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Modelling the Product Development performance of Colombian Companies

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Abstract
This paper presents the general model of the Product Development Process (PDP) in the Metal mechanics Industry in Barranquilla-Colombia, since this sector contributes significantly to the productivity of this industrial city. This case study counted on a five-company sample. The main goal was to model the current conditions of the PDP according to the Concurrent Engineering philosophy. The companies were selected according to their productive profile, in order to contrast differences regarding the structure of their productive processes, conformation of multidisciplinary teams, integration of different areas, customers and suppliers to the PDP; human resources, information, technology and marketing constraints.

Keywords:
Product Process Development, Concurrent Engineering, Multidisciplinary Teams, Human Resources, Information, Technology and Marketing.

1 INTRODUCTION

The Product Development Process (PDP) consists of all the activities that a product would go through from market need, concept design throughout engineering and development as well as manufacturing planning then production until shipment to the customer. PDP represents a key process for manufacturing companies to achieve high levels of competitiveness. Decisions made about costs, delivery times and quality improvement during first stage such as concept design, impact up to 80% the performance of following processes, such as manufacturing, product use and maintenance. As such, PDP plays a determinant roll while designing and implementing differentiation strategies. These strategies imply offering products that are innovative and that fulfil needs simultaneously, considering constraints such as costs, quality and delivery time [1].

PDP based on Concurrent Engineering (CE) involves the interaction among different areas within the company, such as marketing, design engineering and manufacturing. In order to design a product that would satisfy the different aspects of the product life cycle. Design results a keyword in the PDP concept: It engages sub-activities for defining specifications, detail design, planning and production [2]. Manufacturing companies should reinforce the PDP as a strategy for integrating innovation with knowledge and technology, achieving with this a positive impact mainly on quality and time of response [3].

In this paper, the interest is the diagnostic of the current status of PDP in the Metal mechanics industry in Barranquilla-Colombia. The case study is based on the general results from the research project "Design of Product Development Process (PDP) in the Metal mechanics Industry in Barranquilla-Colombia, within the context of Concurrent Engineering (CE)" [4]. This project was funded by the National Research Office COLCIENCIAS and Universidad del Norte, supporting this way the University-Industry relationship for improving productive systems and knowledge from Academy, as well. The Metal mechanics sector was selected for the study given that, as reported by Proexport [5], this sector contributed with US$121 millions to the local economy in 2005 and around US$40.2 millions in 2004. Compared to other sectors, this increasing contribution determines this productive sector as one of the most representative economic activities in Barranquilla-Colombia as an industrial city, representing the 80% of the manufacturing activity in the Colombian Caribbean region.

This paper is structured as follows: A review of relevant literature about the PDP concept based on CE is presented in section 2. A review of previous research works about the tools selected for modelling the PDP for this case study is presented in section 3. Sections 4 and 5 are respectively devoted to describe the methodology designed for analyzing the PDP based on CE and to present the results for each company from the sample. Finally, section 6 presents some concluding remarks.

2 LITERATURE REVIEW

In the literature, authors have addressed the PDP concept from a large variety of vantage points. Clearly related with Design, Pahl and Beitz [6] presented the PDP as the interaction of four main phases: Problem definition & planning, conceptual design, detailed listing of design tools and, finally, the detailed design. According to Ulrich [7], the PDP is conformed by Concept development, System-level design, Detailed design and Product testing and refinement.

Regarding the relation between PDP and CE, Koike [1] presents the PDP set of activities including design, management and utilization of resources. Considering them with organizational nature, these activities must be supported by the concept of CE for reaching functional levels of integration. With this, the PDP is oriented to facilitate a parallel, simultaneous design of product and manufacturing processes, instead of the classic path for executing tasks in a sequential way. For achieving the desired integration within the PDP, Koike, Luna and Al-Ashaab and Molina propose the conformation of multidisciplinary teams in order to count on information from customers, merchandising, sells and production areas while the PDP is in progress. Al-Ashaab and Molina [8] consider that multidisciplinary teams allows sharing relevant information, which in the short-term considers relevant Product Life Cycle issues and facilitates the making decisions process from the very first Design phase. Koike [1] and Luna [3] complement this position since both authors agree that members conforming multidisciplinary teams need to be selected from different functional departments within the organization, with different knowledge expertise as well.

