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The uses and users of design process models in organizations

Os usos e usuários de modelos de processo de design em organizações

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EPIGRAPH

"In a decaying society, art, if it is truthful, must also reflect decay. And unless it wants to break faith with its social function, art must show the world as changeable. And help to change it."

Ernst Fischer

ABSTRACT

COSTA, D.G. **The uses and users of design process models in organizations.** 2016. 101f . Thesis (Master's degree) – Engineering School of São Carlos, University of São Paulo, São Carlos, 2016.

The use of design process models is of great importance for developing better products. Indeed, it is one of the factors that may differentiate the best companies from the rest. However, their adoption in companies is declining. Usefulness and usability issues may be responsible for process models not to meet the needs of its users. The goal of this research is to provide deeper understanding of the users' needs of design process models. Three main perspectives are provided: (1) why organizations use process models, (2) who are the users of process models, and (3) how the context of use of process models is. The research methodology adopted was the Design Research Methodology (DRM). Three stages were performed: (i) Research Clarification, (ii) Descriptive Study I, and (iii) Prescriptive Study. In the first stage, an initial literature review was carried out to collect evidences of why researching process models and their users' needs is relevant for the design theory. During the second stage (Descriptive Study I), literature was reviewed to identify the purposes of use of design process models and its potential users; a focus-group section with 24 subject matter experts was carried out to evaluate these purposes and identify process model users; and, lastly, a case study was perfomed to investigate the context of use of design process models in one organization and to portray the profile of the core users. Finally, the third stage (Prescriptive Study) aimed to uncover directions for organizations develop user-centered design process models. Four main results were achieved through this research. The first result is a deep understanding of three types of application of the design process models: (a) develop the design activity, (b) manage the design project, and (c) improve the design process. The purposes for these aplications were investigated and their level of importance were revealed. In addition, it was mapped the core users of process models for the three applications. The second result is the definition of the context of use of the models.Three dimensions of the context were depicted: the product, the design process, and the organizational structure. The third result is the set of users profiles. Empathy Maps were elaborated to represent the profiles of product engineers, project managers, and technical leaders. The last result consists in recommendations regarding the content provided to users and the process models system design. Finally, industrial practitioners will benefit from this research once it was provided evidences that the activity development application type is not properly considered in organization and that important users' needs are not getting proper attention in the current models. Therefore, they will be able to make use of the recommendations outlined here.

Key-words: Design process models. Contextual design. Business process management

RESUMO

COSTA, D.G. **Os usos e usuários de modelos de processo de design em organizações.** 2016. 101f . Dissertação (Mestrado) – Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos, 2016.

O uso de modelos de processo de design é de grande importância no desenvolvimento de novos produtos. De fato, isto é um dos fatores que pode diferenciar as melhores empresas das outras. De qualquer modo, a adoção dos modelos nas empresas esta declinando. Problemas em utilidade e usabilidade podem ser responsáveis pelos modelos não satisfazerem as necessidades de seus usuários. Nesta pesquisa, busca-se entender as necessidades dos usuários dos modelos de processo de design. Três perspectivas são dadas: (1) porquê organizações usam modelos de processo, (2) quem são os usuários dos modelos de processo e (3) como é o contexto de uso de modelos de processo. A metodologia de pesquisa adotada foi a Metodologia de Pesquisa em Design (DRM). Três estágios foram realizados: (i) Clarificação de Pesquisa, (ii) Estudo Descritivo I, e (iii) Estudo Prescritivo. No primeiro estágio, uma revisão inicial da literatura foi executada para coletar evidências do porquê estudar modelos de processo e as necessidades de seus usuários é relevante para a teoria de design. No segundo estágio (Estudo Descritivo I), revisão da literatura ajudou a identificar os propósitos de uso de modelos de processo de design e os seus potenciais usuários; uma seção de focus group com 24 especialistas no assunto foi executado para avaliar estes propósitos e identificar usuários dos modelos de processo; e, por fim, um estudo de caso foi realizado para investigar o contesto de uso dos modelos em uma organização e para retratar o perfil dos usuários principais. Finalmente, o terceiro estágio (Estudo Prescritivo) buscou revelar direções para que as organizações desenvolvam modelos de processo de design centrados em seus usuários. Quatro principais resultados foram alcançados por meio desta pesquisa. O primeiro resultado é um entendimento profundo dos três tipos de aplicação dos modelos de processo: (a) desenvolver atividade de design, (b) gerenciar o projeto de design, e (c) melhorar o processo de design. O propósito destas três aplicações foram investigadas e os níveis de importância evidenciados. Além disso, os usuários centrais dos modelos de processo foram mapeados. O segundo resultado é a definição do contexto de uso dos modelos. Três dimensões do contexto foram retratados: o produto, o processo de design, e a estrutura organizacional. O terceiro resultado é o conjunto de perfis dos usuários. Mapas de Empatia foram elaborados para representar os perfis de engenheiros de produto, gerentes de projeto, e líderes técnicos. O último resultado consiste em recomendações feitas a respeito do conteúdo fornecido aos usuários e o sistema a ser desenvolvido. Finalmente, profissionais da indústria podem beneficiar desta pesquisa uma vez que evidências são fornecidas de que a aplicação de desenvolvimento das atividades não é adequadamente considerada em organizações e que necessidades importantes dos usuários não recebem atenção satisfatória nos modelos atuais. Sendo assim, eles serão capazes de fazer uso das recomendações aqui feitas.

Palavras-chave: Modelos de processo. Design contextual. Gestão de processo de negócio

FIGURES

TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

PDMA – Product Development and Management Association

DP – Design Process

DRM – Design Research Methodology

DS-I – Descriptive Study I

BPM – Business Process Management

PM – Project management

SUMMARY

1 INTRODUCTION

1.1 Context and gap

In the context of organizations, the design process is an end-to-end business process consisting of mainly intellectual and organizational activities, in which companies transform market opportunities and technical possibilities in information so that the product or service can be produced and delivered to customers (Clark & Fujimoto, 1991; Robert Gravlin Cooper, 2001). The design process is associated and connected to other business processes within any given organization and its value chain.

The design process can often be characterized as a complex and iterative process dealing with ill-defined problems, This is what distinguishes it from other more repetitive business processes, and also it is why is particularly challenging to develop design process models (Maier & Störrle, 2011).

Process models formalize and recommend practices for a domain through representations of a given process providing support for the ones involved in it (Browning, Fricke, & Negele, 2006). In organizations which develop products, the adoption of formalized design process models enables the use of available methods, tools, and activities to shape the process within the company across different projects.

Product Development and Management Association (PDMA) surveys have shown that using formal, cross functional process models containing good practices of design raises the odds of developing better products (Barczak, Griffin, & Kahn, 2009; Markham & Lee, 2013). In contrast, Markham & Lee (2013), when comparing the results of adoption of design process models in 2003 and 2012, reveal that more companies are using informal processes or no process model at all, as well as the use of a cross functional approach is shrinking. Design process models are being used less and less in organizations, even though their adoption improves the results of new product development.

Process models may be discredited because of bad-use, hence bad-design. If a model does not represent the process as perceived by a user the model might be perceived as inadequate, wrong or simply not useful. Gericke and Blessing (2012) encourage better understanding of the needs of product engineers, project managers and other users of design process models to develop design support. Badke-Schaub, Lloyd, van der Lugt, and Roozenburg (2005) also point to the same direction; they affirm that understanding the individuals' characteristics and design process context must be considered to analyze the shortcomings of the available design methodologies.

When creating design process models for the use within organizations, process owners select perspectives of the process to be represented, and in the other end, users of the model interpret

this model according to their goals and background (C. M. Eckert & Stacey, 2010). Among the fundamental concepts of developing design process models it may be understood that this process can never be “fully mechanized” and should rather be outlined “purposefully and intelligently” (Browning et al., 2006).

Purposes represent the intended use a design process model view is created for (Browning & Ramasesh, 2007). Users or group of users access the information about the design process through different views of the reference model (Browning, 2009, 2010; Rosemann, 2003). The combination of model purposes and users’ needs – which are associated to the user’s characteristics and the context of use – lead to the model requirements, which design process model views must attend to – see Figure 1.

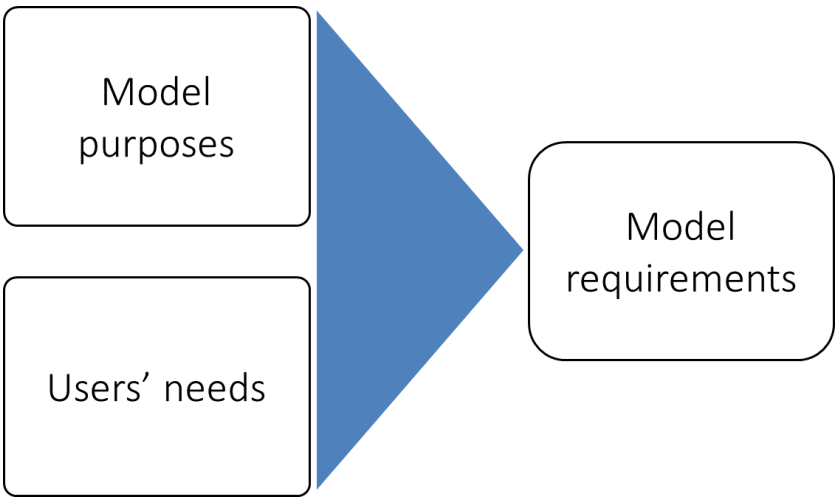

Figure 1 – Model requirements based on purposes and needs of users

There are some ways to interpret model requirements. Besides the definition of the modelling method to develop design process models, two concepts emerge when evaluating user-centered systems: usefulness – related to the fit between content provided and user needs – and usability – related to system’s ease of use (Tsakonas & Papatheodorou, 2006). Defining the content requirements and system requirements may occur prior to the definition of modelling notation and semantics in the process model domain.

Human centered environments leads to process innovation based on mutual benefits for organization and workforce goals (Dul & Neumann, 2009). User-centered models must improve the organization capacity of developing better products by facilitating its use.

1.2 Goals and conceptual model

As presented, design process models must be reviewed so they can attend its users. Investigating the purposes of use and the ones who use them are of vital importance to achieve it. This way, the two complementary goals of this research are:

- to describe the purposes for developing design process models in organizations;
- to identify users' needs on design process models in organizational context.

The theoretical conceptual model of this research is presented in Figure 2. The relevance of process models is grounded by Business Process Management (BPM) theory. According to this theory, the representation of process ensures that they can be managed, controlled and improved. In fact, there are other complementary reasons for creating representations of processes. In the case of the design process, it is well know how challenging and time consuming is to develop process models. Therefore it is highly recommended to clearly define the purpose of their development, e.g. develop activity, manage the process, improve the process.

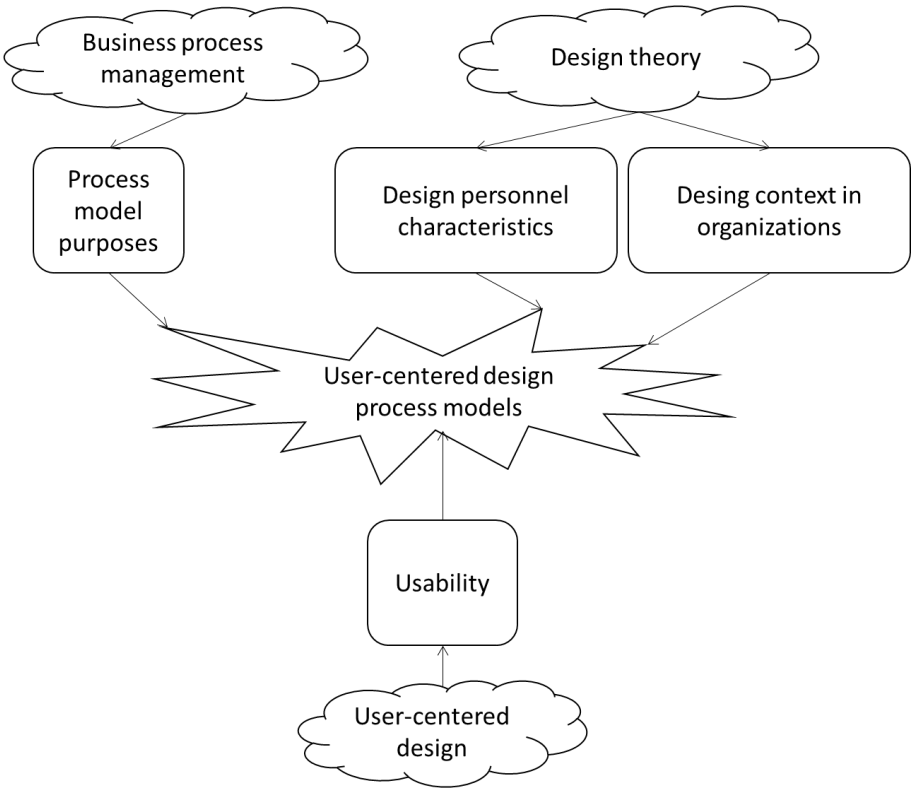

Figure 2 – Conceptual model adopted in this study

The Design theory provides evidence that should be taken into account when creating process models for this domain. During the design process, many people from different disciplines and with different knowledge maturity level regarding the design process are involved. It is assumed

that it is important to understand these differences and, moreover, to understand that the design context can vary significantly from organization to organization. In other words, one size doesn't fit all, therefore the comprehension of the people and the context of design should be taken into account.

Finally, the User-Centered Design (UCD) theory brings out the importance of improving process models usability. UCD is applied in this research to explore the requirements of design process models and provide recommendations towards more user-centered ones.

The focus of this research is large, international organizations which usually present significant process model maturity and high quantity of employees involved on developing new products and/or services.

1.3 Research methodology

This research is based on the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti (2009), which after the definition of research goals, can be used to iteratively describe the understanding of the problem, provide solution to this particular problem (based on gathered experience) and evaluate the provided solution.

In this dissertation the focus is on providing a comprehensive description of purposes of process models and users' needs. This will guide the initial prescriptions presented as recommendations. Research goals, the scope of this research and research steps to achieve it – as presented in Figure 3 – are defined through the literature review on A1.1 as part of the Research Clarification phase.[1]

The comprehensive Descriptive Study I (DS-I) consists of literature review and the involvement of design process models users through the use of contextual design techniques.

Literature provides basis for the application types of design process models and related purposes providing a model-centered point of view on A2.1. Three main applications are considered on shaping the design process and guiding a design project: improve the design process, manage the design project, and develop design activities.

Taking a user-centered point of view, a literature review of how generic design process models address the workforce involved in the design process/projects and of empirical studies of design process models users is performed on A2.2. It provides foundation to identify the users' characteristics and to elicit the roles involved into the process.

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[1] See Appendix 1 for methodological aspects of this research. The use of the Design Research Methodology in this research is explained.

On activities A2.3, and A2.4, two empirical studies are carried out. The first one makes use of the purposes elaborated for each application type and the roles identified on activities A2.1 and A2.2. It consists in specifying which user uses each function of the process models. The second empirical study, developed on A2.4, aims to expand this functional view of design process models by considering its context of use.

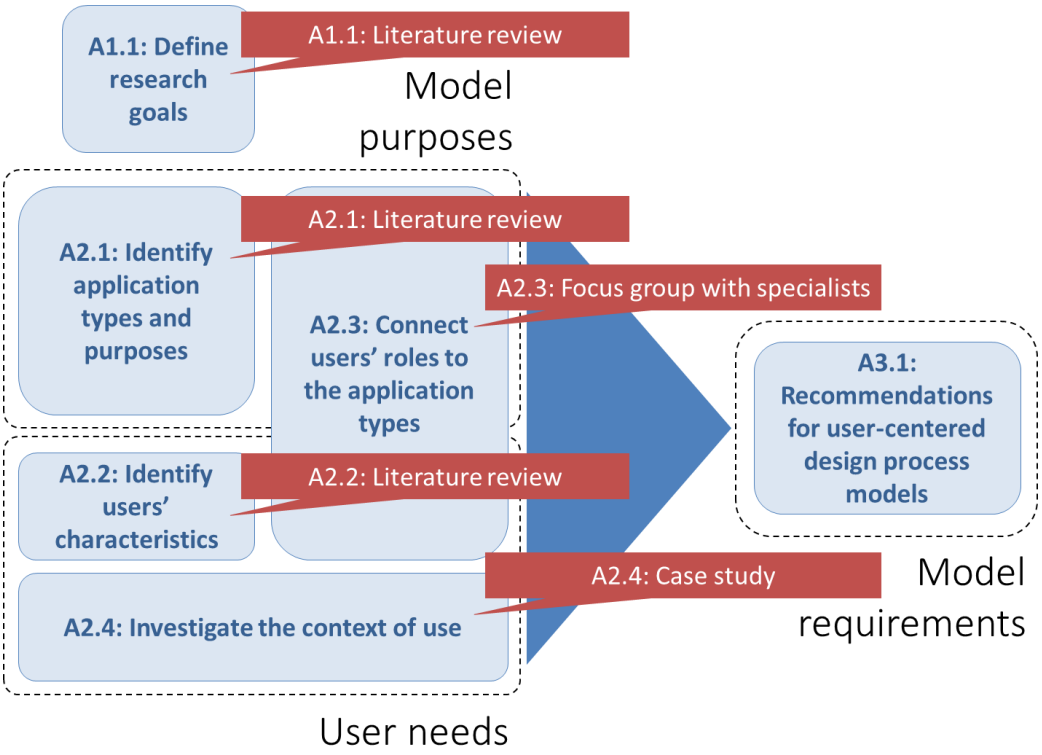

Figure 3 – Research steps and methodological procedures used

Considering that this research aims to elicit requirements of user-centered design process models, contextual design techniques are used on the two qualitative studies performed.

The first empirical study is based on a focus groups session with 24 specialists on product development. Executive managers, operational managers, and design engineers from 10 companies evaluated the purposes and users of design process models through the use of card sorting technique. The session's name was 'Engineering design process models: who uses them? For what purpose?'. Most of the companies used a formal, cross-functional process model.

The focus group was divided into three steps:

1. Purposes of use – Participants evaluate the contribution of each purpose when using design process models;
2. Design process models users mapping – Participants establish the core users of design process models;

3. Users vs. application types – Participants connect the users to the types of application proposed.

The second empirical study is based on a case study performed in an organization with cross-functional and formalized design process models. The users of design process models were investigated in an organizational context when managing the project and developing the design activity. In total, 10 design team members were interviewed. User profiling and contextual inquiry techniques were used to consolidate and analyze design process models requirements. The product, design process, and organizational structure were considered in this context.

Observation and interview protocols were created for both qualitative studies. Observers were also assigned. Notes taken, discussion and reflection provided insights throughout the research process.

An initial Prescriptive Study (PS) is performed on A3.1 and provides recommendations for user-centered design process model views.

1.4 Dissertation structure

The literature review, which comprises activities A2.1 and A2.2 is presented in Section 2. The application types are elaborated and purposes are discussed. Characteristics which are considered to be important when using design process models are presented.

Section 3 comprises the activity A2.3. It presents the focus group with specialists using card sorting technique to connect the users to the application types and define its functions.

Section 4 comprises the activity A2.4. It presents the case study using user profiling and contextual inquiry to describe the context of use of design process models.

Section 5 comprises the activity A3.1. It provides recommendations to develop user-centered design process models in organizations.

2 LITERATURE REVIEW

Process models are representations of reality and are incomplete by nature. Process modeling was initially largely used to implement IT systems for Enterprise Resource Planning (ERPs), which requirement are well defined and aimed to automate repetitive activities (Davenport, 2005). The diffusion of business process management brings the necessity to manage less automatable processes, as the design process, through process models.

This research aims to bring human and contextual necessities to connect to the functional point of view of design process models. Design process models may be represented in different manners according to the purpose of use and to needs of the ones who will use it.

In the literature review application types are proposed for design process models, which are used to analyze existing purposes in literature. Finally, characteristics of users which may influence the use of models are identified.

2.1 Design process models application types

Roughly, reference models for the design process present a sequential approach of a combination of stages and/or activities (Blessing, 1996). Both in literature and practice, there are descriptive or prescriptive models: while descriptive models characterize how design actually happens throughout the process of developing products, prescriptive models are recommendations of specific steps and practices for the design project (Blessing, 1996; Wynn & Clarkson, 2005). Descriptive models are useful if something can be learnt from them. Prescriptive models are useful if they provide guidance for proper navigation and instantiation of more detailed models such as reference processes and project plans.

