development projects as "programs". The "V" shown in the figure represents the way product requirements are unfold. Initially, these requirements are defined for the product and as planning advances, they unfold onto the level of systems and then components. Verification and validation of the product occur at the system levels and later for the complete product, that is, verification can be initiated in separate components and system. However, validation will only be complete when the complete engine is tested.

The objectives defined in the program charter are developed by phases and by functional areas. In this way,

**Table 2.** Comparison of cooper's third generation NPD and QVP.

Third generation PDP	QVP
Overlapping phases	The process allows and encourages overlapping of phases
Flexible revisions	Conditional approval is contemplated in this process
Focus and priority setting	Despite the process indicating a need, there is no structured format for carrying it out
Flexibility	Does not permit customization of the process of the agreement with the project

each functional area of the company has its objectives defined for each phase of the project.

Comparing the QVP process characteristics with the creation of the revisions processes for the phases proposed by Cooper (1994), it will be possible to draw an analogy of its main characteristics and compare them as seen in Table 2.

Analyzing each of the aspects in Table 2, one notes that the overlapping of phases is a practice already used by the company and is also contemplated in the QVP. Another characteristic that has been consolidated at the company is flexible phase revisions, where there exists the possibility of conditional approval. In these cases, the project can go on to the next stage, however pending items revision that is scheduled for the next meeting of the approval committee.

Nevertheless, some important results can be gleaned from this comparison, when the focus and flexibility items are analyzed. QVP indicates the need to analyze the interaction among projects, principally with a focus on the availability of resources, even though this analysis is done in a non-structured way. This point is identified as a process improvement opportunity, since if the project portfolio analysis were structured; decisions could be taken based on objective information. With respect to the last item, there is no opportunity to customize QVP in accord with the needs of each project. The phases and activities are fixed and the process does not contemplate alterations in its structure. In the original QVP process form the matrix of the company in the United States there is scalability for the process, but it is not detailed. Once again, another process improvement opportunity is identified, i.e. the creation of a flexible model allows its fit to smaller projects and for markets in which the requirements of the clients are different.

#### 4.5. Maturity level of the process

The new product development process in a company can have several levels of evolution. Some organizations are more evolved and use sophisticated, established tools which are called best practices, while other organizations carry out product development informally, without structuring the process or extensive use of support tools to develop a new product.

In this context, and aiming to understand the degree of evolution of specific processes, maturity models in several areas of knowledge have been created. According to Burn (1994) and King and Teo (1997) cited in Rocha and Vasconcelos (2004) the maturity models are based on the premise that people, organization, functional areas, processes, etc. evolve by a process of development or growth in the direction of advancing maturity, passing through a certain number of distinct stages. These models have been used to describe a wide range of phenomena. Some examples of maturity models are the CMM (Capability Maturity Model) developed by the Software Engineering Institute at Carnegie Mellon University at the end of the 1980s, which is used to measure maturity in software development. Another example is the OPM3 (Organization Project Management Maturity Model) launched by the Project Management Institute in 2004 and used to measure organizational maturity in project management (PMI, 2004b). These models offer the means for organizations to understand their processes and measure their maturity as compared to the best practices used in the market. These best practices are defined by the institutions that create the maturity models.

In the context of new product development, Rozenfeld et al. (2006) propose a maturity model for the product development process to indicate how to apply best practices to product development. The proposed model is based on levels that depend on carry out certain activities and utilizing the established tools. At each level, the tools, activities and methods are added; five maturity levels are proposed:

- Basic: product development activities are carried out in a non-structured manner;
- Intermediate: there is standardization of activities and their results are predictable, established tools and methods are used. Beginning with this level, the company is already utilizing the product development process in an advanced way; the other levels show evolution in terms of control and learning;
- Measurable: performance measures are used for product development activities;
- Controlled: there is a systematic form of work to correct activities in line with the results of the measures; and
- Continuous improvement: the support processes are

institutionalized and integrated into product development process.

The proposal for this maturity model does not contemplate certification, but rather that companies undertake a diagnostic of the process by means of audits to aid in defining plans to improve the process. With this goal and to aid in creating improvements to the product development process, an evaluation of the company which was the main unit of analysis was done.

The evaluation was done with the aid of a specialist from the company's project office, utilizing the format proposed by Rozenfeld et al. (2006) where colours are used to grade the use of the practices. An audit procedure was used in which each item of the maturity model was surveyed to discover use of the practices. Also, samples from each of the practices were collected as evidence of their use.

Figure 4 shows the proposed maturity model indicating the results of the evaluation.

The following comments can be made regarding the practices that were identified or there is no utilization for all projects:

- Group 1: the majority of the items in the group of practices marked with the number 1, are consolidated in the company. Among the most utilized practices,

highlights are the application of FMEA to design and processes; several uses of the CAE tools were in evidence. There is a structured process for integrating suppliers into development, the criteria for phase transition are clearly defined and utilized; there is a formal management process for engineering changes and the culture of continuous improvement and dissemination is practiced by the company. The exception is applying QFD, which is not utilized in the definition of new production. Thus the item is partially completed;

- Group 2: it was found that there is no application of plans for reutilization, recycling and discard for all the projects. This practice is utilized only when requested by customers, thus the group was considered as partially applied;
- Group 3: for this group, there were activities carried out by the company such as standardizing activities, managing the critical parameters and robust projects. However, there is no structured process for incremental improvements. These items are done in a non-structured way. Thus, this group was considered as in partially fulfilled; and
- Group 4: it was not demonstrated that the cycle of