For measuring the performance of the PDP according to CE, Griffin and Page [9] presented a basic, generic set of measure categories used by Companies and Researchers. The list of metrics included meeting revenue goals regarding customer, meeting profit goals regarding finance, and go to market on time, regarding product and project program. The same research work presented a parallel of metrics that are not commonly used by companies and researches. As for companies, they were reported to use more customer and financial measures. As for researchers, the list included company-level and product-related measures. Complementing the interest of measuring the performance of the PDP, Cohen et al. [10] studied the time-to-market trade-off. Their model evaluates how fast a product is completely designed or, based on a previous version, improved designing minor changes. These authors consider important how large the multidisciplinary team is conformed, and how long members conforming it are devoted to work on the PDP process, as well. The contribution of this research work regarding the PDP and CE results important given that recognizes different stages for completing the PDP, considers production and feedback as simultaneous activities and, finally, integrates Design and Development in the short and long rung.

In this paper, we will present our own methodology for analyzing the PDP based on these contributions as references. Under the scope of CE, we have selected tools for collecting and displaying information, and we have adapted multidisciplinary team and measure categories according to the real context of the Metal mechanics sector in Barranquilla-Colombia.

3 TOOLS SELECTED FOR MODELING THE PDP BASED ON CE

Given that CE involves the interaction of key factors (i.e. people, material, machinery, technology and information), Icam DEFinition level 0 (IDEF0) and Actual-PDP-Evaluation Tool (A-PDP-ET) permit to model properly these interactions in the PDP and to reflect a reliable overview of current conditions. Sections 3.1 and 3.2 describe relevant issues about these tools, in order to justify their selection for modelling the PDP in this research work.

3.1 Activity modelling using IDEF0

IDEF0 is a result of the graphic language Structured Analysis and Design Technique (SADT). According to the National Institute of Standards and Technology [11], it is used as a "function model" to produce a structured representation of the functions, activities and/or processes within the modelled system or subject area.

As a communication tool supporting the PDP based on CE, IDEF0 models helped the Colombian industrial collaborators to visualize graphically the set of phases, activities and resources involved in their product development processes. The main advantage of this set of boxes is that they make it easier to the team to identify inputs, outputs and their connections between two or more activities, either sequential or not. The multidisciplinary team will find this information useful for making decisions about simultaneous activities.

Referring previous applications, Crump et al. [12] consider that IDEF0 captures some constraint-related information, although at a relatively course-grained level. In theory, objects classified as mechanisms must be the starting point for cataloguing and validating controls (constraints). For IDEF0, controls must be validated to determine whether they represent constraints or not, since IDEF0 does not explicitly capture which mechanisms enforce which controls. Bosilj-Vuksic et al. [13] compared IDEF0 with Petri Nets for business process modelling, concluding that using IDEF0 does not represent all the elements important for simulation modelling, such as queues, random behaviour and process dynamics, but could provide the basic elements for simulation model development.

The following are the main advantages the authors have identified while using IDEF0 with the Colombian industry:

- Makes it easier to understand the Product Life Cycle.
- Improves the Planning phase for posterior product development based on the models obtained with this technique.
- Contributes to the definition of information required for each activity and by the integration between two or more of them.
- Integrates the correct information on the correct place, on the correct time and using the correct format.

3.2 Actual-PDP-Evaluation Tool (A-PDP-ET)

Designed and applied by Luna [3], this tool with survey format and graphical representations is useful to collect the perception of the multidisciplinary team for the PDP. This information allows to the leader of the team to analyze the current status of the PDP within the company, in order to detect area(s) to be improved based on CE. The A-PDP-ET tool evaluates the following elements:

- Dimensions: Five main areas a company must be conformed of. These are: Organization, Human Resources, Market, Information and Technology.
- Key factors: The most representative activities that the PDP must include regarding each dimension.
- Management level: Degree of effort for conforming multidisciplinary teams and for keeping this scheme for working during the PDP progress. Level zero (0) and level four (4) are the minimum and maximum values, respectively. This scale of integer values is used for quantifying the level of integration within the PDP reached by a company, counting on its real, current conditions.

In order to illustrate the A-PDP-ET tool, Table 1 presents the list of key factors evaluated in each dimension, and Figure 1 presents a general diagram. Once a key factor is evaluated, it is represented with a mark on the correspondent level from zero to four. This way, the diagram presents a useful overview of the results for detecting factors to be improved.