As represented in Figure 4, Gericke and Moser (2013) classifies design process models into different levels based on the detail they provide and context dependency of the model. Four levels are used in this research: Generic level, organization/branch specific level, project level, and activity level. Generic process models can be instantiated into domain or company specific design process models. In turn, these instances can be deployed into project plans and activity models, which represent the highest level of detail of the design process. These four levels are further developed:

- Generic design process models: normally developed by experts, researchers, or design process institutions, these define a set of phases, activities and strategies for performing activities which may be used as benchmarking for an organization or for learning purposes;
- Specific design process models: domain specific design process models are normally developed by an institution that represents an industry and provide standards on the

process/product for compliance; organization specific design process models formalizes the practices used by a company through the design phases guiding design team members through projects;

- Design project process models: represents project plans to support management of a product / service development;
- Design activity process models: represents the problem solving component for a specific activity to develop a product;

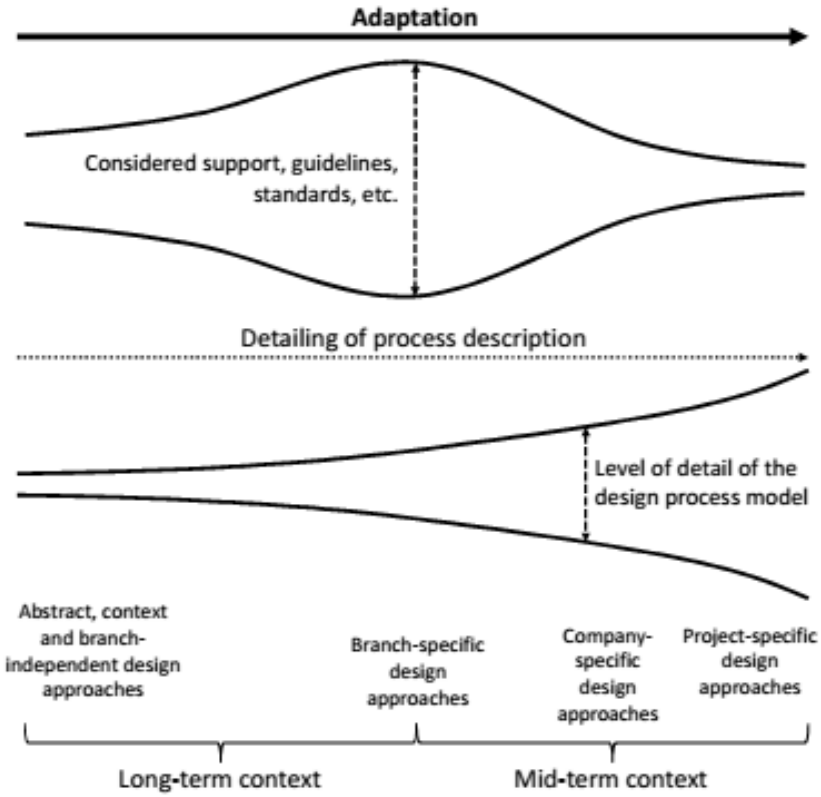

Figure 4 – Adaption of design process models (Gericke & Moser, 2013)

When discussing and modeling the design process in organizations two perspectives may be intertwined: the process perspective and the project perspective. The first one requires the management of the design process through business process management (e.g. Rozenfeld, Amaral, da Costa, & Jubileu, 2009). The second requires support from program/project management knowledge area (e.g. Oehmen et al., 2012, p. 4) and continuous solution of design problems (e.g. Gero, 1998).

Analyzing the four levels of design process models on the process and project perspective, three application types for design process models are explicit[2]:

- Develop the design activity: in which users access relevant information to perform activities. The objectives are twofold: these information may define which activities to perform and their deadlines; and it may define work instructions and methods to be used;
- Manage the design project: in which users delineate the design project plan, through determining main activities, resources and decision points for the projects. The plan, which may be modified during the project, is central for project communication and monitoring;
- Improve the design process: in which users update the organization specific design process models. This may occur by the use of one or more generic process models and/or by evaluating of the as-is situation of the design process and incorporating lessons learned from projects and activities.

On the activity development, the co-evolution of understanding the problem and developing the solution to a design problem is a "central pattern" of the design process (Cross, 2001). Iterations on analysis, design, prototype and test cycles are necessary to explore the possible problem understanding and solution generation. Activity cycles are performed throughout the phases of a design project (Blessing, 1996).

In initial phases, when the design problem is still ill-defined[3], design activity development involves substantial effort in problem structuring rather than accepting a problem 'as given'. This way, it is common to define these wicked, ill-defined problems only by using ideas, possibilities for solution (Cross, 2001). On later stages, after defining a concept, activity cycles focus on more logical activities (Dorst & Dijkhuis, 1995), e.g. detailing systems, subsystems and components providing guidelines towards mass production.

On the project management, planning may occur at the beginning of a project, i.e. initial planning, and throughout the project, i.e. dynamic planning, when the initial plan needs to be modified in response to new events (O'Donovan, Eckert, Clarkson, & Browning, 2005). The project plan represents a particular project, containing relevant practices and deliverables which match the specific product under development.

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[2] Training new organization members, serving as a framework for metrics, and auditing and assessing the process are also possible applications for design process models according to Browning (2002) which were not considered as central for this research.

[3] Design problems are often understood as versions of Rittel and Weber's definition for 'wicked', ill-formulated social system problems, a kind of problem which is never solved – at best it is re-solved over and over again (Rittel & Webber, 1973).

The design process is associated and connected to other business processes within an organization and its value chain. These other processes have different characteristics, require different levels of support and influence design decisions (C. Eckert & Clarkson, 2005). Project plans must provide coherence to the project team.

For process improvement, specific design process models can be obtained through the adaption of generic one(s) and/or through the analysis of the current design process (as-is situation) (Rozenfeld et al., 2009, p. 136). The current process might be already a formalized process, that is, a specific reference model, or an *ad hoc* process, which is a process that still needs to be modeled (Amaral, Rozenfeld, Costa, Magon, & Mascarenhas, 2011, p. 2). No matter what form the specific process is obtained, its development promotes a continuous process improvement initiative. Improvements are uncovered through analyzing how work is done in the design project through modeling it and, incorporating new practices or suppressing non-added-value activities (Pádua, Costa, Segatto, Júnior, & Jabbour, 2014, p. 250).

On improving the design process through the adaption of one or more selected generic design process models, Fettke et al. (2006) points two main tasks: selection a reference model and adaptation of this model to the organization. Based on these tasks, Costa et al. (2015) provides a classification scheme to support process improvement, which evaluates the content, level of detail used, and the support for implementing design process models.

These three types of application presented are extensively used in this research.

2.2 Design process models purposes

As early presented, purposes connects design process model views to the users' needs. In this section we identify and review relevant literature of purposes for design process models connecting to the three application types proposed.

Through a comprehensive literature review aimed on finding the support of design process models to project managers, Browning and Ramasesh (2007) presents four categories of purposes for modelling the design process: project visualization, project planning, project execution and control and project development. These categories are developed into purposes in form of research questions and references for discussing each one.

Later on, Browning (2010) develops these purpose categories based on a case study through interviewing 12 members of an organization looking for connecting the process models to managerial decisions. A final list containing 28 purposes is proposed on his work. Both mentioned articles explicitly focus on managers' needs on design process models.

Using the definition provided on section 2.1 for the three proposed application types we have analyzed the final list of purposes presented by Browning – see Table 1. As expected, most (14) of the purposes are related to Project management, a considerable amount (9) of them are related to Process Improvement, and some (5) relates to Activity development. Furthermore, three of the purposes related to Activity development (IDs 26, 27, and 28) are related to auditing the process, which may be considered as post-development actions.

Table 1 – Classification of purposes defined by Browning (2010) according to the three application types

ID	Purpose	Application type
[01]	Define standard and preferred activities	Process improvement
[02]	Define standard deliverables and quality standards	Process improvement
[03]	Define standard handoffs and structure standard work flow	Process improvement
[04]	Define standard tools and templates	Process improvement
[05]	Define standard staffing, roles, responsibilities, and skills	Process improvement
[06]	Visualize, understand, analyze, and improve processes	Process improvement
[07]	Identify ‘‘ripple effects’’ of process changes	Process improvement
[08]	Organize knowledge about work	Process improvement
[09]	Tailor the standard process to suit project requirements.	Project management
[10]	Filter activities and deliverables (by hardware vs. software, project size and phase, contract type, etc.)	Project management
[11]	Associate processes with elements of the project’s work breakdown structure (WBS)	Project management
[12]	Identify appropriate activities and deliverables for the project.	Project management
[13]	Import deployed process activities into a project scheduling tool	Project management
[14]	Define deployed deliverables and quality levels	Project management
[15]	Choose tools and templates	Project management
[16]	Set project schedule and secure formal commitments	Project management
[17]	Identify skill (or clearance) gaps in the workforce	Process improvement
[18]	Estimate project time, cost, quality, and risks	Project management
[19]	Allocate resources	Project management
[20]	Visualize planned work flows and integration points	Project management
[21]	Assign activity roles and responsibilities (staffing)	Project management
[22]	Monitor project status in terms of activities and deliverables	Project management
[23]	Renegotiate commitments where necessary	Project management
[24]	Access knowledge about activities, tools, and deliverables	Activity development
[25]	Deposit lessons learned	Activity development
[26]	View practices relevant to a given standard	Activity development
[27]	Confirm performance of requisite practices	Activity development
[28]	Confirm production of appropriate deliverables	Activity development

Apart from the purposes related to auditing the process, only two purposes for using process models related to design activity development are available in Browning (2010): ‘access knowledge about activities, tools, and deliverables’ and ‘deposit lessons learned’.

We claim a lack of focus on the Activity development application. If the purposes for activity development are not taken in consideration nor prioritized, probably the reference model will be useless for a portion of the users. This way, we intend to develop purposes for the three application types aiming to connect the many levels of design process models. The focus group with specialists is used for this aim and further can be found on section 3.2

2.3 Design process models users’ characteristics

It is necessary to accommodate different user’s perspectives when developing decision support systems and management information systems (Bucciarelli, 1988). Badke-Schaub et al. (2005) proposes the human centered network of designing to adjust design methodologies to ones that applies them. This network suggests that the characteristics of individuals must be taken in consideration along with group and organization context to improve support through the process of designing. Design process models users’ characteristics may be organized to help formalize the necessities of users relevant to these models.

Literature reviews are recommended by Blessing and Chakrabarti (2009) as a good mean to define and understand factors for improving support for the design process. We focused on researching the design personnel considering two research questions:

- Which characteristics of the design personnel as users of design process models should be considered?;
- Which needs each of these characteristics brings on developing design process models?

The analysis in this research is based on a literature review of two different kinds of sources: (1) generic design process models in sections which discuss design team members and (2) empirical studies of the design process.

The use of an inductive approach is recommended by Nickerson (2012) when classifying objects of interest based on common characteristics. The coding process for classifying the empirical studies emerged when reviewing the twenty studies:

- Conceptual - In which patterns and concepts of the design process are presented;
- Organizational - In which the findings were related to organizational factors as size of organization or comparing different projects;
- Cross-disciplinarity - In which different domains of the design process were analyzed in different levels of abstraction;

- Design expertise - In which comparison of novice and expert design team members are presented and the way they experience the process.

Few of the reviewed empirical studies were directly related to the adaptation or use of different levels of the design process models. Most of them presented aspects of the proposed classification with no reference to design process models.

Grounded on the review of generic design process models in sections which discuss design team members we discuss the roles individuals perform in the process as major influencers in their needs as design process models users. Roles connect the organizational and multidisciplinary viewpoints of this research. The definition and discussions of this characteristic is provided on section 2.3.1.

Grounded on the empirical studies review, two types of level of expertise are presented as relevant characteristics: the design activity development expertise and the design project management expertise. These two kinds of expertise connect the multidisciplinary and design expertise viewpoints of this research. Definitions and discussions of these two characteristics are presented on sections 2.3.2 and 2.3.3.

2.3.1 Roles of design process models users

People from distinct areas are involved in the process of developing new products, not only engineering. Apart from the core team, support processes as quality, finance and sales are involved on virtually every design project. Each one involved in a design project depends on results produced by other members. Pahl et al. (2007, fig. 4.5) [4] show the engagement of organizational members across the different stages of a design project: project teams, which are temporary, are responsible for developing the products; on the use phase, continuous processes are vital to manage the life cycle of products and to keep close contact with clients.

The composition of design teams varies according to the design problem, which determines the centrally involved disciplines (Pahl et al., 2007; Ulrich & Eppinger, 2012). Members of the design team from different disciplines engage in different stages of the design process and make decisions in different ways (C. Eckert & Clarkson, 2005). Differences between disciplines as the uncertainties in their activities and type of decision making each perform are presented by Eckert and Clarkson (2005, fig. 7). The perception of the process by team members are influenced by the type of activities which are under their responsibilities. Key activities of different disciplines across design stages is shown by Ulrich and Eppinger (2012, fig. 2.7).

[4] Most of the figures indicated in the references are available in the Annex

As a cross-disciplinary process, the organizational structure influences the roles and responsibilities throughout the design process. Lightweight project organization / team structure, heavyweight project organization / team structure, or project organization / teams are presented by Wheelwright and Clark (1992, fig. 8.1) and Ulrich and Eppinger (2012, fig. 2.8) as possible organizational structure which specifies responsibilities for the one involved in the project. While functional-oriented organizations may achieve deep specialization and have problems in coordinating members from different groups, project-oriented organization may easily allocate resources while having trouble to maintain technical knowledge created.

According to organizational structure and to product complexity, function boundaries may be surpassed. In the other hand, the responsibilities are stable along different organizations and contexts. This way, roles are the chosen characteristic to be connected to the application types in the focus group with specialists on section 3.3.

2.3.2 Design activity development expertise

On activity development, one possible spectrum to understand the differences regarding disciplinarity is if the designer comes from a technical field, such as mechanical engineering, electrical engineering, software design or a subjective field, such as architecture, industrial design and user experience design. Stacey et al. (2002) point out that while designers with a background in a technical area are less prepared for the conceptual thinking involved in designing, those that are 'subjective' designers may fail to face the problem solving characteristics of designing. Some designers may be more prepared to think in concepts of products while others may be more familiar to think in functions.

Cross and Roozenburg (1992) state that the differences between the cognitive styles of technical and subjective designers arises from the science-based education given for engineers and art-focused education given for industrial designers and architects. Different traces of personality may be also apparent when comparing them, see Durling et al. (1996). Technical people may be more used to structure information to perform design activities, while subjective people may be used to abstraction.

This is also apparent on generic design process models: the models from technical fields like engineering design tend to focus on the sequence of stages of the design process, while the models from subjective fields emphasize the way designers think while developing a solution (Cross & Roozenburg, 1992). Technical designers could make use of the content of subjective design process models and vice versa. Process models in organizations must both fit the sequence design stage approach as well as the support for conceptual thinking in activity development according to the type of problem design personnel have in hand.

The behavior of design team members may change as they gain expertise on specializing a certain discipline and working in a related field. Cross (2004) shows common behavior of

designers from different levels of expertise: while expert designers are able to use their experience in an specific field/domain using solution principles to alternate between ‘breadth-first’ and ‘depth-first’ approaches to perform the design activity[5], novice designer tend iterate using a trial and error approach. In addition to provide proper knowledge and information, design support methods should inform novice designers on strategies for approaching the design activity (Ahmed & Wallace, 2003). While novice may need detailed guidelines for their activities, more experienced design team members may need help on organizing principles of solution they already know when designing.

The gain of design expertise passes through different phases (Cross, 2004) and may not be a gradual process (Dorst, 2008). It may be important to guide design personnel to evolve through the different levels of expertise. A model of design expertise levels is presented by Lawson and Dorst (2005) in which 'an acquisition of a certain amount of knowledge or experience enables a new way of operating or perceiving'. This model, which contains eight levels, is also addressed by Dorst (2008) and Eder (2009):

1. Naive - Still do not understand design as a sequence of activities. Treat design as a solution they want to try for a design problem;
2. Novice - Tend to follow strict rules when designing. Novices are starting to classify generic principles and increasing knowledge on the specific language, symbols and models of their field;
3. Advanced Beginner - Getting habituated to exceptions to the strict rules for designing. There is a fair knowledge regarding the language, symbols and models of their field, making them capable to discuss and criticize design solutions;
4. Competent / Proficient - Able to understand the needs of their users and create plans to achieve goals. Competent design team members focus on incremental development of products. Some people may be resigned on achieving this level of expertise and avoid further challenges.
5. Expert - The many years of experience and involvement on the design field helps to develop heuristics to approach design. Are able to recognize design patterns and respond intuitively. May be great tutors for lower levels design team members.
6. Master - A development of the expert, which can understand the logical connections in the allegedly intuitive responses of an expert.
7. Visionary - Are usually interested on the margins of a domain and their work are usually extending it.

[5] In a 'breadth-first' approach the designer is able to work on a bigger picture of the design solution, while in a ‘depth-first’ approach the designer focus on identifying and developing sub-solutions in depth.

The different levels of expertise explicit a non-linear process: considerable amount of knowledge is necessary to pass the initial levels of expertise until the advanced beginner level. After becoming a competent designer, the mentality and motivation may be important to define the track taken by the designer, either: proficient, or expert/master, or visionary (Lawson & Dorst, 2005). Process models should be able to adapt to these different levels, both providing proper guidance according to user's level of expertise as to support moving from a naïve approach to design to further levels of design expertise.

The way design team members experience the process of designing may be critical to help them to gain expertise. Daly et al. (2012) propose the existence of ways of facing design (lenses) and reflecting on previous practices (experiences), which modifies the way one designs. Design lenses are shaped by past experiences and impact the approach taken on future designs, see Figure 5.

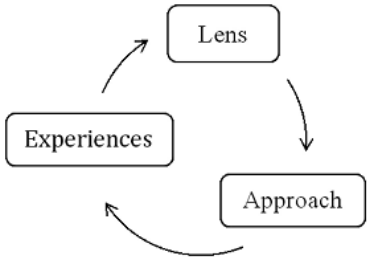

Figure 5 – Impact of design experiences, lens and approach (Daly et al., 2012)

Six different lenses are proposed. Although the learning progression is not clear, it is pointed out by the authors that each lens comprises the last, implying broader understanding of design:

1. Design as evidence-based decision making: Driven to find the best solution through the use of information from different sources and investigating various solutions;
2. Design as organized translation: Are now able to interpret the information and ideas towards a design solution by understanding how one influences others. It does not imply taking a step-by-step path;
3. Design as personal synthesis: Are now able to discuss their experiences and others' work. Make design choices through using intuition and personal repertoire to create something new from design ideas.
4. Design as intentional progress: Are now able to relate their experience to their field and society contexts, aiming at building on previous work and facilitating future contributions for a larger goal.
5. Design as creative exploration: Are now able to identifying new paths, taking calculated risks of exploring emergent ideas, thus creating room to explore the boundaries of designing;

6. Design as freedom: Designers now welcome ambiguity, perceiving boundaries and constraints as drivers for their free exploration towards design solution instead of limiting them.

Evidences show that the design activity development is faced differently by technical and subjective designers. This may be explained by how there are taught and the different contexts they are normally inserted. By any means, the development of expertise seems pass through specific phases which is nurtured not only by the amount of experience, but by the way one experiences design. Different levels of detail of guidance provided by design process models may be of interest for each level of expertise.

2.3.3 Design project management expertise

Project manager is a person or group of people responsible to lead the team towards project objectives (PMI, 2013). Managers are concerned about directing one or more projects efficiently by defining processes, selecting methods, allocating resources, facilitating communication, and coordinating and monitoring progress of activities (O'Donovan et al., 2005, fig. 2.4). Design project plans are used by project managers to fulfil their purposes. Engwall et al. (2005) have identified that managers may interpret a project plan in five different ways according to their conception of project management and use of models:

1. Administrating – Procedures standardize projects, which enables project management through plans;
2. Organizing – Good practices provides support for exploration, which enables cooperation through plans;
3. Sense giving – Common language provides the creation of a shared understanding on a chaotic environment;
4. Team building – Good practices provide focus enabling a motivating environment for the projects;
5. Engineering – Plans must present the technical reality. Procedures are seen as something bureaucratic and burdensome.

Models are, as well, created based on the conceptions of managers, whose capacity of adapting the organization model to a specific problem is central to success. If the project is seem as something bureaucratic, either the design process models are not adding value or the person involved is facing it wrongly. Engwall et al. (2005) proposes the conceptions of managers towards project management and the use of models must be considered and changed, if necessary. The set of conceptions may lead to selecting managers that better fits projects, and awareness of personal conceptions may lead managers to adapt when necessary.

Through any conception, design process models work as a common language for managers and designers so they can properly work together. Collaboration among design personnel with

complementary skills through the design process varies according to the mix of products and the ability to handle radical innovation of an organization (Sim, Griffin, Price, & Vojak, 2007). Design project managers be prepared and well supported to communicate with people from different backgrounds. They must be familiar to technical and branch specific terms and representation and include them on project plans and rituals.