Level	Knowledge area	Sub-level	Pre-development		Development					Pos-development		Support processes	
			Product strategic plan	Project planning	Informational design	Product concept	Detailed design	Production preparation	Product launching	Product and process monitoring	Product phase-out	Change management	PD continuous improvement
1 - Basic	Product engineering	1.1	Board meeting	Scope, macho tasks and timeframe	Define requirements, concept, structure, drawings, CAD, items dimensions		Subcontract resources	Actions connected	Comply with legislations				
	Marketing and quality	1.2			Cascade requirements evaluate lifecycle	Consider specific requirements during product	Release for production						
	Process engineering manufacturing and logistics	1.3	Process planning and suppliers integration	Pilot batch and process validation									
	Project and cost management	1.4	Portfolio	Viability studies, use of systems	Phase submissions (gate)			Plan product launching					
2 - Intermediate	Product engineering	2.1	Product platform planning integrated with portfolio management	Risk and quality analysis	Functional modeling, define principles for solutions, apply DFX (design for x), alternative concepts, apply QFD		1	Use of DFMEA and CAE	Monitoring teams integrated with product development		Informal	Improvements are implemented without performance monitoring or integration	
	Marketing and quality	2.2	Portfolio management integrated with strategic plan	Include partners form supply chain	Manufacturing and assembly process design and detailing, use of CAPP e PDM	Business processes are designed simultaneously							
	Process engineering, manufacturing and logistics	2.3				Project management activities, integrated planning, gate submissions with pre-defined requirements, cost, volumes and risks monitoring, project management performance index		2	Reuse and recycling plans are integrated				
	Product engineering	2.4							Formal process, use of systematic approach				
3 - Measure		3	Performance index for all activities										
4 - Control		4	All activities controlled based in the indicators and corrective actions are taken integrated into the management support process or changes and continuous improvement. Robust design and control of critical parameters are used (Tagushi method).										3
5 - Continuous improvement		5	Continuous improvement cycle of PD transformation integrated into incremental improvement cycle, to management changes and project planning.										4

Figure 4. Maturity Evaluation (analysis based on ROZENFELD et al., 2006).

**Table 3.** Opportunities to improve the product development process.

	<b>Practice</b>	<b>Application at the company</b>	<b>Proposal for improvement</b>
NPD Generations	Focus and priority setting	The process indicated the need, but is not a structured process	Carry out an analysis of the project portfolio that can help to show the set of project in the organization, their distribution over time, utilization of resources, financial situation and market perspectives
	Making the process flexible	Does not allow customization of the process according to its type	Create a structure for scale of projects, allowing customization of the process for different types of projects
Maturity analysis	Application of QFD	The method is not applied to development of new products	Introduce the use of QFD in the process, especially for projects for basic products where the focus of development is on market requirements
	Plans for reutilization	Only exist when there is a need for some specific customer	Expand the utilization of plans for reutilization, recycling and exclusion for all the projects
	Incremental improvement	The process contemplates the need for incremental improvement, even though there is no formalization	Structure the incremental improvement process for implementation in the company, in this way meeting an already-existing need
	Integration of the processes for incremental improvement, management of changes and planning of the project	There is no integration among the processes	In addition to the structuring of the incremental improvement process, it is necessary to integrate it into the management of changes and project planning

transformation for the development process is integrated into a process of incremental improvement, change management or project planning. These activities occur, but in a non-structured way. Considering this evidence the group was considered not to be in compliance.

In the framework proposed by Rozenfeld et al. (2006) there is no partial classification or for a situation in which activities are carried out at different levels such as the situation found in the studied company. The authors even admit the possibility, but clearly express that it is not logical for this to happen and allege that over time the company will perceive the need for a harmonious evolution according to the logic presented. The relevance of this study is not in classifying and defining the company's maturity level, but in identifying the best practices that were not adopted by the company and which could provide opportunities to improve the process. The authors themselves stated that defining the levels of maturity permit the realization of a product development process diagnosis and help to define transformation projects.

At this stage, the present study demonstrated that the engine manufacturing company seeks to restructure its product development process and its organizational structure. This evolution can be compared to the practices found in the literature and in the maturity analysis, by identifying which practices are still not adopted by the company or are utilized in an inadequate way. The preliminary result of this analysis is shown in Table 3. In

this sense, six opportunities for improvement identified were divided into two groups, those that come from the analysis of the product development process creation and those from the analysis of maturity.

## 5. Conclusions

In this study, the analysis of the literature is complemented with the case study presentation of a diesel engine manufacturer. Concerning the review of the literature, it shows a significant evolution of the product development process, since the 1960s, in the search to meet the growing demands to develop new products. These demands have distinct origins: marketing and environmental. The marketing demands have causes that run from increased competitiveness, due to the evolution of technology and greater demands from consumers who are looking not just for reliable, cheap products, but those that are safe and up-to-date as well. Environmental regulations are already in effect in the automotive industry with the rise of regulations that control vehicle gas emissions, and are now evolving to noise control and utilization of environmentally harmful substances.

Even though this work is still under development, it can be concluded that there is a certain alignment of the new product development process at the company studied with the literature. Despite this alignment, some opportunities for improvement were identified and the next step in the work should be in the direction of deepening the research on one of these opportunities.

Due to some constraints, the study did not consider some aspects into consideration, which could be more deeply investigation in future work. Initially, it can be cited the validity of utilizing a maturity model applied to the product development in the company diesel engines manufacturer. Another aspect that can be deepened has to do with the demonstrating the practices suggested by the model, and which were utilized as opportunities for improvement, are appropriate for this specific company. Finally, it has not been possible to demonstrate the benefits of these improvements opportunities, since they have not been implemented by the company. However, these are opportunities for work and studies to be developed in the near future.

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