Dimension	Key Factor	I.D.
Organization	Support received from Board Committee	1
	Conformation of multidisciplinary teams	2
	Suppliers	3
	Continuous Improvement	4
	Methodologies for supporting processes.	5
	Methodologies for Planning.	6
Human Resources	Empowerment	7
	Motivation and Creativity	8
	Continuous education and Training.	9
Market	Meeting customers' demands.	10
	Marketing analysis	11
	Planning and checking potential markets	12
Information	Product Management	13
	Management of product data	14
	Documentation and utilization of Manufacturing capabilities.	15
	Feedback	16
	Information exchange	17
	Standards	18
Technology	Technological strategy	19
	Computer Aided Technology	20

Table 1: List of dimensions and key factors evaluated with the A-PDP-ET.

4 METHODOLOGY PROPOSED FOR MODELING AND ANALYZING THE PDP

The methodology applied for evaluating the current status of the PDP was proposed considering as a reference the research work by Luna [3]. This proposal included the following stages:

Stage 1: Conformation of the five-company sample for the case study

For characterizing the PDP in the Metal mechanics sector to conform the sample for the case study were selected based on the following criteria:

- PDP clearly defined in the company. This means, activities within the PDP are not usually confounded with external activities for supporting the process (i.e. Transportation and Packing).
- General Manager and members from different areas are willing to establish a multidisciplinary team for executing their projects.
- Inclusion of technologies in the PDP.

Stage 2: Introduction to the CE.

The aim of this stage is to make the company board to understand the advantages and benefits yielded from CE as a strategic policy. This view of the CE represents a better, competitive management of the PDP and a positive impact on its profile in the market.

Stage 3: Creation of the model of the PDP in each company from the sample

This stage is addressed to comprehend how the PDP is performed in each one of the companies from the sample. Given that financial, marketing and some other characteristics change from company to company, the result of this stage is to obtain a standard model of the PDP. This model reflects agreements within the multidisciplinary team regarding activities, responsibilities and requirements of information and some other resources, as well. Once the model is obtained, it becomes useful for evaluating the actual level of CE involved in the PDP in each case.

5 STANDARD MODEL OF THE PDP BASED ON CE

The standard model for the PDP includes two sections: Section 5.1 presents an overview of the general conformation of PDP, where issues are common to the set of companies from the sample for the case study. Section 5.2 presents the evaluation of the key factors grouped in dimensions, according to CE.

5.1 General conformation of the PDP

In order to identify general issues regarding the PDP, the required information related to each key factor was collected through direct observation, visiting the process in-situ, interviews and oriented surveys applied to members of the multidisciplinary team for the design and development of products.

The drawings of the standard model were obtained using the IDEF0 technique, representing the general function (Figure 1), phases (Figure 2) and activities (Figure 3). In general, these three levels reflect common stages within the PDP for the five companies participating in the case study.

Figure 2 presents that one single input, control and/or mechanism could be equally required for more than one single activity. Figures 2 and 3 illustrates the fact that each phase and each activity could receive more than one input, more than one mechanism and more than one control, if needed.