Through analyzing the variation of languages used and acting by a group of designers in design meetings, Adams et al. (2009) proposes the existence of three modes of designing connecting different disciplines switching over the course of the design process:

- Interdisciplinary - individuals work together in a way that is not specific to any discipline, on an interdisciplinary manner;
- Multidisciplinary – individuals keep their disciplinary identity while working with others, in a multidisciplinary manner;
- Disciplinary - a single discipline controls individuals' actions.

Cross-disciplinary modes are inherent to the different stages of the design process: interdisciplinary mode to develop initial concepts and understand the design problem, multidisciplinary mode to select the concept, and disciplinary mode to develop and test iteratively the solution. Managers must conceive project plans to accommodate these different cross-disciplinary modes in order to better develop joint disciplinary products. In order to achieve cross-disciplinary practice, flexibility in languages must be encouraged (Adams et al., 2009).

The way managers face the models created for project management and their capacity to foment cross-disciplinarity through the project are competences which may be fostered by the use of design process models. Comparing it to design activity development expertise, it is not clear the evolution levels in project management expertise.

In the performed review, roles and levels of expertise in activity development and project management are characteristics which emerged from literature. Identify further characteristics and the ability to assess them in practice may lead to potential user profiles, which can be used to develop and continuously improve design process models.

3 APPLICATION TYPES PURPOSES AND USERS' ROLES IN ORGANIZATIONS

This chapter details the first qualitative study mentioned in section 1.3. The methodological support and steps taken to elicit knowledge from specialists on product development in organizations and analyze the generated information are presented on section 3.1. The outputs from the focus group with specialists are provided: the analysis of purposes pertinent to each application type, analysis of users according to their role into the design process associated to each application type, and expected benefits of using design process models are detailed in sections 3.2, 3.3, 3.4, respectively.

3.1 Focus group goals and description

This focus group is outlined to reinterpret the purposes of Browning (2010) and Browning and Ramasesh (2007) for the three application types and connect them to the roles performed in the process. The aims defined for this focus group with specialist are:

1. Verify relevance of identified purposes for the three application types in large, mature and international organizations which develops products in Brazil; and
2. Connect the roles taken by design personnel to the three application types.

Discussions were performed in one group meeting with 24 subject matter experts from automotive, aerospace, medical and white goods sectors (Table 2). Those experts were selected according to their experience in creating, managing and using design process models.

Table 2 – Participants of the focus group with specialist

Company	Sector	Company Size[6]	Member Function / Position
3M	Automotive	10,001+ employees	Project staff Technical manager Project staff
Bosch	Automotive	10,001+ employees	Project staff Project manager
Caterpillar	Automotive	10,001+ employees	Business manager Business manager Business manager
ZF	Automotive	10,001+ employees	Technical manager Project staff
Eaton	Automotive	10,001+ employees	Technical manager

[6] The company size follows the LinkedIn Standard.

Company	Sector	Company Size[6]	Member Function / Position
Dabi Atlante	Medical	501-1000 employees	Project manager Project staff
Embraer	Aerospace	10,001+ employees	Project staff Project staff Project staff
Natura		10,001+ employees	Technical manager Business manager
Prática	White Goods	501-1000 employees	Business manager Project staff
Tecumseh	White Goods	10,001+ employees	Business manager Technical manager Technical manager Business manager

Four steps were followed as depicted in Figure 6: warm up discussion; evaluation of purposes of use of design process models; design process models' user mapping; and evaluation of users according to application types. Card sorting technique was applied to assist knowledge elicitation from experts involved in the focus group. This technique is prescribed when the kind of information that needs to be organized is known and researchers need to understand how users would expect this information to be organized and terminology to be used (Kuniavsky, 2003).

Two card decks were created as illustrated in Figure 7:

1. Deck A containing 27 purposes related to each of the three types of application of design process models: 8 purposes for activity development, 10 purposes for project management, and 9 purposes for process improvement – different colors were used to represent each application type. Each purpose was described in the cards.

2. Deck B containing the roles each design process models user may perform through the process. 21 users roles collected from literature were included. The description of each user role was provided on the card back.

Purposes were elaborated grounded on the research questions presented by Browning and Ramasesh (2007) related to project visualization, project planning, execution and controlling, and process development were used. These suggested purposes were further compared to the ones available in Browning (2010) in order to achieve a list of purposes and associated descriptions to be used in the Focus group. A common terminology across the application types was sought through the use of process attributes identified by Rosa and Rozenfeld (2016) as activity, methods, deliverables and good practice. A consistent terminology is expected to help to connect the process, project and activity levels.

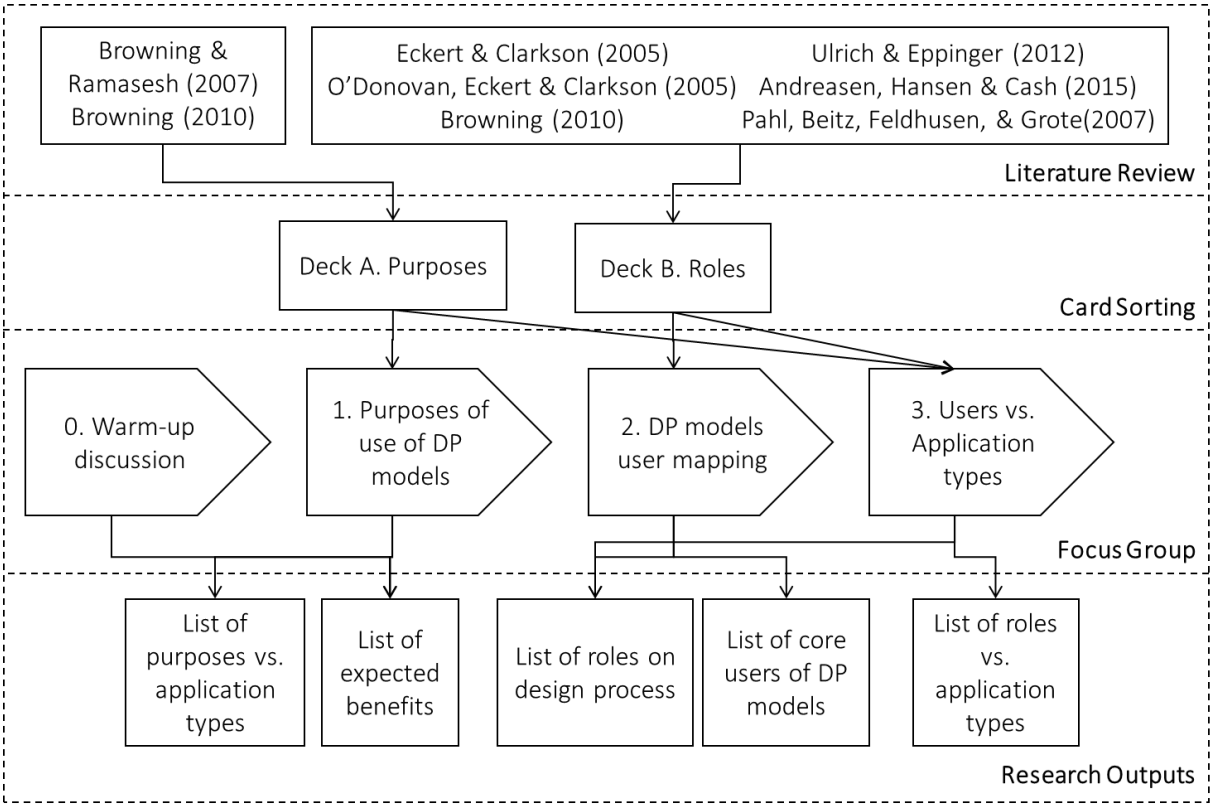

Figure 6 – Outline of qualitative study comprising the research inputs (through the use of card sorting technique), focus group steps and research outputs

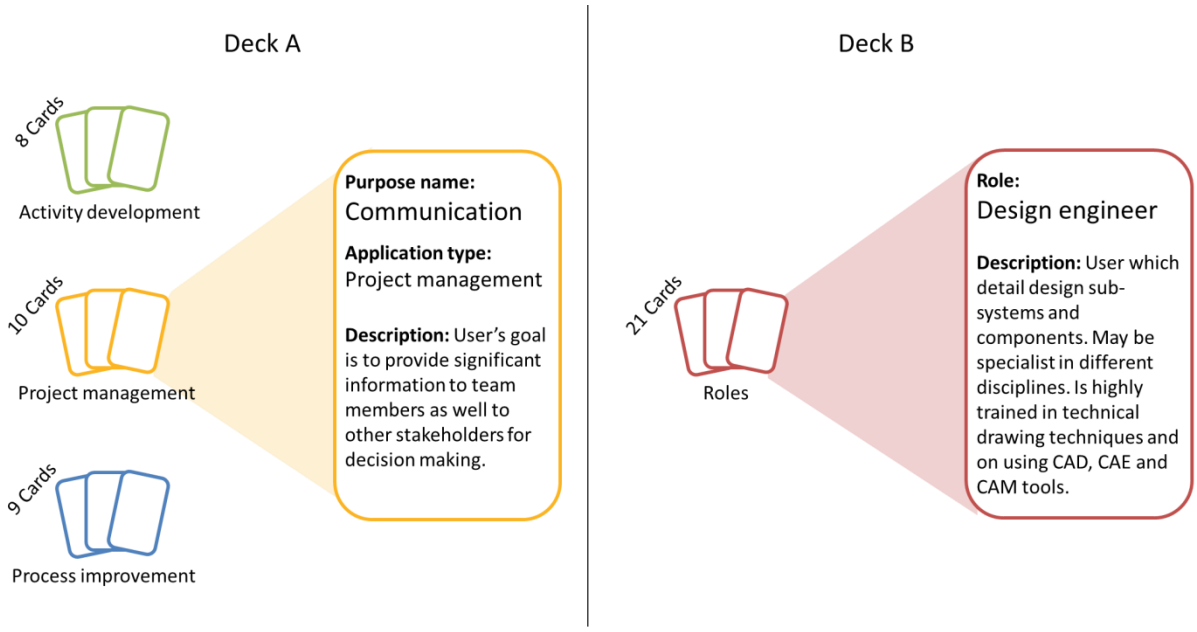

Figure 7 – Samples of cards developed for sorting. Deck A presents purposes for each application type and Deck B presents roles involved in designing.

The provided list of roles and corresponding descriptions is grounded on following sources: Eckert and Clarkson (2005), O'Donovan et al. (2005), Pahl et al. (2007), Browning (2010), Ulrich and Eppinger (2012), and Andreasen et al. (2015).

To start the Focus group, the warm up step was held in order to contextualize the activity. Grouped along with their colleagues participants should briefly discuss the use of design process models in their companies.

After this, in order to perform step 1, participants were organized in six groups to evaluate the purpose contribution on the use of design process models for the application they were assigned. Two groups were designated for each application type. Deck A, which includes the purposes, was distributed. Each group received the cards related to the application types of their responsibility. Specialists were asked to analyze and position each of the card into a board according to the utility of each purpose in relation to the others. After completing the evaluation of the cards, suggestion of new purposes was encouraged. This step of the focus group with specialists results in a new version of the list of purposes related to each application type (see section 3.2). Furthermore, expected benefits on using design process models, which was not an expected result from the focus group, were compiled (see section 3.4). The result of this step are the List of purposes vs. application types and the List of expected benefits. Figure 8 and Figure 9 provide pictures of the group session setting and results related to the purposes evaluation.

Figure 8 – Group of participants analyzing the purpose cards related to the application type they were designated. Note the observer on the upper-left corner of the image

Figure 9 – Purpose cards related to one application type organized according to their contribution on design process models according to one group. In the bottom part, the new purposes proposed by the group

Step 2 intended to discuss the users of the models and the creation of a map of users. Card Deck B, containing the description of proposed roles on the design process, was provided for each group. Specialists were asked to discuss the role within the companies and to classify the roles in core, internal and external, following the stakeholders mapping technique proposed by Stickdorn and Schneider (2011). After it, suggestion of new roles was encouraged. This step contributes to the List of roles on design process, and results on the List of core users of DP models, both discussed on section 3.3.

Step 3 intended to connect the map users created to the three proposed application types. Specialists should evaluate the most important roles for the application type they were assigned. Stickers were given to specialist so the group could choose the roles they would focus on to develop process models to their application type. This step contributes to the List of roles on design process, and results on the List of roles vs. Application types.

See Figure 10 for a picture of results related to Steps 2 and 3.

Observers were assigned to accompany each group of experts as part of the focus group methodology. The observer's role was to take notes on the discussion held during the session. See Table 12 in the appendix for the observation protocol provided for each of the six observers. The results and contributions of the workshop, comprising the definitions of the cards, application through the focus group and analysis of outputs are further presented on the next three sections.

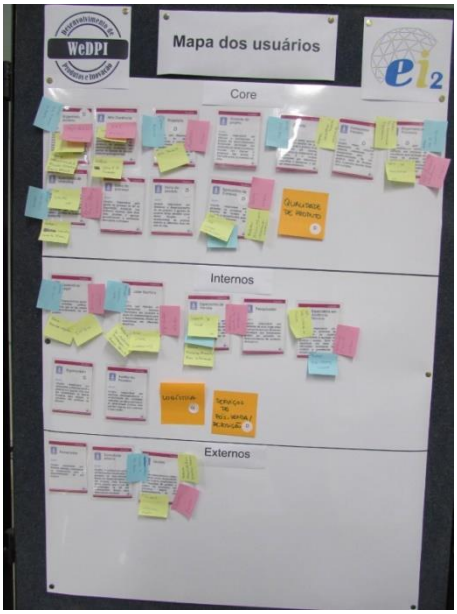

Figure 10 - Roles cards organized according to Core, Internal and External users and according to the application type defined to the group – evidenced by round stickers

3.2 Purposes of the three application types

The evaluation of model purposes results in the new version of the list of purposes and its descriptions for the three types of application. Besides, the evaluation of the level of importance of each purpose according to its application category for this set of organizations is presented.

For the design activity development application, four purposes were identified in Browning (2010), four were suggested based on Browning and Ramasesh (2007), and one was identified in the focus group discussion. The purposes, descriptions and sources are developed on Table 3.

The Activity development purposes ranking is presented in Figure 11. The purpose considered the most important was the Gate. We may observe that the technical and managerial evaluation criteria for gates must be available to guide the development team (Robert G. Cooper, 2009). These criteria may work as major guidelines for the many decisions to be made by the ones involved in the activity development.

Provide knowledge about the way Good practices should be performed was considered essential by the specialists. Process models users need to easily find information from analogous projects which must be well documented in order to work as good practices in the future. However it is important to highlight there was a consensus that the design process model should not be so rigid that the team do not think in novel solutions.

Table 3 – Purposes related to design activity development application

Card ID	Name	Description	Source
1.1	Activities	User's goal is to recognize project activities of group or individual responsibility. Relevant information may be provided. Activity relates to what may be accomplished throughout the project.	Browning (2010)
1.2	Method	User's goal is to filter/select methods to support accomplishing a set of activities towards a set of deliverables. Methods may be defined by the branch/ organization or by design team preference. Procedures on how to perform methods steps are of importance.	Browning (2010)
1.3	Good Practice	User's goal is to filter/select activities deliverables and good practices from analogous projects which better fit the project situation. These documents may be used as guides for performing a set of activities.	Browning (2010)
1.4	Lessons learned	User's goal is to deposit lessons learned during the development of activities which may be both used for improve the process as well as insights for future projects.	Browning (2010)
1.5	Requirements	User's goal is to identify the inputs and expected outputs for a given activity. Requirements are defined by necessities of users and clients, as well by technical standards of a certain branch.	Suggestion based on Browning (2007)
1.6	Gate	User's goal is to identify the criteria through which the deliverables will be evaluated during technical and managerial gates. This information may guide the strategy design team members will take to perform activities.	Suggestion based on Browning (2007)
1.7	Deliverables	User's goal is to recognize project deliverables (or parts of it) of group and individual responsibility. The deliverable relates to what is expected to obtain from a set of activities.	Suggestion based on Browning (2007)
1.8	Responsibilities	User's goal is to identify team members which are responsible by project activities and deliverables. Recognizing the role and involvement of these members is important to improve communication and foster cross-disciplinary work.	Suggestion based on Browning (2007)
1.9	Artifact	User's goal is to access the information which better represent the design state. The artifact may be represented through CAD software, prototypes, process maps, and others, which represent the maturity of the product.	Added based on the Focus group

As a positive remark, users are interested to share their Lessons learned, as long as there is not a significant effort demand. Process models which facilitates the deposit and access to relevant

documentation of the development of activities may provide a virtuous cycle for the re-use of information and, thus, to evolve the products developed within the organization.

The selection of a Method is positioned as providing lowest contribution. This was a major discussion issue when analyzing data. Despite that methods may be part of the user's background, guidance must be provided to guarantee the quality of their application and coordination among the team. In the other hand, the methodological approach to perform activities must not stifle the company's management system and overload auditing works.

The artifact card was added as the ones involved on activity development need to access up to date information which represent the product under development. Along with the requirements and expected deliverables, the design team must develop the artifact.

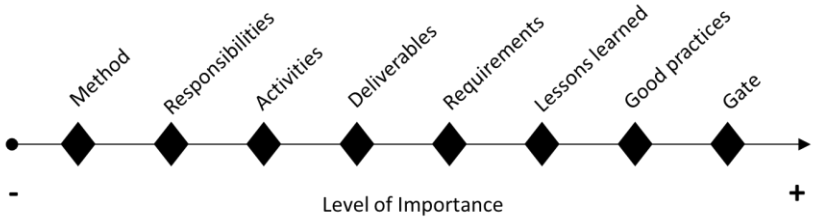

Figure 11 – Purposes contribution ranking for design activity development application

For the design project management application, seven purposes were identified in Browning (2010), three were suggested based on Browning and Ramasesh (2007), one was identified in the focus group discussion, one was replaced, and two were merged into other cards. The purposes, descriptions and sources are developed on Table 4.

Table 4 – Purposes related to design project management application

Card ID	Name	Description	Source
2.1	Deliverables	User's goal is to filter/select deliverables which fit the project. Deliverables are related to what is expected from a set of activities. The obtained deliverables are input for other activities.	Browning (2010)
2.2	Activities	User's goal is to filter/select activities which fit the project. Deadlines are defined for these activities. A set of activities normally lead to a deliverable. Methods and good practices may be used for guidance.	Browning (2010)
2.3	Resources	User's goal is to formalize and communicate responsibilities for accomplishing activities among the team members and external resources. These responsibilities are related to the roles to be performed throughout the design project.	Browning (2010)

Card ID	Name	Description	Source
2.4	Monitoring	User's goal is to estimate and monitor the risks of the project according to the plan and defined metrics. If necessary, the project plan may be adapted to mitigate risks in order to achieve planned time, costs and, quality.	Browning (2010)
2.5	Communication	User's goal is to provide significant information to team members as well to other stakeholders for decision making.	Browning (2010)
2.6	Templates	User's goal is to filter/select deliverables and good practices of analogous projects which adequate to the project condition to be used as a template.	Browning (2010) – Merged with Good practice card of Activity development
2.7	Project estimates	User's goal is to estimate project restrictions related to time, cost, quality and risks.	Browning (2010) – Merged with Monitoring card
2.8	Gates	User's goal is to define the moments and criteria for decision making throughout the project. These may be technical or managerial gates.	Suggestion based on Browning (2007)
2.9	Methods	User's goal is to filter/select methods which fit the project. Methods are related to rationale procedures to perform a given set of activities and achieve a set of deliverables.	Suggestion based on Browning (2007)
2.10	Precedence	User's goal is to evaluate the relation among activities and define the order through which activities will be performed. Precedence is related to capacity limitations and activities inputs vs. outputs.	Suggestion based on Browning (2007) – Replaced by project type
2.11	Project Type	User's goal is to select the project type which better fit the characteristics of the product under development. Standard activities, roles, deliverables, and decision points may already be preset for the selected type.	Added based on the Focus group

The Project management purposes ranking is presented in Figure 12. The purpose considered most important was Communication. Project plans are used as communication artifacts between managers, project team members and other stakeholders. Managers must be able to present the right information to guide the ones involved in the design process. Summarized versions of the project plan may also be created to update different levels of stakeholders on project progression.

Gates, Activities, Resources, Methods and Deliverables are the main elements of the project plan. These elements work as a base line to the execution and control of the design project.

Guidance must be provided to define them for each project. Participants brought to attention that one element influence others. Methods may define expected Deliverables and Activities, which in turn may define the Resources to perform them.

Project estimates card was integrated into the Monitoring one, as the understanding of both groups assigned to project management were similar for these cards. A greater emphasis was given to risk management in the Monitoring card. Risk estimates must be performed throughout the project in order to monitor it according to the plan.

Templates were moved to the activity development application, as discussions pointed out that managers should not need to control practices used by each one involved in the process.