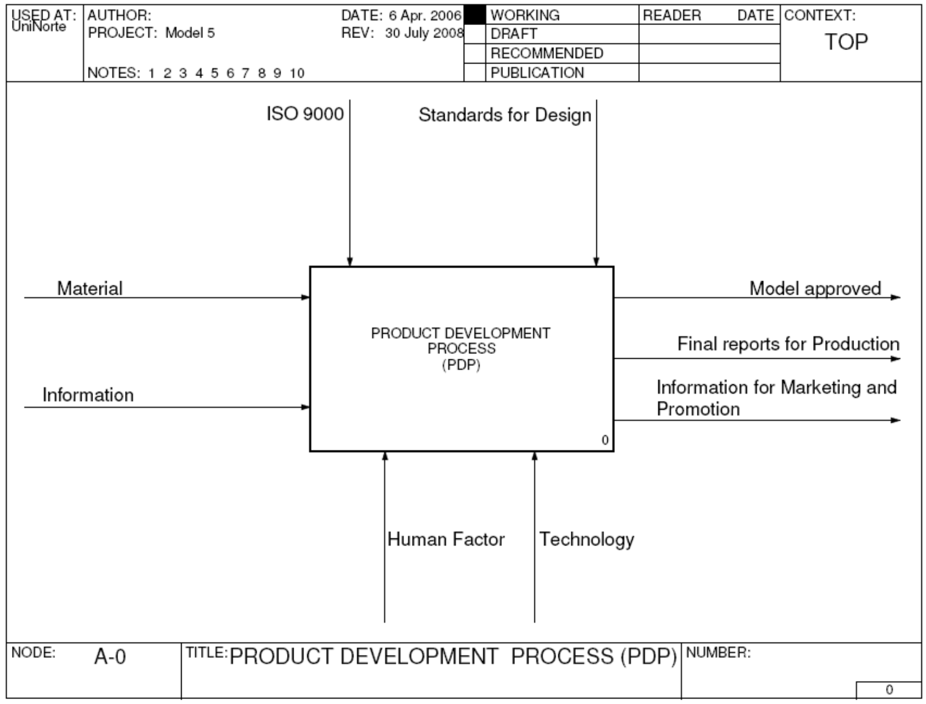

Figure 1: Standard model, General Function.

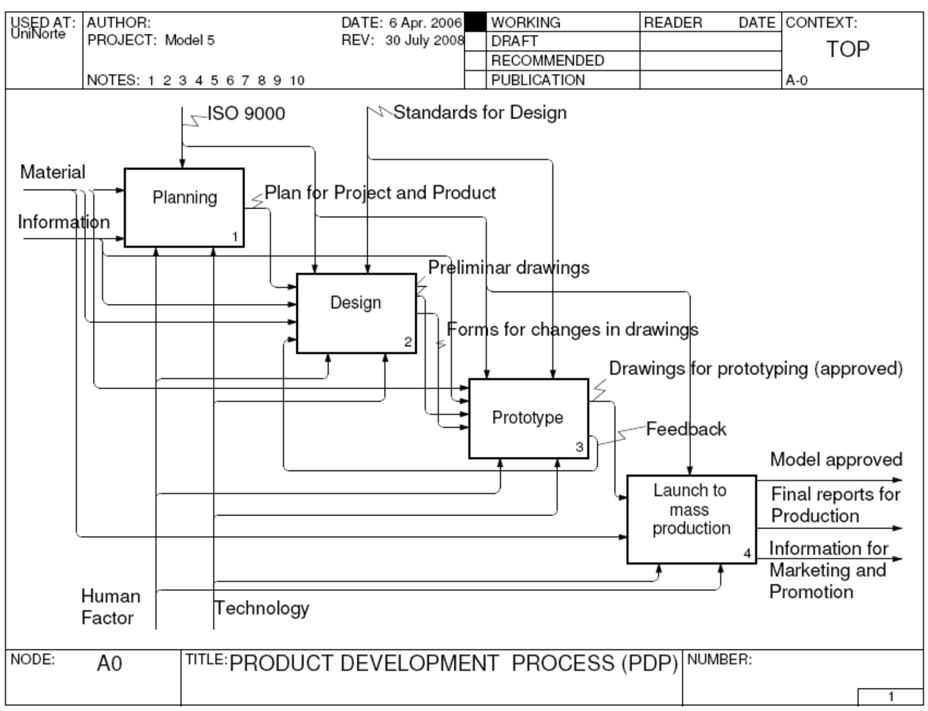

Figure 2: Standard model, Phases.

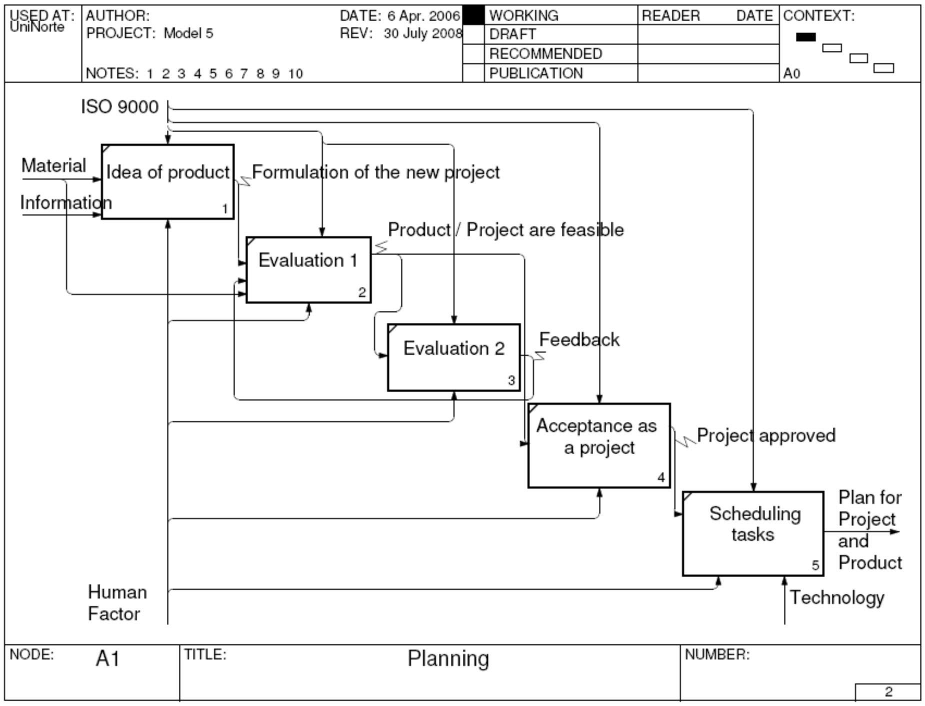

Figure 3: Standard model, Activities (for Phase 1).

The common pattern presented by companies in the sample involves the importance of having feedback between phases (level 2) and activities (level 3). For example, the standard model reflects that the Design and Prototyping phases (Figure 2) represent the most critical phases within the PDP, since it allows correcting inconsistencies in Design in order to assure that the product will result as functional as planned. Simultaneously, the feedback between Design and Prototyping allows optimizing the utilization level of the manufacturing capacity according to the current conditions in each company.

5.2 DP Performance Measurement

A PDA performance measurement has been carried out for each participating company according to dimensions and correspondent key factors proposed by CE. Each key factor presented on Table 1 was evaluated by members of the multidisciplinary team using a scale of integer values, from zero (0) to four (4). Level zero (0) and level four (4) are the minimum and maximum values, respectively. The evaluation assigned to each key factor quantifies the level of integration within the PDP actually reached by each company.

The Figures 4 to 8 present graphical representation of the evaluation given to each key factor.

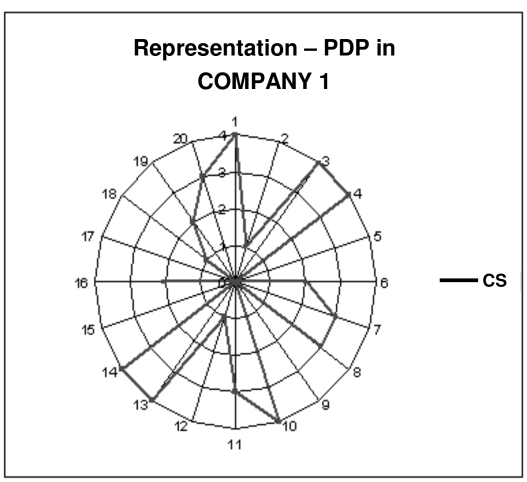

Figure 4: Results for company 1.

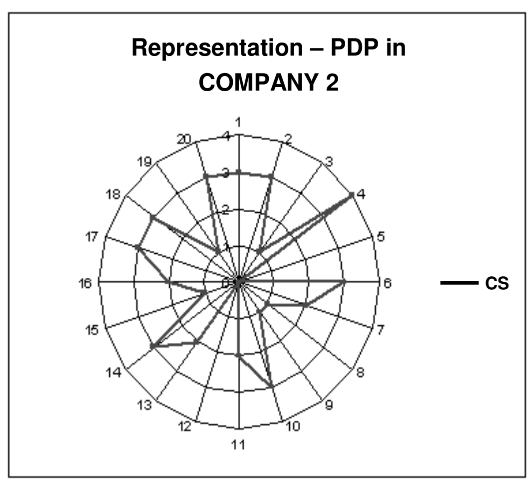

Figure 5: Results for company 2.

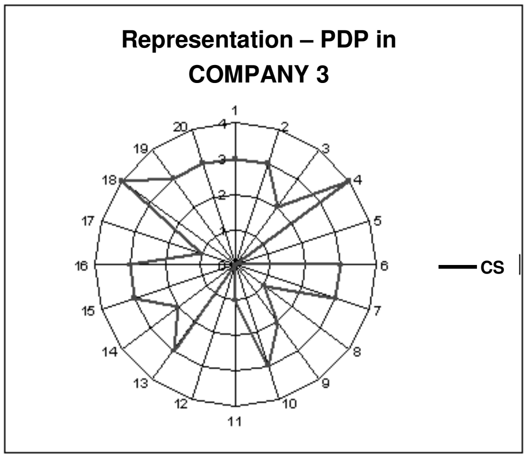

Figure 6: Results for company 3.