A project typology was brought to attention as a necessity. On project formalization, participants suggested that characteristics of the new product, e.g. innovation level in relation to previous products, should define the type of project, and determine the main activities, deliverables, gates and so on. Participants were not interested to define precedence for each activity, but to rely in project types.

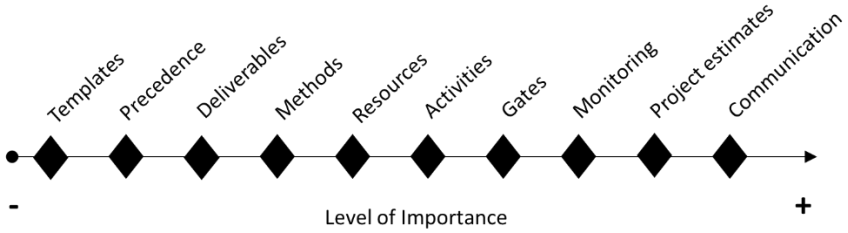

Figure 12 – Purposes contribution ranking for design project management application

For the design process improvement, two purposes were identified in Browning (2010), seven were suggested based on Browning and Ramasesh (2007), two were identified in the focus group discussion, one had its name changed, and one was replaced. The purposes, descriptions and sources are developed on Table 5.

The Process improvement purposes ranking is presented in Figure 13. The purposes ranking obtained in the focus group corroborate the value of the two paths for improving the process: through the use of generic process models and through analyzing the as-is situation. Nevertheless, greater focus is given on the second path: obtaining the activities that do not add value on the process as well as incorporating lessons learned through projects.

Table 5 – Purposes related to design process improvement application

Card ID	Name	Description	Literature Source
3.1	Standard deliverables	User's goal is to define and embody one or more standard deliverable to the organization specific design process models. Templates, checklists and meeting procedures may be defined for each standard deliverable.	Browning (2010)
3.2	Standard roles	User's goal is to define and embody one or more roles to the organization specific process model. These roles may be linked to standard activities and deliverables.	Browning (2010)
3.3	Waste	User's goal is to identify waste and bottlenecks in the way the organization develop its products. Activities which do not add value on the process are suppressed.	Suggestion based on Browning (2007)
3.4	Lessons learned	User's goal is to embody lessons learned across projects into the organization specific design process models. Managerial and operational lessons are expected.	Suggestion based on Browning (2007)
3.5	Standard gates	User's goal is to define the moments and criteria for decision making which may be embodied to the organization specific process model. These may be technical or managerial gates.	Suggestion based on Browning (2007)
3.6	Standard methods	User's goal is to define and embody one or more standard methods to the organization specific process model. Method relates to how to perform certain group of activities in order to get to expected deliverables.	Suggestion based on Browning (2007)
3.7	Project management approach	User's goal is to define the management approach to be used on developing its projects. Approaches that may be taken are related to agile and heavy-weight project management practices.	Suggestion based on Browning (2007)
3.8	Technical standards	User's goal is to filter/select activities which fit the project. Deadlines are defined for these activities. A set of activities normally lead to a deliverable. Methods and good practices may be used for guidance.	Suggestion based on Browning (2007) – Name changed from Quality standards
3.9	Activities flow	User's goal is to define the possible connections and information flow between standard activities. The goal is to decrease the time taken to develop products.	Suggestion based on Browning (2007) – Replaced by project typology
3.10	Process metrics	User's goal is to define and embody one or more process metrics to the organization specific process models. These metrics may help to evaluate the effectiveness and efficiency of the design process.	Added based on the Focus group

Card ID	Name	Description	Literature Source
3.11	Project typology	User's goal is to define and embody one or more pre-defined type of project according to its characteristics, e. g. project complexity and innovation level. Standard activities, roles, deliverables, and decision points may already be defined for each type of project.	Added based on the Focus group

A terminology issue was resolved based on the focus group. Technical standards, which may be demanded by industry branches or imposed by legislation, replaces Quality standards. Selecting and adapting them to the organization specific process models may facilitate to apply into projects.

The necessity to define Process metrics to evaluate the process was brought to attention in the group session and incorporated as a purpose. These metrics are important to guarantee that when the design process 'improves', better results are obtained.

Project typology as brought to attention in this application as well. Define Project typology through evaluating project's characteristics is understood as a necessity. Participants are less interested to evaluate the connection between activities among many projects to seek for process improvement. Thus, the Project typology purpose was added and the Activity Flow one was removed.

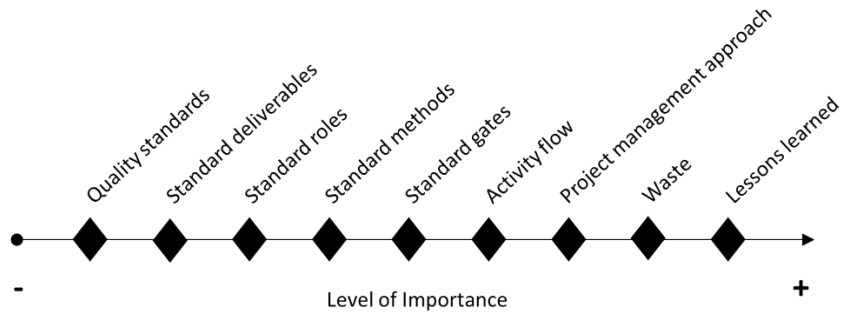

Figure 13 – Purposes contribution ranking for design process improvement application

3.3 Roles of design process models users vs. application types

The evaluation of roles of design process models users results in the new version of the list of roles and its descriptions. Besides, the evaluation of the central roles of design process models, through the Core, internal, external classification is presented. The roles are classified and analyzed for each application type as well.

In total 15 users were identified in literature, six were suggested for the focus group, and four were added grounded on it. Though users' role could be found in the academic literature and books, there were no comprehensive roles compilation and descriptions. Along with the literature review performed on generic design process models, many professional associations websites and several Wikipedia articles contributed on the descriptions of roles. With the feedback from the focus group, four new cards were defined. The roles, descriptions and sources are developed on Table 6.

Table 6 – Roles of personnel involved in the design process

Card ID	Name	Description	Literature Source
4.1	Researcher	User which is involved in longer term activities of applied research. Seeks for technologies which may be applied on organization portfolio.	Ulrich and Eppinger (2012)
4.2	Product engineer	User which defines and designs functionalities of sub-systems and components. May be specialists in disciplines such as mechanical, electronical, software engineering, among others. The field specialty requirement is defined by the product under development.	Eckert and Clarkson (2005), Ulrich and Eppinger (2012), Browning (2010), O'Donovan, Eckert and Clarkson (2005)
4.3	Design engineer	User which detail design sub-systems and components. May be specialist in different disciplines. Is highly trained in technical drawing techniques and on using CAD, CAE and CAM tools.	Eckert and Clarkson (2005), Ulrich and Eppinger (2012), Browning (2010), O'Donovan, Eckert and Clarkson (2005)
4.4	Manufacturing engineer	User which develops, controls and operates manufacturing processes for mass production of the product. May be specialists in mechanical, materials, electronical, among other manufacturing processes.	Ulrich and Eppinger (2012)
4.5	Project manager	User which plans and monitors the design project. Project managers are rarely involved on developing design activities. The focus is on maintaining tasks progress and team members' interaction.	Eckert and Clarkson (2005), Ulrich and Eppinger (2012)
4.6	Process owner	User which manages the organization design process seeking for continuous improvement. Process owners must create, update and approve procedures and protocols to support the process.	Browning (2010)
4.7	Executive manager	User which represents management board and investors interests to drive the organization product portfolio. Executive managers are normally involved on decision points as managerial gates.	O'Donovan, Eckert and Clarkson (2005)

Card ID	Name	Description	Literature Source
4.8	UX designer	User which develops product - user interface. UX designers consider human factors to adapt product requirements to the user.	Andreasen, Hansen and Cash (2015)
4.9	Legal specialist	User which deals with legal and financial restriction. These specialists are responsible to resolve legislation and patent restrictions and the processing of financial information.	Ulrich and Eppinger (2012)
4.10	Marketing specialist	User which identifies value for the clients throughout the design process. Seeks for market segments which the organization could provide products. These information guide the organization portfolio.	Eckert and Clarkson (2005), Ulrich and Eppinger (2012), Pahl et al. (2007)
4.11	Sales specialist	User which defines sales goals and plan activities to reach these goals. Values defined by them help on estimate and monitor success of a product.	Eckert and Clarkson (2005), Ulrich and Eppinger (2012), Pahl et al. (2007)
4.12	Process auditor	User which systematically checks conformity of performed design activities and deliverables. Internal and external standards may be used.	Browning (2010)
4.13	Supplier	User which provides systems, subsystems or components for a product under development.	Ulrich and Eppinger (2012), Pahl et al. (2007), O'Donovan, Eckert and Clarkson (2005)
4.14	End-user	User which uses the product under development. They may be involved in the process to guide product's requirements. Normally users don't have much technical knowledge related to the product and may be involved in different stages of the design process.	Andreasen, Hansen and Cash (2015)
4.15	Client	User which buys the product under development. The product is being developed for them. Clients participates on defining deadlines and technical requirements.	Pahl et al. (2007)
4.16	Technical leader	User which maintains technical knowledge related to products on a given discipline / knowledge area. Helps on driving technical decision making.	Suggestion for Focus group validation
4.17	Product owner	User which drives the development of a product. Product owners make decisions on defining systems functions and characteristics throughout product life cycle.	Suggestion for Focus group validation

Card ID	Name	Description	Literature Source
4.18	After sales specialist	User which manages services and users satisfaction after product / service acquisition. After sales must maintain relationship with customers and provide technical assistance.	Suggestion for Focus group validation
4.19	Purchasing specialist	User which manages purchasing processes and makes decisions to buy components and equipment for developing a certain product.	Suggestion for Focus group validation
4.20	Partner	User which jointly develops systems, subsystems or components for a product under development. Besides providing SSCs, the partner supplier assumes project risks.	Suggestion for Focus group validation
4.21	External consultant	User which provides knowledge related to a certain development stage of a product. May provide methodological support for the design process or technical knowledge to certain activity.	Suggestion for Focus group validation
4.22	Testing engineer	User which determines the most suitable testing process for a product under development. Tests must guarantee the designed artifact meet defined requirements.	Added based on the Focus group
4.23	HR specialist	User which recruits and develops human resources for the organizations. HR specialists are responsible for the human capital on designing products.	Added based on the Focus group
4.24	IT specialist	User which develops and monitors information technology systems. IT specialists may guarantee functional management systems.	Added based on the Focus group
4.25	Quality specialist	User which ensures conformity on manufacturing process and service through setting continuous analyzing production specifications. Quality specialists must guarantee requirements are met by manufacturing.	Added based on the Focus group

The classification of roles according to centrality of the use of process models and types of application are depicted in Table 7. An analysis of results was performed based on the organized sets of cards, discussions in sessions and notes taken by observers[7].

[7] See Table 12 in the appendix for the observation protocol provided for each of the six observers

Table 7 – Classification of design process models roles

Role	Core / Non - Core	Internal / External	Develop activity	Manage project	Improve process
Product engineer	C	I	●	-	-
Product owner	C	I	-	●	●
Project manager	C	I	-	●	●
Process owner	C	I	-	●	●
Executive manager	C	I	-	●	●
Marketing specialist	C	I	-	●	●
Quality specialist	C	I	-	-	●
Technical leader	C	I	-	-	-
Partner	C	E	●	-	●
Client	C	E	-	●	-
Purchasing specialist	N-C	I	●	-	●
Design engineer	N-C	I	●	-	-
Manufacturing engineer	N-C	I	●	-	-
UX designer	N-C	I	●	-	-
Researcher	N-C	I	-	-	-
HR specialist	N-C	I	-	-	-
IT specialist	N-C	I	-	-	-
Legal specialist	N-C	I	-	-	-
Post sales specialist	N-C	I	-	-	-
Sales specialist	N-C	I	-	-	-
Process auditor	N-C	I	-	-	-
Testing engineer	N-C	I	-	-	-
Supplier	N-C	E	-	-	-
External consultant	N-C	E	-	-	-
User	N-C	E	-	-	-

The first two classifications (core/non-core and internal/external) lead to the ones which need most support of process models in their routine work regardless if they are normally part of the organization or outsiders. Some roles, which were considered core, may be part of the central design team: product engineer, product owner, and project manager; perform in support processes: marketing specialist, and quality specialist; or from outside the company: partner supplier and client. Core users are frequently involved in more than one application type, e.g. product owners may be able to both make decisions on products characteristics supporting project management and to embody lessons learned across projects to improve the design process within the organization.

The influence of the organizational structure within companies on the members performing each role are reinforced through the focus group – in some companies, people from different areas and with distinct functional description performed the same role. Anyhow, the responsibilities related to the design process are maintained across organizations and their structure. The roles here presented are a source to develop process models to attend design personnel needs.

Two main groups of users may be depicted from the users vs. application types data analysis: the ones which are involved in the design activities and the ones involved in both managing projects and processes. Product engineers, design engineers, manufacturing engineers, UX designers, quality specialists and partners are the main responsible for developing design activities. The cycles of designing, prototyping and testing as well as detailing design towards mass productions are of main interest to the groups of designers. Product owner, project manager, process owner, executive manager, marketing specialist are the ones responsible both for managing the project and improving the process. The structured stages and go/no-go gates are fundamental for the managing group, to both conduct the portfolio of projects within the company and guarantee continuous improvement across projects.

Four roles – purchasing specialist, design engineer, manufacturing engineer and UX designer – were considered important for design activity development but were not considered core users. This may show a managerial point of view of these models by companies. This may explain why ’process models are usually too abstract and ambiguous for most workers’ day-to-day needs’ as pointed out by Browning et al. (2006). Organizations should consider both the operational and managerial functions of process models in order to provide guidance to the iterative, ill-defined activities through well-defined, go/no-go phases of the design process.

3.4 Expected benefits of using design process models

Warm-up session discussions, in which participants analyzed the use of design process models in their organization, and some of the suggested purposes within the focus group where not related to a specific application. These refer to higher level necessities related to the advantages of using these models, and were classified as expected benefits of using design process models in organizations.

Tarallo and Forcellini (2007) discuss the value added to the organization and team members by using design process models, calling it benefits of the models. Benefits are related to the advantages of using design process models. Eckert and Stacey (2010) connects achieving benefits to the quality of a design process models. Some of these advantages are also brought to attention by Blessing (1996) and Engwall et al. (2005).

Expected benefits, which emerged from the card sorting, were later examined in literature. A consolidation is presented on Table 8.

Table 8 – Descriptions of Expected benefits of using process models

Name	Description	Source
Common language	Design process models in organizations must provide common language between the ones that improve the process, manage the project and develop the design activities.	Blessing (1996) and Engwall et al. (2005) – Corroborated by Focus group
Less rework	Organization process models must help on rapidly evaluate if a project is on the right track and help on communicate decisions to decrease rework by the design team.	Engwall et al. (2005)
Creative work	Organization process models must be able to rationalize creative work, aiding the development of relevant and innovative design solutions.	Blessing (1996) and Eckert (2010) – Corroborated by Focus group
Teamwork	Organization process models must provide a common way of working to disseminate a team culture within the company.	Blessing (1996), Engwall et al. (2005), and Eckert (2010) – Corroborated by Focus group
Integration	Organization process models must aid the involvement of everyone involved in designing: external people and different business units and sites should also be considered.	Tarallo et al. (2007) – Corroborated by Focus group
Agility	Organization process models must improve and facilitate the process of decision making, helping project requirements to be fulfilled in shorter period of time.	Tarallo et al. (2007) – Corroborated by Focus group
Innovation Culture	Organization process models must be able to promote an innovation culture within the company, fostering values as: out of the box thinking, early prototyping and testing ideas, and openness to fail.	Added based on Focus group

The goals for using design process models for each application type must attend higher level necessities as innovation and integration, not just to achieve conformance to defined procedures. Purposes must be considered as means to achieve benefits expected by organizations when using process models.

Different purposes must be attended when developing design process model views in organizations. It must be debated that the purposes for each application types are substantially different. If one of these types are not considered, probably some expected functions of design process models will not be represented.

Apart from that, roles taken by design personnel define much of their needs as users of each application types. Operational and managerial users must be mapped to elicit their needs in that specific organizations, otherwise some of the design process models under development will not

be attended, and users will find them not useful. These users will probably be less integrated to the process, decisions will be less agile, and other benefits of using these models will not be achieved.

4 DESIGN PROCESS MODELS CONTEXT ASPECTS IN AN ORGANIZATION

This chapter details the goals of the second qualitative study mentioned in section 1.3. The methodology used and steps taken to investigate the use of design process models for project management and activity development in an organization are here presented. The representations obtained through the use of contextual design techniques and their analyses are also provided.

4.1 Case study goals and description

In order to advance the description of the users' needs of design process models, the context they are inserted will be explored. As stated on the TU/Delft's Product Innovation Management website: "Designers are different to one another and so is the context they work in!"[8]. This way, a case study is carried out in a specific organization, which instances one context.

The investigated organization is an international company composed by the headquarters and three subsidiary sites. In total it comprises more than 10000 employees. The organization is part of the white goods sector. This investigation represents the subsidiary from Brazil, and is hereafter called Company Alfa.

A contextual design approach is adopted based on Holtzblatt and Beyer (2012) to elicit users' needs. User profiling and contextual inquiry techniques are performed for both case preparation and data analysis in this study – see Appendix 3.

Contextual inquiry is a field data-gathering technique that helps the researcher to understand the environment people perform their tasks, and identify their needs within that environment (Kuniavsky, 2003). It is a technique which helps users show their environment approximating to a shared understanding of their context with researchers (Holtzblatt & Beyer, 2012).

User profiling is a user requirement elicitation technique which is applied to depict a common representation for groups of people and help the researcher to understand user needs through creation of models of them (Kuniavsky, 2003). Personas and Empathy maps are well-known user profiling techniques. We use the empathy map procedure proposed by Osterwalder and Pigneur (2010) in this work. Figure 31 in the Appendix 3 is used as a template in this research for the empathy map.

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[8] Access at http://www.io.tudelft.nl/over-de-faculteit/afdelingen/product-innovation-management/design-methodology/research/

Badke-Schaub et al.'s (2005) human centered Network of designing is adapted for the scope of this research: the empathy map technique represent the Individual Design scope, and the contextual inquiry is used to represent Organizational context, Design process and Product scopes – see Figure 14. The Network of designing is used to make sure the contextual aspects of the use of design process models which otherwise would be hidden. An interview protocol was prepared according to the research scope for data gathering – see Table 13 in the Appendix 3.

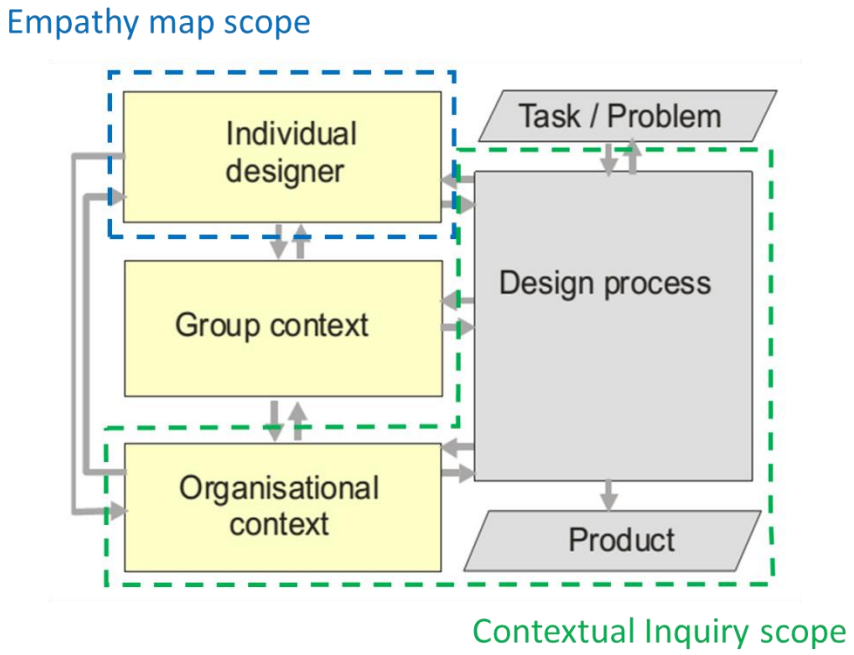

Figure 14 – Context and users investigation based on the human-centered network of designing (Badke-Schaub et al., 2005) *assisted by contextual design techniques*

To begin the investigation, it is noteworthy that recruiting people who will provide good feedback is of as much importance as interviewing them (Kuniavsky 2003). One person from Company Alfa whose role is process owner in Company Alfa facilitated the selection of which personnel should be interviewed. In this way, apart from interviewing the process owner, which gave inputs to refine the protocol, a set of nine interviews was performed with members from different areas – see Table 9. The average duration of interviews was 87 minutes, and interviews were recorded with consent of participants for further analysis of information.