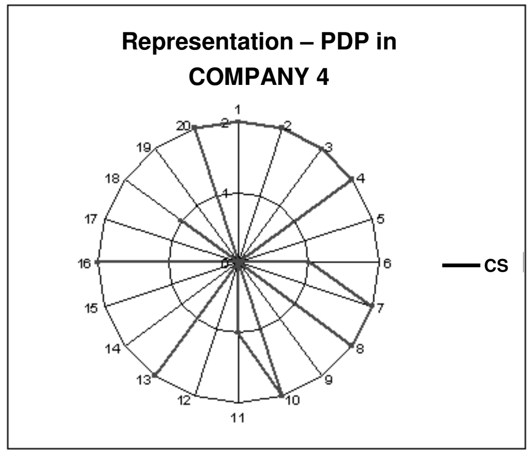

Figure 7: Results for company 4.

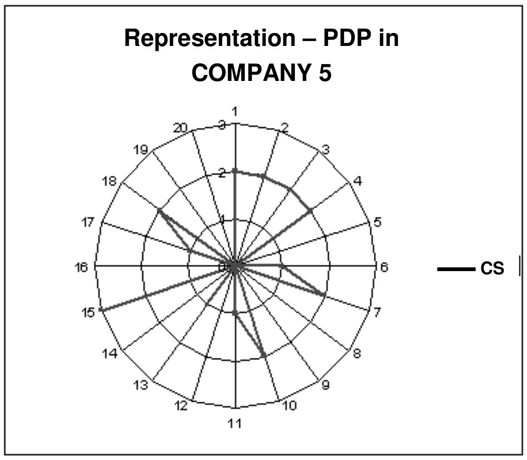

Figure 8: Results for company 5.

6 CONCLUSIONS

This case study modeled the performance of the PDP in the Metal mechanics sector in Barranquilla-Colombia.

Based on the PDP in the five-company sample, relevant results are:

- IDEF0 technique has been a good tool to illustrate functions, phases and activities within the PDP that helped communications among the multidisciplinary team.
- Just three companies consider executing activities simultaneously (always that possible). Just one of the three companies had previous, formal knowledge of this analysis coming from CE. This company commented having experienced a reduction of the time of response and an improvement of the utilization of resources required in the PDP.
- All five companies tend to establish multidisciplinary teams for the PDP. Just one company establishes a team for the PDP including members from areas related to the process, having them participating actively even if they participate in some other teams for some other projects within the company. Two companies establish temporal (heavy) teams. This means that some of the initial members of the team for the PDP do not participate all the way until the end of the process. Instead, they are consulted whenever it is necessary, while they work on their regular, daily functions.
- Just one company presents multidisciplinary teams supported 100% by the Board Committee. This means that the team receives autonomy for making decisions related with the project in the PDP. The other four companies establish multidisciplinary teams, but members are allowed just to formulate possible sceneries for making decisions. Final decisions are made by the Board Committee of each company.
- Just one company involves partially its suppliers in the PDP. The other four companies present weakness for evaluating and selecting suppliers. After selecting them (based on an informal way, based on previous experiences), these suppliers do not participate in the Planning and Design phases in the PDP.
- None of the companies recognized either the existence or the advantages of QFD, DFX, FEMA and so forth as methodologies based on knowledge, oriented to support and improve the results obtained in the Design phase.
- The five companies count on technology for Design, but just two companies have integrated them to the multidisciplinary activity in the PDP. Just one company presents a high evaluation regarding the acquisition and utilization of this type of technology.

The results of this research have helped the companies to have methods to identified opportunities of improvement through detail performance measurement.

In addition, activities modelling using IDEF0 aided to have an enhanced structure of the key activities involved in product design and development. Furthermore, the analysis of the current practice helps to identify then introduce new practices into their product design and development. Such practices are multidisciplinary teams, Quality Function Deployment (QFD) and Design for Manufacturing and Assembly (DFMA). This assisted the participating companies to have a better understand of customers' need and then translating them into product design. At the same time, gaining a deeper understanding of the impact of process and resources capabilities on product design and supporting more effective DFMA consideration.

7 ACKNOWLEDGMENTS

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