Table 9 – Interviewees information

#	Personnel role	Years in company	Years in design related areas	Interview Duration
1	Marketing - Senior product specialist	23 years	23 years	01:20
2	R&D - Coordinator (mechanics)	26 years	15 years	01:07
3	R&D - Project manager/Researcher	14 years	18 years	00:51
4	Product engineering - Coordinator (electrics)	13 years	19 years	01:28
5	Product engineering - Project manager / Analyst	13 years	7 years	01:12
6	R&D - Coordinator (electronics)	7 years	7 years	01:41
7	R&D - Researcher (mechanics)	16 years	16 years	01:30
8	R&D - Researcher (electronics)	4 years	7 years	02:02
9	R&D - Researcher (electrics)	2 years	2 years	02:00
10	Product engineering - Design engineer	5 years	7 years	01:26

In order to take most advantage of the interviews, a research assistant[9] attended each meeting to take notes. After each set of interviews a debriefing session was performed, in which information was organized into the context aspects according to areas the interview protocol. Team interpretation sessions, which enable different perspectives to be considered when analyzing the data (Holtzblatt & Beyer, 2012), were held. Initial representations were created according to contextual inquiry and user profiling techniques. At this point, three main roles were apparent as central for this study: technical leader, project manager, and product engineer.

After the realization of all interviews, the audio files were used to iterate on the initial representations created. The researcher listened up to two interviews of each identified profile, in a total of six interviews. Records were not transcribed. Instead, post it notes was used to collect important information as it can be seen in Figure 15. Both the protocol and representations guided the notes to be taken. Notes taken during interviews, debriefing sessions and notes from listening to the audio files were used to get to a these representations, which was presented for the organization process owner for feedback and resolving punctual issues. The complete set of representations is listed on Table 10. Only the most relevant of them are depicted in this manuscript.

[9] The author express his gratitude to Felipe Albuquerque Soligon and Victor Macul for their contribution in this research

Figure 15 – Picture of the development of user profiling and contextual inquiry models

Table 10 – List of representations created in the case study

Contextual design deliverable	Element	Representation title
Context of use	Product	Product requirements and knowledge areas related
Context of use	Process	Connection between idea, product and technological development
Context of use	Process	Project typology
Context of use	Process	Organization specific design process model (as used)
Context of use	Process	Communication and Design process models elements
Context of use	Process	Design process information system
Context of use	Organization	Roles vs design process stages
Context of use	Organization	Meetings and rituals
Context of use	Organization	Roles, main activities and relationships in a project
Context of use	Organization	Product development facilities in Brazil
Context of use	Organization	Relationship among sites in different countries
Context of use	Organization	Macroeconomics, organization and group influences
User profile	Individual designer	Product engineer profile
User profile	Individual designer	Project manager profile
User profile	Individual designer	Technical leader profile

This cycle of information gathering and analysis sustain the representation of the contextual aspects of use of design process models in an organization. The context of use of design process models is presented on section 4.2. User profiles are presented on section 4.3.

4.2 The context of use of design process models

In this section we present a portrait of the context of use of design process models in Company Alpha on managing their projects and on supporting activity development. Contextual inquiry technique provided means to depict three dimensions of the context in this study:

1. The Product – comprising the product role in the value chain and the knowledge areas involved;
2. The Design process – comprising the scopes of the design process and project typology; and
3. The Organization aspect – comprising the roles the behavior of roles in the structure of the organization.

4.2.1 Product Context

The context inquiry reveals two aspects of product context dimension, which is represented in Figure 16.

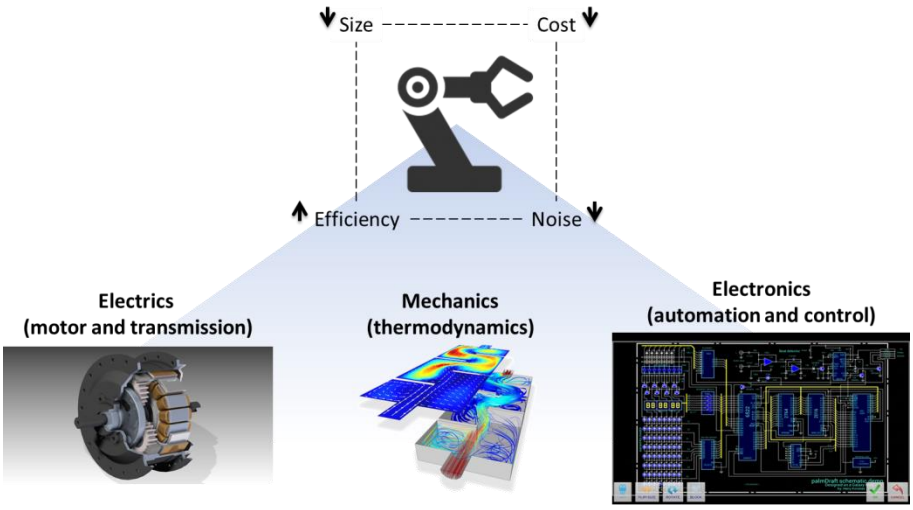

Figure 16 – Representation of the product requirements and knowledge areas related

First, considering the product role in the value chain, Company Alfa acts as a relevant supplier in the white industry. Their products are parts of more complex products assembled in other organizations. Their requirements are more connected to the client than to the end-user. Interacting and coordinating with the client's design team brings the necessity of guidance for both Company Alfa's and client's design teams.

Being lees connected to the end-user causes the design personnel to face the product through its requirements, which act as constraints of the project. [10] The described aim of design personnel is to decrease the costs, size and noise, while increasing efficiency of the product.

Another aspect is the definition of knowledge areas by the product. The portfolio of products in Company Alfa is organized by families of mechatronic products. Product subsystems define the engineering knowledge areas within the organization, which are: electrics engineering related to the electric motor and transmission; mechanical engineering related to thermodynamics and casting; and electronic engineering related to automation and control. Engineering related roles in this organization are organized into functional areas representing these knowledge areas.

4.2.2 Design Process context

The context inquiry reveals four aspects of design process contexts dimension. On the design process scope, the process in company Alfa is called New Product Development (NPD). This process interfaces with two other processes: Marketing and Technological development process (Figure 17). Although company Alfa doesn't refer to Marketing as a process, but as a department, normally it is the process which acts as the fuzzy front end they refer to. The Ideas backlog funnel contains not-formalized concepts and suggestions for the products. If considerable marketing opportunities are foreseen in an idea, it is considered for product development.

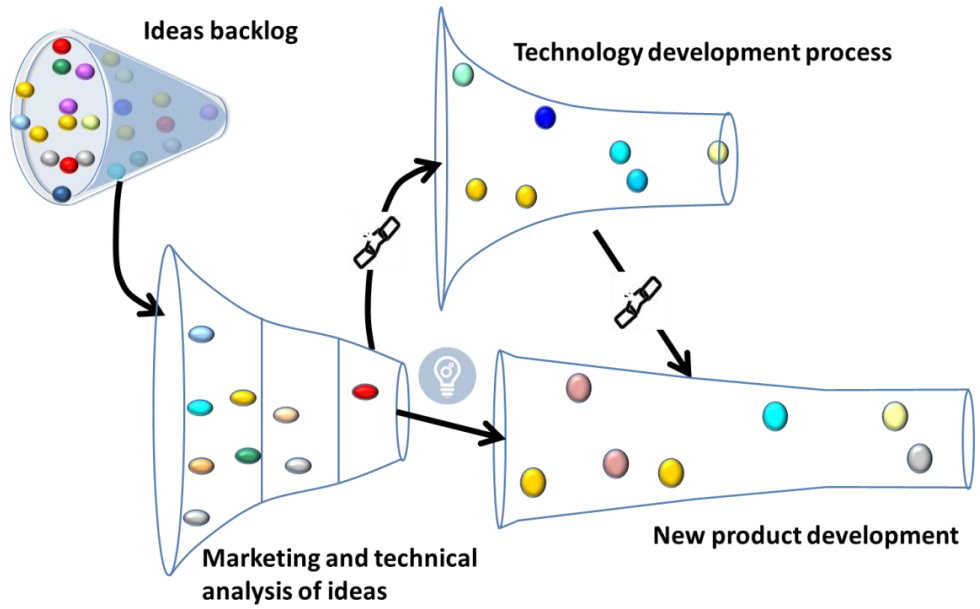

Figure 17 – Representation of the connection between idea, product and technological development[11]

[10] See a set of common design project constraints in Eckert and Clarkson (2005, fig. 8)

Ideas and/or suggestions must pass through technical analysis, as well. If there is a lack of technical maturity for the envisioned solution, company Alfa would like that these concepts were first sent to the technology development process. In some occasions, interviewees reported that the technical knowledge was not mature for the use in projects under development, which caused major impacts on development lead time. Broken chains on the connections to the Technical analysis of ideas and New product development were used to represent it in Figure 17.

Taking into account the design process scope aspect, it is important to inform the design team the interface between these processes, e.g. what activities and deliverables should be executed, and what meetings should be held.

The use of project typology is something remarkable in the company. The type of project indicates the customization of the design process that should be performed. Only projects which bring major changes on existing products goes through all the phases of the design process. The NPD process is a fairly structured staged gate process where phases, gates, and main deliverables for each phase are defined. Design team members access the process model through excel files, which are customizable and are shared through emails to other members.

Another aspect of the design process is the high number of design process models elements created and/or used during this process, as shown in Figure 18. There are communication elements and artifacts for each process model instance (organizational design process level, design project level and design activity level). Communication elements comprise email, conference call, meeting and workflow systems. These are the elements through which information is distributed among team members as well to other stakeholders for decision making. Emails, conference calls and meetings are used for day-to-day communication and decision making about the project. Each is used according to convenience and requirements for the event, e.g. if it's a group discussion, if the group is co-located, and so on. A workflow solution is used by the company for a high level communication with areas from outside the project team.

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[11] This model was created based on lecture notes – Rozenfeld, H. (2014). O Início: estratégias, ideias, conceitos, visão e propostas. Available at: http://www.veduca.com.br/assistir/gestao-do-desenvolvimento-de-produtos-e-servicos

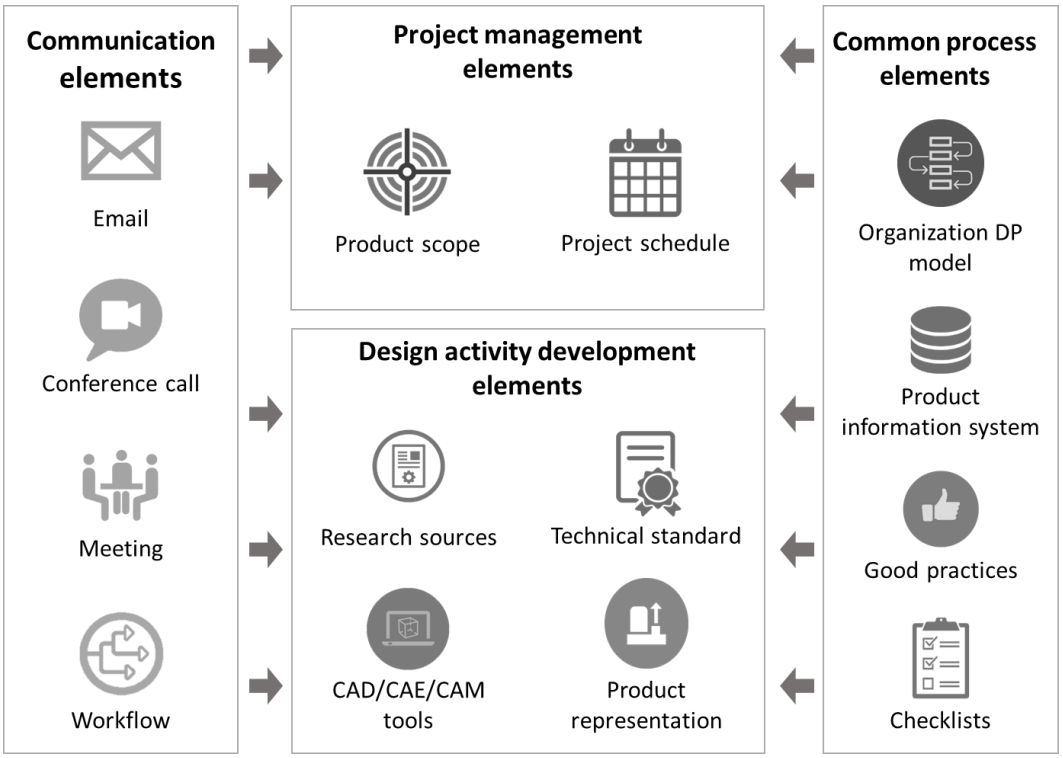

Figure 18 – Representation of the communication and design process models elements

There are elements that are common for the two process model application types:

- Organization design process model: composed of phases, gates, and main deliverables for each phase;
- Product information system: Information system used to store and manage project deliverables and data;
- Good practices: deliverables and good practices from analogous projects, which act as a guide for the project situation. These may be related to project management or engineering knowledge areas; and
- Checklists: lists of project management or development activities and deliverables directed to a responsible team member for verification purposes.

Elements regarding design activities are technical standards, research sources, CAD/CAE/CAM tools and product representation. Technical standards defines engineering criteria and methods for a branch of products, technical standards may be internalized according to organization/products' needs. Product representation artifact provides information which better represent the design state – for a definition of design state, see Eisenbart et al. (2011). The maturity of the artifact may be also represented

On project management application, the project plan is composed by the product scope, and the project schedule. Product scope is the document representing market requirements, which directs

the project and decision making. The project schedule represents activities and deliverables organized according to organization design process model based on the type of project to be developed. Scope and priorities among projects may change, influencing the project plan.

The product representation is only taken in consideration during gates for management purposes. Team members must be able to present and maintain the product representation under scrutiny. If the product representation seems not mature enough or in a wrong direction towards meeting client needs, executive management may cancel, freeze or iterate o the phase.

Finally, the last process aspect is regarding the impact of information system for design data. The design information system within the organization is represented in Figure 19. Process related information is available and stored in folders which are shared among the different teams: engineering teams have access to the Engineering folder and project managers to Management folder.

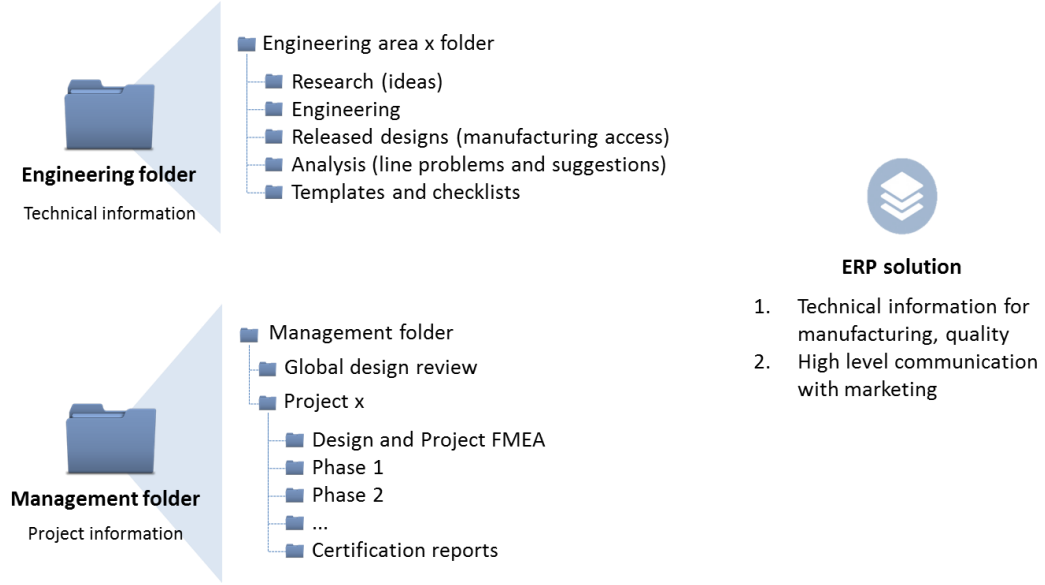

Figure 19 – Representation of the design process information system

The Engineering folder contains the technical deliverables created through the engineering knowledge areas. Ideas under research, engineering information until the definition of a concept, drawings for manufacturing access, and analysis of engineering improvement opportunities are example of information stored in the folder. Post-concept definition information as bill of Materials, process maps and quality control maps are uploaded on the ERP solution.

The Project management folder contains project management deliverables. Apart from the information from the Global design review, which influences the whole portfolio of the organization, the folders are organized into the design process phases and main deliverables expected for a project. Documents on these folders are mainly consolidations of the activities

performed until the date of the document and evidences of the achieved results. Communication with areas from outside of the project team happens through the ERP solution.

At the point of this study, the company was on an initial implementation phase of a product data management tool. Some of the interviewees expected it to improve the information access within projects and facilitate on decision making. The organization of practices, checklists, and deliverables would be closer to the design process steps.

4.2.3 Organizational structure context

The context inquiry reveals aspects of organizational contexts dimension. On the roles involved in the process aspect, twelve roles were identified based on definitions for the twenty-five roles obtained from the focus group with specialists presented on section 3.3:

- Researcher: person involved in longer term activities of applied research. Seeks for technologies which may be applied on organization portfolio;
- Marketing specialist: identifies value for the clients throughout the design process. These information also guide the organization portfolio;
- Technical leader: maintains technical knowledge related to products. Helps on driving technical decision making and on defining the design team. May be specialists in different disciplines;
- Project manager: plans and monitors the design project. Project managers are rarely involved on developing design activities. The focus is on maintaining tasks progress and team members interaction;
- Product engineer: defines and designs functionalities of systems, sub-systems and components. May be specialists in different disciplines;
- Testing engineer: determines testing strategy and perform tests on designed artifacts to analyze if they meet defined requirements;
- Design engineer: detail design systems, sub-systems and components. Is highly trained in technical drawing techniques and on using CAD, CAE and CAM tools. May be specialist in different disciplines;
- Process engineer: develops, controls and operates manufacturing processes for mass production of the product. May be specialists in mechanical or electrics manufacturing processes;
- Quality specialist: ensures conformity on manufacturing process and service through quality control. Quality specialists may guarantee requirements are met on mass production of products;
- Executive management: represents board and investors interests to drive the organization product portfolio;

- Partner: jointly develops systems, subsystems or components for a product under development. Besides providing SSCs, the partner supplier assumes project risks;
- Process owner: manages the organization design process seeking for continuous improvement. Process owners must create, update and approve procedures and protocols to support the process.

The identified roles participate through the process differently and on different intensity. Involvement varies according to the stages of development as represented in Figure 20 by the varying length of filled rows.

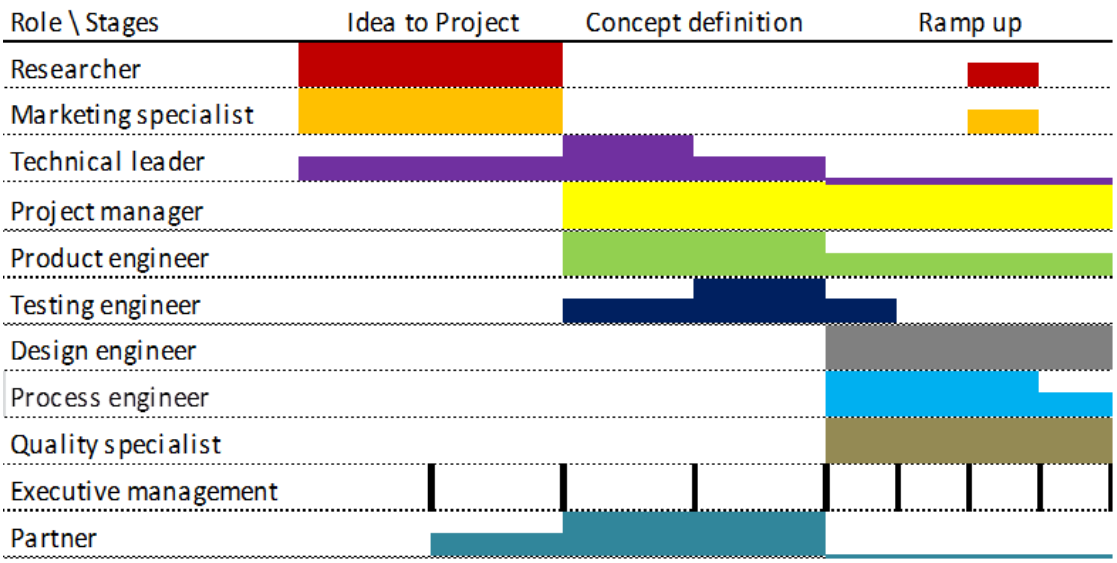

Figure 20 – Representation of the roles involved on the design stages.

The process owner is not represented since she/he does not take action on the design project phases, but on improving the process itself. Executive management is periodically involved on the project, they influence on design projects by guiding it through gates making go/no-go decisions. Three main moments in the process direct the participation of roles: before project scope is defined mainly researchers and marketing specialists are involved; later, technical leaders, product engineers, testing engineers and partners impacts until validating a concept; the concept is developed until launch by design engineers, process engineers, and quality specialists. Project managers are responsible for the project after the scope is defined until its end.

On the roles relationship aspect, Figure 21 connects roles, activities, and meetings. Product engineer, project manager and technical leaders are centrally represented in this model. The main identified activities performed by other roles through the project are also represented. Group influences may be obtained from this representation. Project managers are mainly directed by the market, translating the necessities for product engineers and supported by technical leaders.

Product engineers direct most of the testing, and detailing performed by testing engineers and design engineers.

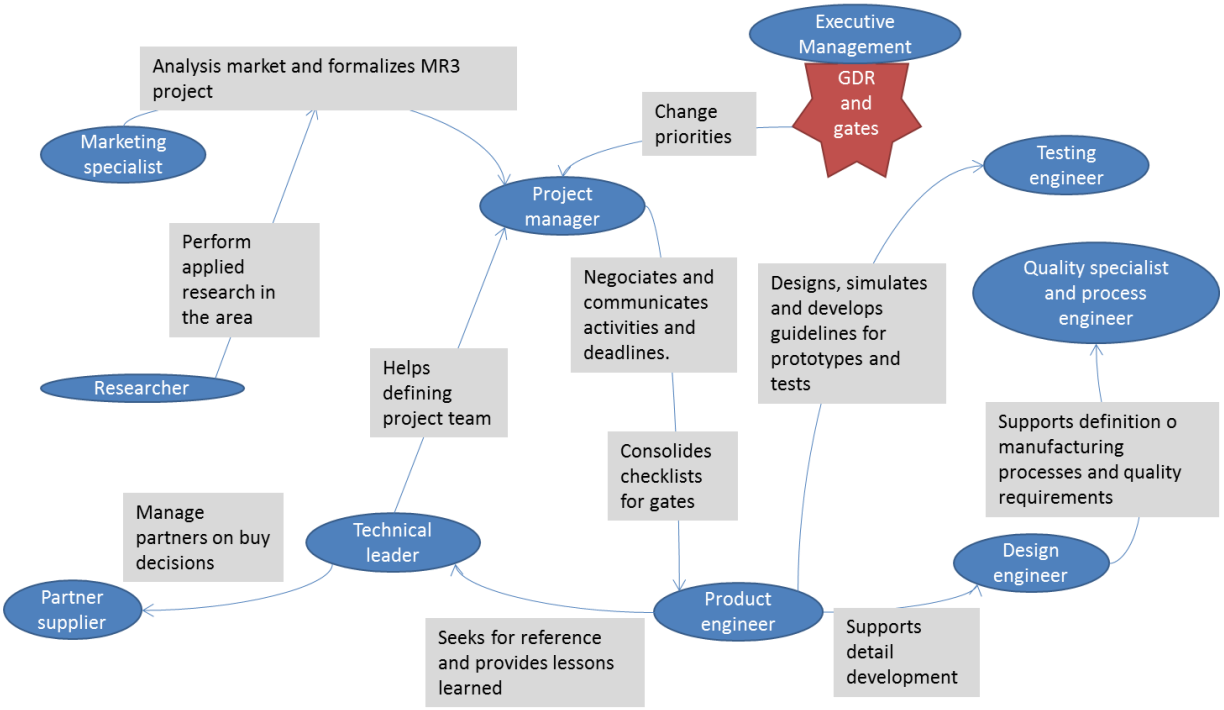

Figure 21 – Representation of the roles, main activities and relationships in a project

Important rituals for project progression and portfolio review are part of the organization's design process. Weekly meetings for project management issues and gates for project evaluation are related to a specific design project. Monthly Global design review meetings address the design project portfolio of the organization. The specific purposes for which each type of meeting takes place leads the expected participants: executive management are just involved on decision making events, project managers on meetings for planning and monitoring issues, and technical leaders and engineering designers when technical inputs are necessary according to the project phase.

The project management structure can be classified as "weak matrix structure", or lightweight project organization using Whellwright and Clark's terms (1992). It is expected the organization structure to influence the distribution of roles among members. As part of the organizational structure, product engineers, design engineers and technical leaders are members of an engineering knowledge area team, which is defined by the systems of the product developed by the organization as earlier discussed. Project managers were active member of engineering teams, as well.

Finally, the location and infrastructure aspect are analyzed. Areas and rooms related to the design process in the sites of the organization in Brazil are shown in Figure 22. Researchers, technical

leaders, project managers, product engineers, and testing engineers are located on the site one. The location of manufacturing roles varies according to the place each system is produced. Electric motors are produced in site one and related design engineers are there. Mechanical parts are produced on site two and the same applies for mechanical design engineers. As the company does not manufacture electronical systems, there are no design engineers in the electronics team. Assembly line is on site two, as well as process, and quality specialists.

Furthermore, rooms coexist with product representations in different stages of development. The product evolves through the facilities structure: while ideas are discussed on meeting rooms, CADs of product concepts are mainly developed in the rooms of each knowledge area, concepts are brought to physical existence in the development workshop, which are later tested to exhaustion in the testing room for concepts. Later on, process maps and quality standards are developed in the engineering area leading to pilot production in the manufacturing areas. The information for each product representation is available in the product data management structure of the organization when possible.

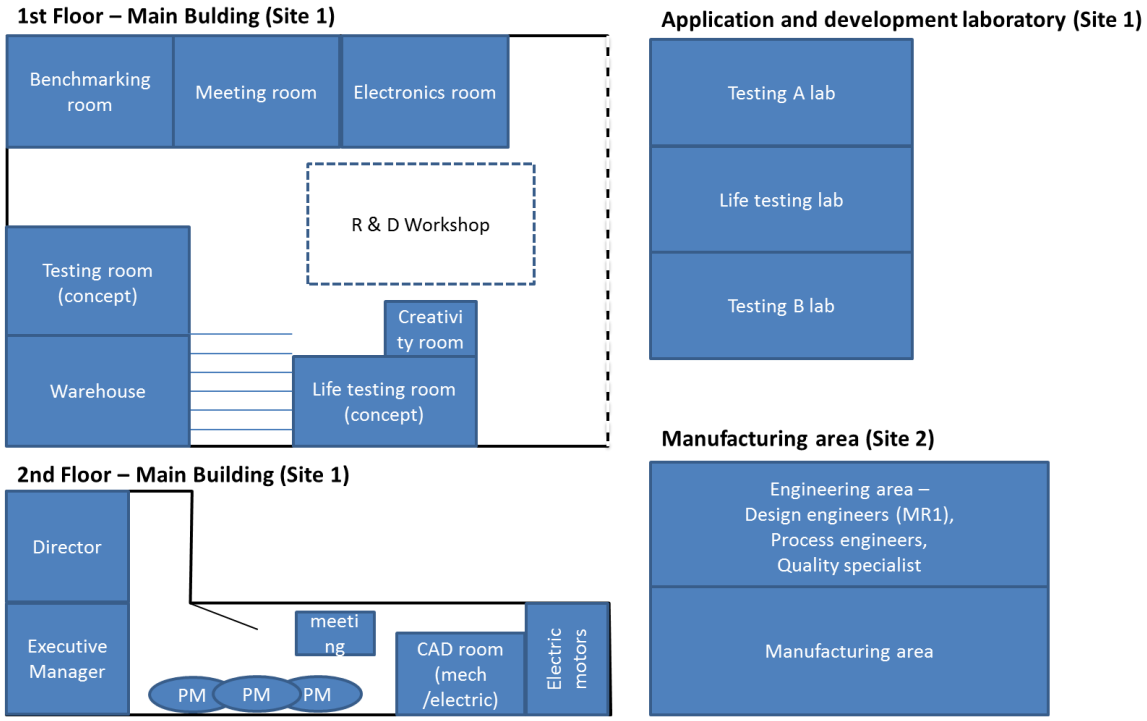

Figure 22 – Representation of the product development facilities in Brazil

On a broader point of view, the organization's distributed industrial sites on different countries influences both flow of technical knowledge among teams as the management of projects of new products. Each country's site is specialized on different knowledge areas according to manufacturing capability. Technical leaders and product designers nurture their professional network according to available expertise in each area. Projects are split among sites according to

expertise, availability and manufacturing capabilities. Cultural differences among design personnel from different countries bring some special challenges when managing projects and coordinating efforts.

After presenting the context of use of design process models next subsection elaborates on the identified user profiles.

4.3 Design process models user profiles

User profiles in Company Alpha are depicted through the use of empathy map technique. Since the large number of roles involved in the design process, it is not possible to draw a single profile for all users. Thus, three profiles from the apparent singularities each role provided are here presented: Product engineer, which is depicted in Figure 23, project manager in Figure 24, and technical leader in Figure 25.

User profiles are presented by means of their empathy maps. As the name proposes, empathy map serves to create empathy to the user of a system or product through representing their behavior, concerns and aspirations. It is a tool to help synthesize observations and draw out unexpected insights (Plattner, 2010). Apart from a functional-only view of use of design process models, we aim at providing a view of the users related to their contexts and personalities. Reading the map is rather straightforward, the four fields (think and feel, see, say and do and hear) on the top represent what from the context stimulates the user, and the way she/he acts which is relevant in this environment. At the bottom on the map, pains represent fears and frustrations, while gains represent needs and motivations

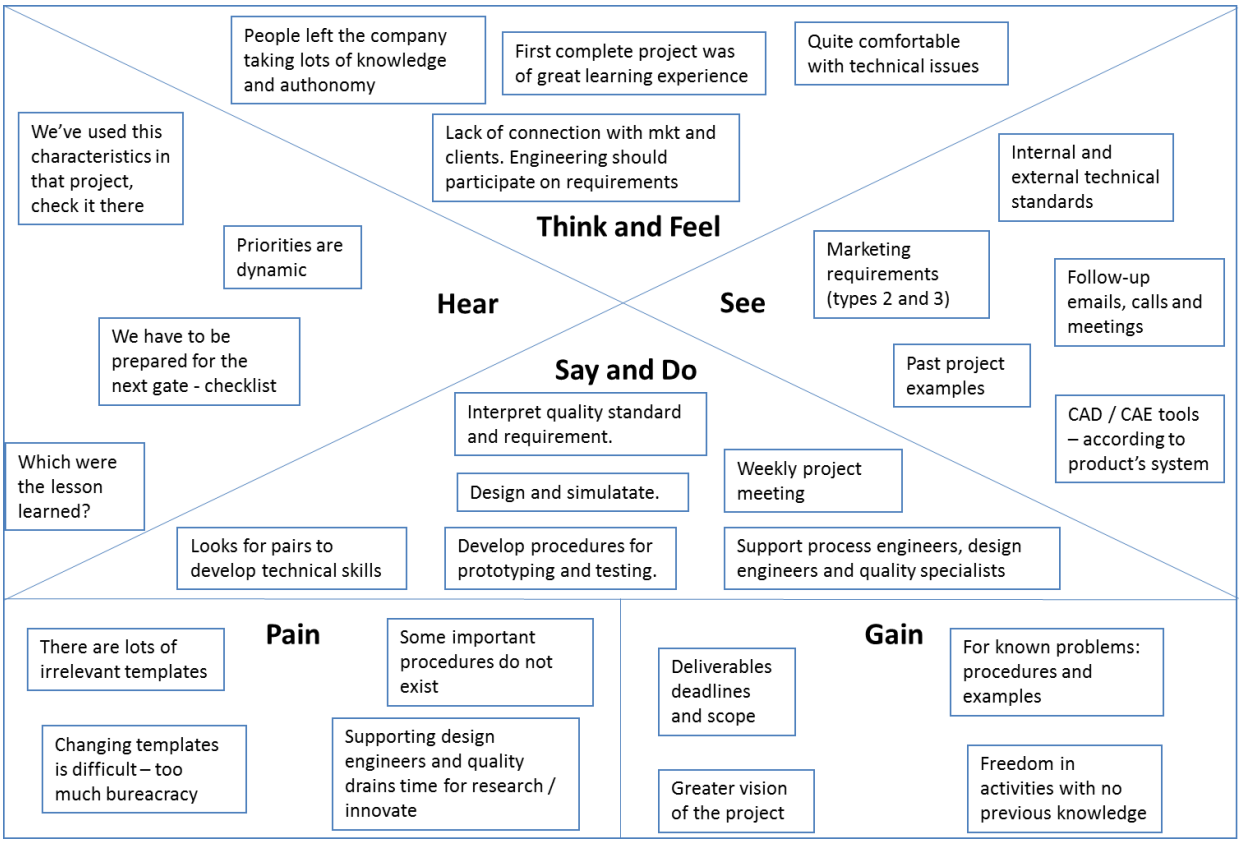

Figure 23 – Empathy map of the product engineer role

The first profile description is the product engineer role. As it can be observed from the map, these users enjoy talking about the technical features of the product and are open and motivated to develop skills on their areas. On their daily work, engineers are highly guided by internal and external technical standards available in the organization. After interpreting these standards, product engineers iterate on designing and simulating virtually the product behavior to develop procedures for prototyping and testing. They are open to collaborate with people from other roles and disciplines towards a solution.

The available design process models provide guidance through procedures and examples from previous projects. Product engineers get frustrated by bureaucracy resulting from irrelevant templates and checklists. In the other side, these users tended to enjoy activities with no previous knowledge, praising freedom to choose a design path. Words as freedom, research, exploration, and concept arouse their interest.

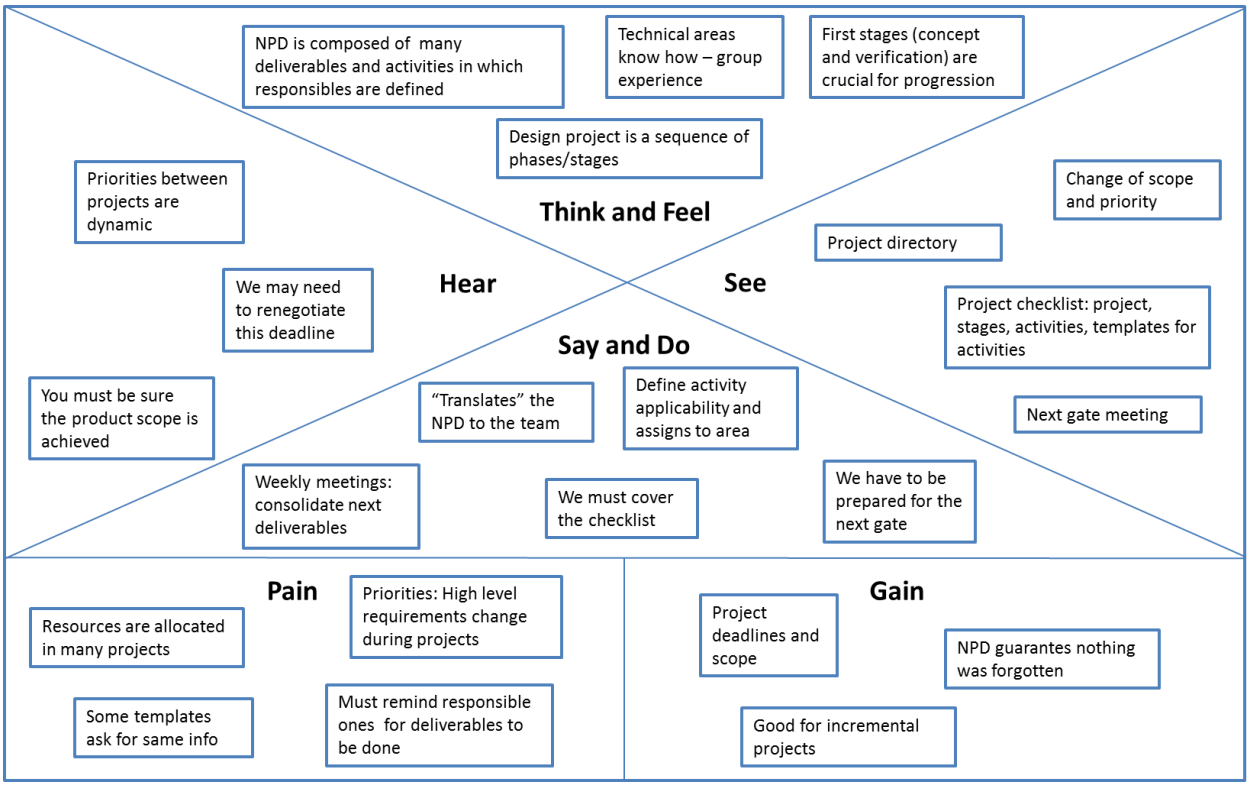

Figure 24 – Empathy map of the project manager role

The second profile elaborated is the project manager role. As it can be depicted from the map, project managers were likely to face the design project as a sequence of phases/stages. Their main concern was "in the next gate meeting", which represents the deadlines and requirements to be fulfilled. The idea of completing the phases towards project completion gives an extra motivation to them.

Managers act as "translators" of the organizations specific design process model to the team when managing projects. The process model and project management checklists available guarantee nothing is left behind. They rely on the staged process and procedures used by the company.

The dynamics of the design process contexts motivates them. Projects, priorities, deadlines, meetings are constantly in their vocabulary. Enjoy being in touch and coordinating with people from other areas.

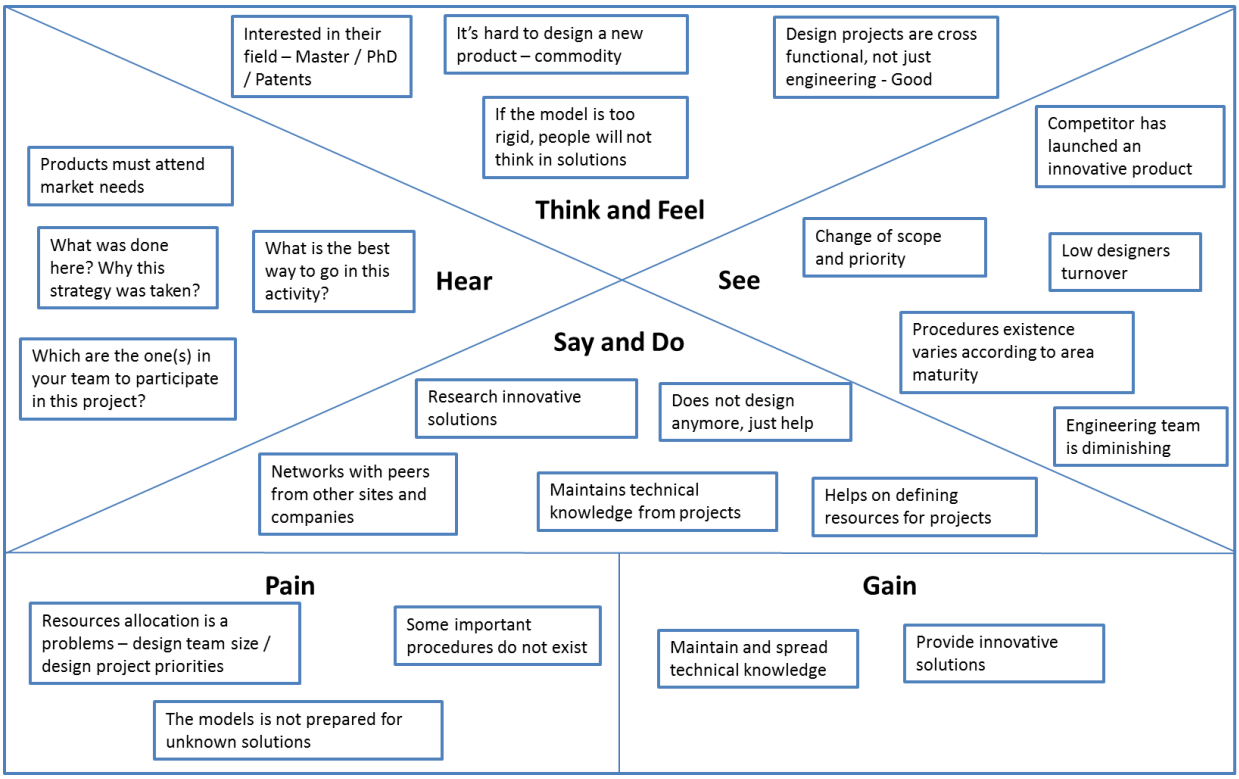

Figure 25 – Empathy map of the technical leader role

Finally, the third user profile addresses the technical leader role. As it can be observed in the map, technical leaders are concerned with process model flexibility, which, in their viewpoint, promotes innovation and problem solution. These users tend to believe that too rigid procedures would lead engineers not to think in solution possibilities. The fact that the organization specific process model is not prepared for unknown solutions is a problem in their viewpoint.

They act as coaches within their teams, the main responsibilities are on both providing the best way to approach design activities as to maintaining the knowledge created through projects. Appreciate cultivating and sharing knowledge.

It is observable that technical leaders feel responsible for technical excellence in their knowledge area. This keeps their motivation on developing their teams and on chase innovation at every moment.

Although in the same context, these roles present significant differences among each other. Empathy maps could support on eliciting personal traits which will be helpful on providing needs on design process models.

4.4 Case study considerations

This study represents the contextual aspects of design process models uses within an organization. The aspects considered in this research are elicited in Figure 26.

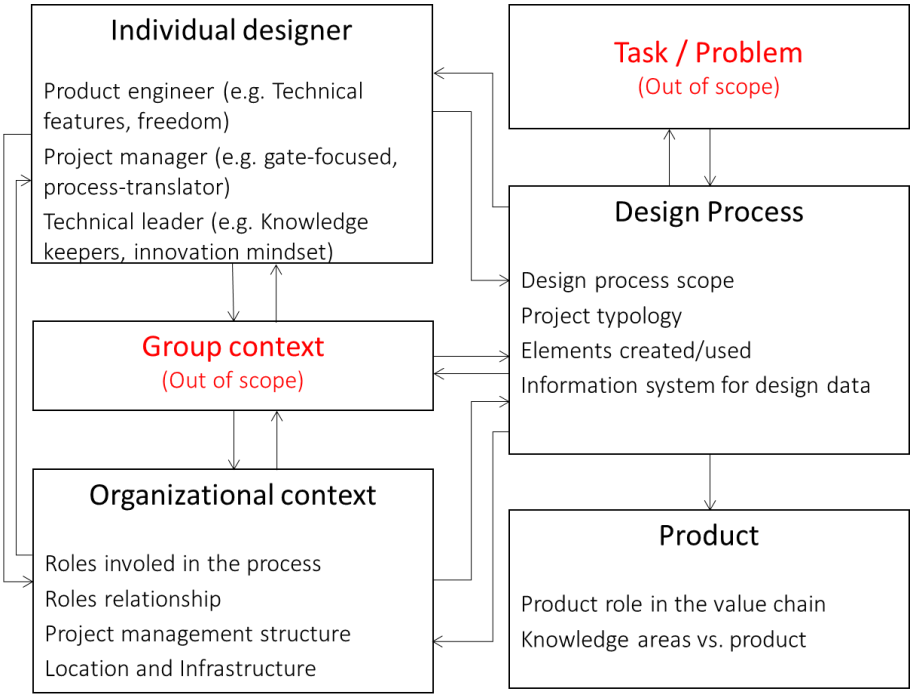

Figure 26 - Contextual aspects of design process model use

Users of design process models users are in the context. Three roles were characterized: project managers, technical leaders and product engineers. These roles may be found in different organizations, which make possible the definition of common characteristics to a branch or event related to design in the longer term.

The three roles interact among them and to the contextual aspects throughout the design process. Their relation within the project happens through the handoff of input/output of a given task, or during the realization of joint activities, and during decision making meetings. Design personnel involved in these interactions may have different traits and needs which must be attended by process model. Procedures, templates, and meetings structure must be designed to guarantee that a group of people will achieve their different purposes.

Also, the layout of the area used for developing products influences group formation and accessibility to personal interaction. In an organizational context, collocation of the team, and location of manufacturing sites influences the existence and behavior of team members performing different roles. Organizations commonly have their employees and manufacturing

areas in different global locations. The companies must be able to foster communication for project management and relationship development between technical related roles.

The connection of the three roles to the three types of application of design process models (activity development, project management and process improvement) is shown on Table 11. Even though the process improvement application was not focus of this research, part of concern and participation of technical leaders was in this application.

Table 11 – Relations between design process roles to application types

Type of Application / User	Develop design activity	Manage design project	Improve design process
Product engineer	✓	-	~
Project manager	-	✓	~
Technical leader	✓	✓	✓

Symbol	Contribution
-	Not identified
✓	Contribution – direct
~	Contribution – indirect

While project managers are the main responsible for managing the project, product engineers seems to be the focal point in developing design activity, providing much of the information to test and detail design the product. Technical leaders may be involved on design process improvement by maintaining the technical knowledge related to design, on design project management by aiding resource definition and on design process improvement on providing strategies and fomenting innovation.

The connection among roles and application types is an initial step to evaluate the different purposes in a real context. Lower level requirements to develop process models may be elicited based on the context and for different user profiles.

5 FINAL REMARKS

The goals of this research are twofold, describe the purposes for developing design process models and investigate the users' needs on these models in organizational context. These were pursuit to draw recommendations for user-centered design process models, which are elaborated on subsection 5.1 on content and system design.

Considering the scope of this research defined through the Research clarification step, we claim the goals were achieved of the outlined comprehensive Descriptive Study I and initial Prescriptive Study. Theoretical and practical contributions are elaborated on subsection 5.2.

There is much to be done towards a broader understanding on the purposes and needs to develop user-centered design process models, which includes the elaboration of a solution from the elicited requirements and test it through Descriptive Study II settings. Limitation and future works are outlined on subsection 5.3.

5.1 Recommendations for user-centered design process models

As part of an initial Prescriptive Study, recommendations are draw for the development of user-centered design process models. It is envisioned an application for managing the four levels of design process models to ensure organizations and design personnel the ability to improve the design process, manage the design projects and develop design activities according to good practices. The recommendations are made for content provision for the users and system design of the application.

Two recommendations are drawn regarding content provision:

Represent the design process scope

The process scope in an organization must be properly defined to represent what workforce should and should not mind about when designing. Technological development must be represented to provide applied research ready to implement into products. The front end of innovation must be covered so that ideas are correctly managed and transformed into concepts to be developed. If the company develops a product-service system, it may need guidance to develop services to be offered along with the developed products. The scope of the design process delimit the necessary rituals and roles to be considered in process models.

Provide user-centered content

There are many sources for design process content, which are available in many forms. Towards user-centered models, content should attend the many purposes identified for improving the design process, managing the design project and developing the design activity.

Content should be adapted to roles, knowledge areas and levels of expertise of designers. Roles are involved differently through the process, which requires guidance to adapt to their responsibilities. Each knowledge area, which is defined by the product/design problem, requires technical/branch related knowledge available in the organization's process models. Finally, design process models may make use of common behavior of designers from different levels of expertise to provide relevant guidance for novices and experts.

Two recommendations are drawn for system design:

Design process models flexibility

There is a need of flexibility on the models both to guarantee continuous improvement of the process as to easily instantiate projects and design activities according to the context and aligned to design theory. We suggest that connecting the four identified levels of design process models may lead to flexibility. The life cycle of each level of design process models must be considered, both on the way they are conceived as they lifespan. While specific design process models may be developed and used by tens, hundreds, or thousands of people, design activity models are meant to be ephemeral and for personal or team use.

The definition of a set of building blocks, which could contain and connect all relevant types of information and guarantee scalability and flexibility, is an important step. Modeling languages must be evaluated – or even created – to attend building blocks requirements.

Capacity to adapt to and learn from users

Towards adaptable models, profiles of users could be of use to adapt process models views to users' characteristics. We propose user`s roles in the process and level of expertise as two relevant characteristics in this direction.

Furthermore, users can be great source of information to depict and improve the design process in a given context. While process model views should be designed to provide consistent and up to date information to everyone involved in the process, it may also be designed to obtain information from them. The right set of information may be enough to adapt models to users' needs and to automatically learn from users. This learning process may be content-related as well as to the format through which content is provided.

Design process models may be designed to help users to assess and evolve through the levels of expertise. The set of design lenses may lead to understand the way design team members experience the design process and on means to develop through it.

5.2 Contributions

The contributions are built on the perspective of the users of design process models and the context they are inserted when designing, which was stressed out in this research. The application of literature review and contextual design along with research methods provided a comprehensive description of the application types and purposes, the users characteristics, and the context of use of design process models to define its requirements. Recommendations consolidate the description into initial prescriptions.

The first theoretical contribution of this work is the relation between the four levels of design process models (generic design process models, specific design process models, design project models, and design activity models) and the application types proposed (develop design activities, manage the design project, and improve the design process). This relation is presented in Figure 27. Literature review was important to define the levels and application types. The case study clarified the limits between project management and activity development applications.

Project requirements and deadlines, which are 'translated' by managers, and technical standards guide most of the progress in design activity development. Regarding design project management, the organization specific design process model guides the definition of design projects, which are communicated and updated according to the progression of activities and strategic changes. Finally, considering design process improvement, generic design process models are used along with existing organization design process models towards the definition of a new version of guidelines and rituals towards process enhancement.

The second theoretical contribution is the reinterpretation of the purposes through the focus group with specialists preparation, application and analysis. We are able to affirm that the identified purposes are relevant in large, international organizations and they provide a step further to connect the activity level to process models.

DP models levels / Type of Application	Generic DP models	Specific DP models	Design project models	Design activity models
Develop design activities	-	✓	~	✓
Manage the design project	-	✓	✓	~
Improve the design process	✓	✓	~	~

Symbol	Level contribution to application type
-	Non applicable
✓	Contribution – direct contact
~	Contribution – indirect contact mostly

Figure 27 – Contribution of design process models to manage the design project and develop design activities

Concerning activity development, it was identified nine purposes, which are mostly concentrated on supporting the evolutionary development of the product artifacts through process stages. Activities of distinct nature may be presented according to process progression along with relevant guidance to knowledge areas and users.

To support the development of design activities, the process models must be able to guide users to perform their activities, e.g. to access company specific practices. The model should provide a guideline to users perform a finite element simulation for a recurrent type of body structure. Special care should be taken to ensure process models not hinder the user`s creativity but provide inspiration showing past examples, which is imperative for novices.

Concerning project management, the purposes show a focus to develop and update project plan representations through stages for accurate decision making. In the adaption into project plans, specific design process models must help managers to: estimate time, cost, and quality; to assign resources; and to identify main risks. Information of previous projects as well as methods and guidelines must be available for management purposes.

Design project plans are created to coordinate the design team, communicate the project to relevant stakeholders, and make personnel aware of the many risks of a project. Project adaptations may happen according to project progress and to identified risks. Normally, organizations have more than a project in their portfolio and the impacts on each other must be considered.

Concerning process improvement, the purposes show the use of models towards continuous adaption of the process to better direct design project team members and other stakeholders. Purposes concentrate on the creation of models of the as-is situation with the ones engaged in the process and development of procedures and rituals based on external models used as reference to define and achieve a to-be situation.

Process improvement users must participate on the definition of standard plans with defined gates, activities, roles and deliverables in the organization specific design process model to be used across projects.

Expected benefits of using these models may be followed as well. In order to connect the models to the expected benefits, the culture of the company and team environment to be considered and enhanced by the use of design process models. The use of process models must be able to accelerate decision making and foster creative work. Formalized, cross-functional process models should not mean too-rigid process models on either managerial or operational level.

Providing the right type of information and demanding the right set of rituals and procedures should also lead to an innovative culture within the organization.

The third theoretical contribution is the systematization of design process models users. Literature was used to define characteristics which deserve attention on design process models use. Roles were further investigated in the focus group with specialists.

A number of roles use design process models. It may be impossible to attend the needs of every one. Among the 25 identified roles, ten of them were considered as core users in large, international organizations according to the focus group performed. These roles should be prioritized when developing design process models in companies. Their responsibilities and necessities may guide the definition of many of the sets of information to be provided by the models. The description of identified roles, the classification of central, not-central, internal and external users, and the ones involved on each application type may work as an initial guide on this direction.

Moreover, trends as open innovation and user-centered design bring a growing need on the involvement of people from outside companies' walls. Users and clients are important to set requirements and deadlines for the project. Universities, research institutes and consulting firms may participate by providing methodological support or technical assistance about applied research for the organization.

User profiling techniques details roles description and provide personality-related information and connect it to the context. It's deemed necessary to empathize with design personnel in order to develop better process models. The product engineer, project manager and technical leader descriptions in this manuscript are a source for the needs related to design process models.

It is expected that the relationship among roles becomes more difficult to predict according to organizational complexity based on its size, associated knowledge areas, location of personnel and product development facilities. This way, the context in which each roles is performed must be considered.

Finally, the depiction of the context of use of design process models is the fourth theoretical contribution. Contextual design techniques used on the case study were sources for description of the design personnel and the design context. The depiction is focused on project management and activity development.

Through contextual inquiry, the product, process, and organizational context are described considering the use of design process models.

With respect to the product context, the product strategy taken by the company influences the information necessary through the process. In the case, which families of product exist, there is

much space for the reuse of information. In a more innovative strategy, technical knowledge may be acquired and there may be extra need of conceptualization effort. Much of the strategy is defined by the role of the artifact under development in the value chain.

The product context defines the knowledge areas involved in the design process. Most of technical standard, the necessary CAD/CAE/CAM tools, and relevant good practices are defined by the artifact under development. The growing complexity of products results the involvement of more knowledge areas, which must be attended by process models.

Considering the process context, design process models must be able to represent the scope clearly and define the boundaries of technology, ideas, concepts development and mass production. The connection among the idea funnel, technology development, and new product development must be identified to be represented in the company design process models. A project typology helps on managing incremental to innovative products, through pre-defining standard activities, roles, deliverables, and decision points for each type of project.

Many elements are created and used through the process. This data are managed through a variety of information systems. Cataloguing the elements related to communication, project management, and design activity may help to assess process maturity and to obtain further information through document analysis.

On the organizational context, it is fundamental to consider the structure. While in functional organizations the roles of project manager and technical leader may be performed by the same member, in matrix or project-based organizations these roles tend to be performed by different members. In pure project organizations, as startups, one member is expected to perform many of the roles as the project evolves, in addition to administrative processes to keep the company.

Among different organizations, the relationship between clients and suppliers can be strengthened by the use of shared design process models.

The context of use of process models described in this manuscript can be used to understand other organizations with similar contexts and to compare with organizations in different realities which develop products and could make use of user-centered design process models.

Some <u>practical contributions</u> can be pointed out: (1) evidence that the activity development application type is not properly considered; (2) evidence that several users do not get enough attention; and (3) the initial recommendations for design process models, which can be already used to guide organizations.

5.3 Limitations and Future works

Investigate the use of design process models in organization is a very broad task and limitations of this research can be pointed out as gaps for future work.

Considering the focus group with specialists and the case study, this research describes the use of design process models in large and mature organizations. The cards prepared for purposes and roles provide the opportunity to effortlessly replicate the focus group. Reapplying it with specialists from academia or members of different types of organization could bring more insights on the use of design process models. Furthermore, the case study represents only one context, i.e. one organization. The contextual design approach outlined in this manuscript may be used to investigate different organizations or contexts.

The characterization of users of design process models is an ongoing issue as well. In one hand, user profiling may be used to represent the needs and pains on using process models for other roles and in different contexts. It is a fact that design personnel characteristics are broader than roles. Literature contains other characteristics – e.g. level of expertise – which should be further described in organizations.

Concerning content provision, communication elements and design process models artifacts may be sources for document analysis towards detailing the type of content available and created through the process for the many purposes. User roles may be used to evaluate which content should be provided to each user. It must be considered that too-personalized views of the models may hinder the commonality of process understanding in groups.

The interface through which content is accessed by the ones involved in designing to perform their activities and make decisions must be thought of. Models' format and content positioning influence the model-user interaction and should be researched and designed for the user in organizations. Model visualization was not considered in this research and should be explored.

Concerning design process models systems, concepts as flexibility, personalization and adaptability must be clearly defined. The adaption of systems to specific contexts and users is widespread in applications used daily by billions of people, as social media and e-commerce applications, which can be benchmarking sources. Parsimony is necessary because of the creative, complex, and iterative characteristic of the design process. There is an ample space for argumentation on the extent a set of process model views can guide the ones involved in designing.

Contextual design techniques are still an option towards the to be developed application for design process models. Sequence models and use case diagrams can be created for the purposes related to each application by partnering up with the ones involved in designing while they perform process-related work. A possibility is to develop views prototypes for identified

purposes and test them with different users towards better provision of content and system. Apart from understanding process-user interaction, it may also be important to identify user-user interactions to measure their behavior and assure the use of the application improves design results.

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APPENDIX 1 – METHODOLOGICAL ASPECTS

This research aims at developing knowledge on the area of design. The overall aim of a design research, as pointed by Blessing and Chakrabarti (2009), is to understand and improve the design process by developing more successful products as an ultimate goal. In that direction, Blessing and Chakrabarti (2009) developed the Design Research Methodology (DRM) aimed to assist scientific research in the Design area. This methodology consists of four stages: Research Clarification (RC), Descriptive Study I (DS-I), Prescriptive Study (PS), and Descriptive Study II (DS-II). The framework presented on Figure 28 clarifies the stages and shows the iterative trait of the methodology.

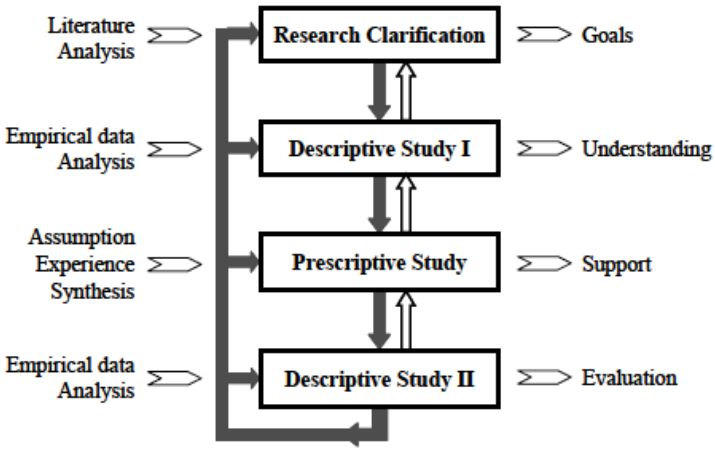


Figure 28 – Design Research Methodology Framework (Blessing & Chakrabarti 2009, p.15)

The first stage, Research Clarification, is intended to find indications that support the assumptions of the research so that a worthwhile research goal is formulated. The Descriptive Study I (DS-I) stage aims at elaborating an initial description of the existing situation through performing further literature reviews on empirical research, undertaking empirical research, and, reasoning. The goal of Prescriptive Study (PS) stage is the development of the support, that is, the development of the results that realize the research goals. Finally, during the fourth stage, Descriptive Study II (DS-II) the support that has been developed is evaluated.

According to the type of the research project, some DRM stages can be suppressed or carried out with thoroughness. The DRM framework addresses seven types of design research projects. The types of studies that can be undertaken on each phase are: review-based study, comprehensive, and initial studies. A review-based study is only supported by literature review of the design area; a comprehensive study includes both a review-based study as well as empirical studies undertaken by the researcher; finally, an initial study closes the project and prepares the results for the use by others. The seven research types are shown in Figure 29.

Research Clarification	Descriptive Study I	Prescriptive Study	Descriptive Study II
1. Review-based →	Comprehensive		
2. Review-based →	Comprehensive →	Initial	
3. Review-based →	Review-based →	Comprehensive →	Initial
4. Review-based →	Review-based →	Review-based → Initial/ Comprehensive	Comprehensive
5. Review-based →	Comprehensive →	Comprehensive →	Initial
6. Review-based →	Review-based →	Comprehensive →	Comprehensive
7. Review-based →	Comprehensive →	Comprehensive →	Comprehensive

Figure 29 – Types of design research projects and their main focus (Iterations omitted). (Blessing & Chakrabarti 2009, p.18)

As previous mentioned the aim of this research is to comprehend why organizations use process models, who are its users, and it the context of use to provide recommendations for user-centered design process models. That said this research follows the DRM stages of the second type of project presented in Figure 29.

APPENDIX 2 – FOCUS GROUP PROTOCOL

This protocol presents the event preparation, data gathering and data analysis of the focus groups with specialists using card sorting technique.

Preparation

- The first point is to elaborate the **research target** of the event. Two targets were defined:
  - Verify the purposes for the three application types;
  - Connect users' roles to the application types.
- Secondly, **participants** are defined. Managers and engineers from large and mature organizations on product development were invited.
- The third point is **card preparation**. Three decks of cards were prepared containing purposes for each application type (according to Tables 3, 4, and 5), and one deck of cards was prepared containing the roles involved in the design process (according to Table 6).
- An special interest may be given to **practical takeaways** from the perspective of participants as they must learn something from the session as well. Awareness to the three application types of design process models and the most important roles to be considered when developing them was expected after the participation in the focus group.

Data Gathering

- Participants were organized in six groups of four people – two groups were responsible for each application type. An introduction of the topic and the objectives of the focus group was presented to them – a presentation was elaborated for this introduction and for the whole focus group with specialists;
- Firstly, groups of participants should evaluate the purposes according to their level of importance for that specific application, and propose new cards if necessary.
- Secondly, groups of participants should name core roles as users of design process models.
- Thirdly, groups of participants should name the most important roles for their application types.

Observers were instructed to make notes according to the observation protocol presented on

- Table 12.

Table 12 – Observation protocol for focus group sessions

Observation protocol
1. Purposes of use What did they discuss regarding purposes' names and descriptions? Did participants agree on the purposes description? Do new purposes fit to the ones proposed regarding to name and description? How participants reacted to purposes of other application types?
2. Design process models users mapping What did they discuss regarding users names and description? Did participants agree on users' names and descriptions? Which users generated discussion when positioning in the map? What did they discuss?
3. Users vs. application types Which users generated discussion when classifying according to the application types? What did they discuss?

Data analysis and sharing

- Interviews were performed to each observer to review their field notes and gather insights;
- Patterns across groups of participants were sought based on what was delivered by them and on field notes and observation;
- Finally, a practitioner report and an academic report were elaborated to share lessons learned and knowledge to relevant stakeholders – both participants, their organizations, and researchers from academia.

APPENDIX 3 – CASE STUDY PROTOCOL

Towards identifying users' needs in an organizational context, the contextual design process proposed by Holtzblatt and Beyer (2012) was followed in order to characterize what design personnel do as users of design process models – see Figure 30.

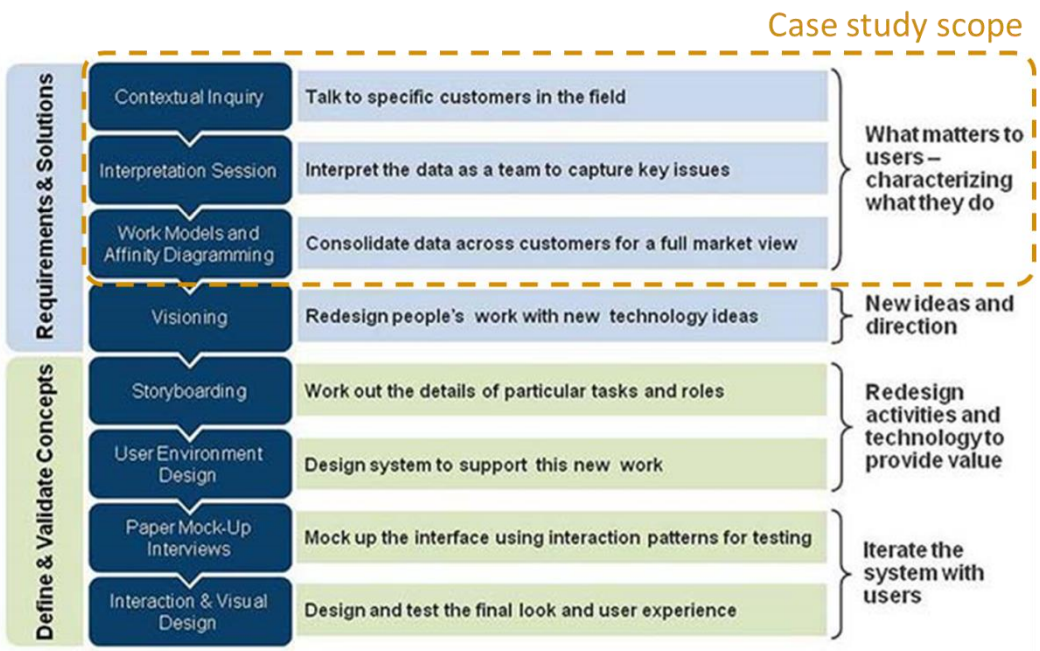


Figure 30 – The contextual design process (Holtzblatt & Beyer, 2012, fig. 8.1) *and scope adopted for this research*

This protocol presents the case study preparation, data gathering and data analysis performed through the use of contextual inquiry and user profiling.

Preparation

- The first point is to elaborate the **research target** of the case study. The target was stated as:
    - Investigate the context of use of design process models in one organization.
- Secondly, the **interview protocol** is elaborated. It was developed in this research framed in the Network of designing (Badke-Schaub et al., 2005) – see Table 13.
- A supporting person in the organization must be established to facilitate the research and to **define participants**. The goals and research scope were presented her/him in order to find design personnel which could provide valuable feedback. Two rounds of appointments were made so that there was enough time to iterate in the research.

Data Gathering

- Both rounds of interviews were performed. A relationship was established with each interviewed person, in which the user is the expert and researchers wanted to understand the use of design process models.
- Notes were made by the researcher and research assistant and, when possible, photographs were taken. Every interview sessions were recorded. Care was taken not to interrupt the interviewee, open issues were asked when convenient.
- After each interview, debriefing sessions were held among research and research assistants.

Data analysis and sharing

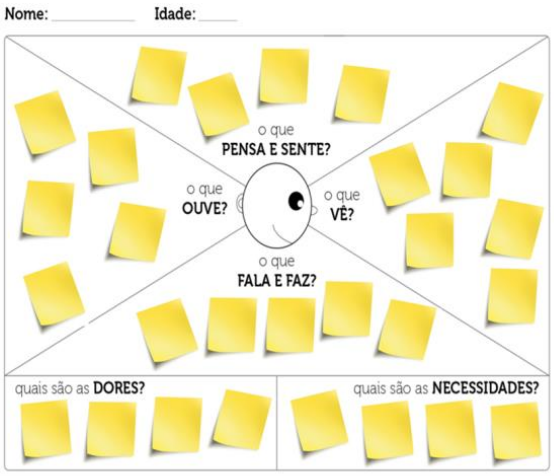
- All the research data was reviewed and labeled according to the interview protocol.
- For contextual inquiry, models of contextual aspects identified from interviews were created.
- For user profiling, design personnel behavioral patterns were identified. Similar respondents were grouped together. Empathy maps were assembled according to behavioral patterns following the template provided by Kayo (2013) – see Figure 31.
- Models created were presented to the supporting person and users; feedback was gathered. Further questions were made.

Table 13 – Interview protocols for case study

Dimension	Area of interest	Questions
1. Individual designer	1.1. Background	1.1.1. How long he/she works in engineering design related areas
		1.1.2. Number of design projects he/she participated in
		1.1.3. What brought he/she to this field and main goals in the area
		1.1.4. Motivation to develop products
	1.2. Best / Worst project	1.2.1. Description of a project he/she considered successful
		1.2.2. Description of a project he/she considered unsuccessful
2. Organization	2.1. Role	2.1.1. Functional area at the company, main responsibilities and interface to other areas
		2.1.2. Design phases in which the functional area is involved

	2.2. Innovation	2.2.1. Opinion regarding innovation in the organization. Does the process model help?
3. Product	3.1. Product types	3.1.1. Types of products which he/she participates on developing
		3.1.2. Average time o involvement with the same product / project
		3.1.3. Quantity of projects at the same time
	3.2. Project situations	3.2.1. Participation on defining activities
		3.2.2. Changes on scope and priorities among projects
4. Process	4.1. Process model use	4.1.1. Moments he/she comes into contact to the organization process model / project plan
		4.1.2. In which system is it possible to find information regarding organization process model / project plan
		4.1.3. Benefits and expectations on using these models / systems
		4.1.4. How models help on performing the design activities (what to do / how to do / when to do)
	4.2. Types of content	4.2.1. Model parts that prescribe the practice and steps to be performed (model, deliverables, colleagues)
		4.2.2. Descriptions, examples of deliverables performed in other projects (deliverables, colleagues)
		4.2.3. Use of literature and quality standards
		4.2.4. Other fonts (events / internet / YouTube / personal contacts)
		4.2.5. Information of a specific project (where / what)
		4.2.6. Integration of information to organization systems
	4.3. Activity types	4.3.1. Frequent activities on the engineering design process
		4.3.2. Comparing routine activities to uncertain ones
		4.3.3. New activities and situations to organization
		4.3.4. Type of information necessary to perform design tasks
	4.4. Improvement opportunities	4.4.1. New opportunities / What to do

4.5. Communication	4.5.1. How people communicate relate to an activity (email, personally, system, WhatsApp...)
	4.5.2. How people communicate relate to a group decision (email, meetings, videoconference...)
4.6. Other participants	4.6.1. Participation of clients, end users and partner
	4.6.2. How to guide them through the process



User profiling – represents groups of people providing user needs:
SAY: What are some quotes and defining words your user said?
DO: What actions and behaviors did you notice?
THINK: What might your user be thinking? What does this tell you about his or her beliefs?
FEEL: What emotions might your subject be feeling?
PAINS: What are the negative emotions and undesired situations which user experiences?
GAINS: What are the main benefits users achieve?

Figure 31 – User profile template translated into English (Kayo, 2013)

ANNEX

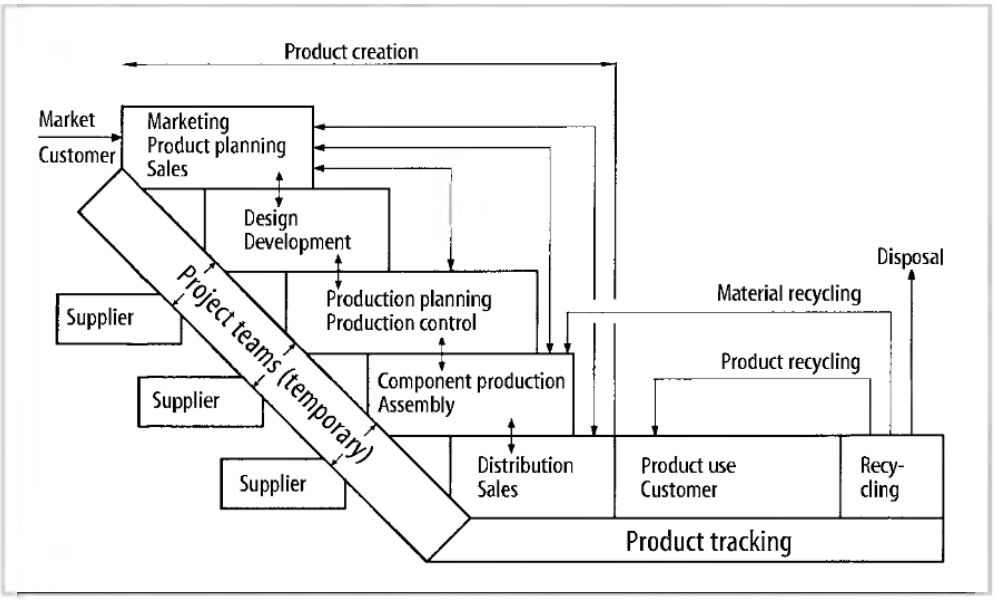


Figure 4.5. Product creation and tracking processes using Simultaneous Engineering, showing the overlapping activities of different disciplines, the formation of a project team and close contact with customers and suppliers

(Pahl et al., 2007, fig. 4.5)

7 Differences between disciplines. Examples of the variation in the disciplines that may be involved in the design of a complex product, such as a car or an aircraft.

organisations and can lead to inefficiencies in the product development process. Conversely, people who have worked on the same aspects of problems share a common understanding of their tasks and are likely to use similar mental and social constructs.

Discipline	Description	Uncertainty	Degree of detail	Distance to goal	Decision making
Sales and marketing	High-level product characteristics	Company capability, market, world events	Low	Known	Selection of alternatives
Management	Tasks, deadlines, budgets	Resources, technical risk	Low	Known	Constraint resolution
Engineering design	Sketches, drawings, CAD systems	Technical, missing information	High	Not known	Function and fit
Applied mathematics	Formulae, simulation models	Underlying specifications	High	Known	Objective evaluation
Materials science	Formulae, empirical models	Physical performance	High	Known	Physical evaluation
Systems engineering	High-level diagrams	Influencing factors	Low	Not known	Weighting
Product design	Sketches, models, mood boards	Context, emergent properties	Low, high	Not known	Subjective
Manufacturing and logistics	CAM systems, MRP systems	Known types	Very high	Known	Potentially objective

(C. Eckert & Clarkson, 2005, fig. 7)

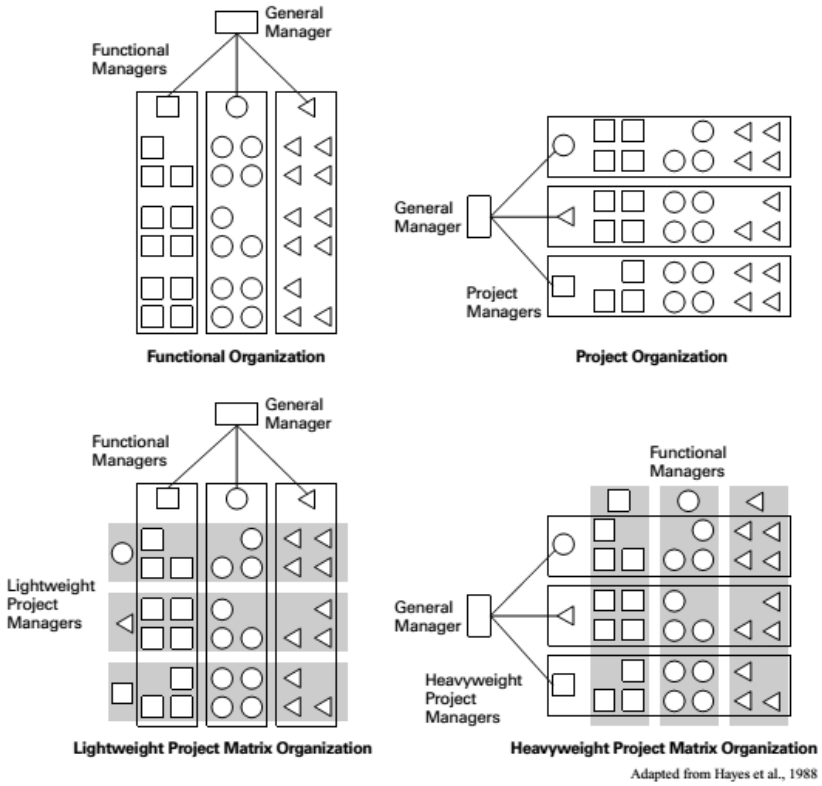


EXHIBIT 2-8 Various product development organizations. For simplicity, three functions and three projects are shown.

(Ulrich & Eppinger, 2012, fig. 2.8)

Visibility and Juxtaposability. Ability to view components easily. How easy is it to see or find the various parts of the notation while it is being created or changed? If the users need to compare or combine different parts, can they see them at the same time?

Strategic management. At the highest level in a company, the directors and CEO will make decisions about which products to develop, the allocation of resources and contingency funds for each project, and about responding to requests for tender . Strategically, companies are also interested in knowledge retention and management, which can be structured by process models.

Operational management. At the level of the project managers, functional managers and chief engineers, the primary concerns are in directing the course of a project, or a number of projects, as quickly, cheaply and effectively as possible. This may involve choosing tools and methods, scheduling, planning, allocating resources and facilitating communication of information. Process models aid in the standardisation of methods, tools, and training within and across projects.

Design engineers. These are the participants most directly involved with creating the product design. They require the critical information for their activities to be delivered, and guidance as to what the 'next step' in the process should be.

Process newcomers. New recruits to a company or division of a company will require training about the characteristics of the design process.

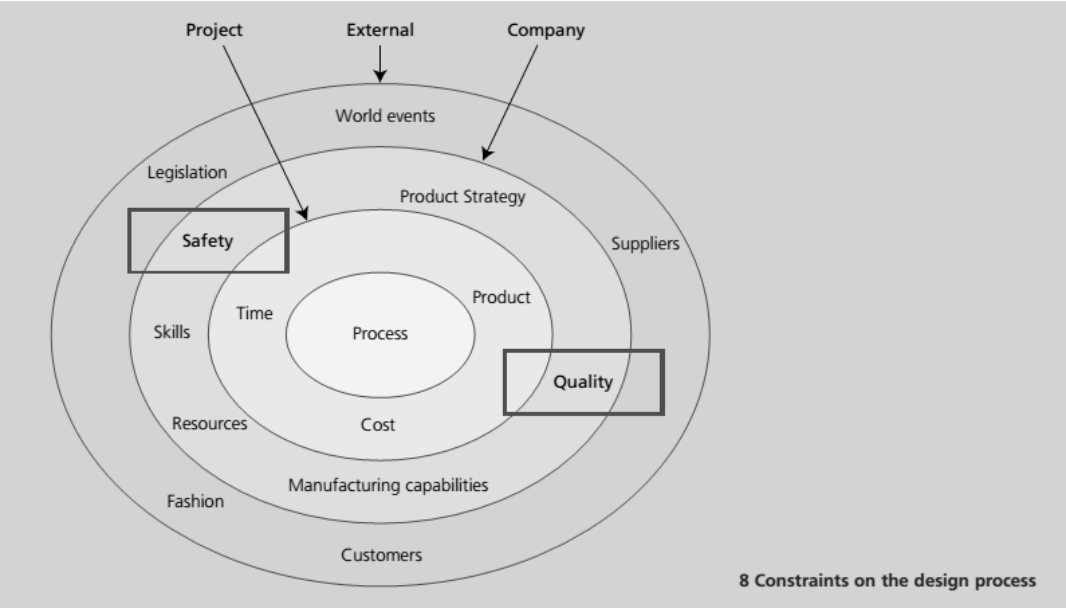
Supply chain. The increasingly close integration with the supply chain observed in the automotive and aerospace companies visited creates opposing pressures: on the one hand, to provide information and understanding of the design process to ensure that external work is compatible with internal design effort both technically and in terms of timing; but on the other hand to control the information released to the suppliers to attempt to slow the migration of expertise out of the core company and into the supplier base. Shared models of the design process may help to build trust, assisting in explaining the causes of delays or problems with the work.

Academia. Because many existing case studies are carried out with a fairly narrow focus, or specific purpose in mind, it is difficult to adapt existing fieldwork to test a new idea. A rich, standardised model format would facilitate transfer of data from one project to another, increasing the quantity of data available to researchers, and so assisting or even driving the hypothesis creation and testing process. If the model is sufficiently rich, it may be possible to test some hypotheses without the need to gather additional data, simply by analysing existing models in a new way.

2.4 Some markets for process modelling

cost and duration of the process change and decisions must be made about

(O'Donovan et al., 2005, fig. 2.4)



(C. Eckert & Clarkson, 2005, fig. 8)

Rally Point Phase	0. Project Registration	1. Concept Definition	2. Feasibility and Planning	3. Preliminary Design	4. Final Design	5. Product Verification	6. Process Verification	7. Launch	8. Post-Launch Assessment
Primary Goal	Define project and business unit needs	Develop project concept and charter	Create product description	Create preliminary detailed design	Detail and optimize design	Demonstrate product performance	Demonstrate process performance	Launch product	Identify lessons learned
Marketing and Sales	Identify customers and market size Describe competitive features and benefits Identify target cost and price	Capture voice of the customer Analyze customer needs Document customer needs	Develop marketing and sales plans Create phase-in and phase-out plans	Review concepts with customers		Initialize field trials	Complete field trials Finalize training plans	Finalize pricing and sales forecasts Complete sales and service training	Solicit customer feedback and satisfaction ratings Measure sales vs. forecast Complete phase-in and phase-out
Engineering	Identify project risks	Identify critical-to-quality specs Develop and select concepts Update project risks	Create functional specification and performance metrics Review concept selection Define product architecture Assess technical failures modes	Conduct a preliminary design review Build and test alpha prototypes Assess product failure modes	Freeze hardware and software design Complete engineering documentation Draft technical documentation Secure beta prototypes	Finalize design documentation Complete beta prototype and field testing Apply for regulatory approvals	Obtain regulatory approvals	Finalize product metrics	
Quality Assurance			Create preliminary test plan		Test beta prototypes for robustness	Complete quality assurance testing	Conduct process verification testing		
Manufacturing				Begin manufacturing process development Conduct a preliminary manufacturing process review	Finalize bill of materials (BOM) Develop manufacturing control plans	Update manufacturing control plans	Run manufacturing pilots Finalize manufacturing control plans		Register obsolete and scrap products
Purchasing				Create a supplier participation matrix Assess suppliers for certification	Identify long lead-time items		Verify supply chain readiness		
Legal		Search patents	Identify trade compliance issues	Identify potential patents	Prepare patent applications	Assure trade compliance			
Financial	Prepare preliminary business case	Refine business case	Complete financial package						Monitor return on investment
Project Management	Identify project timing, resources, and capital Prepare RP0 checklist & submit for approval	Assess team capabilities/skills Identify development team members Select a Rally Point process variant Prepare RP1 checklist & submit for approval	Plan integrated product development schedule Assign a project manager Update RP1 deliverables Prepare RP2 checklist & submit for approval	Update RP1-2 deliverables Prepare RP3 checklist & submit for approval	Update RP1-3 deliverables Prepare RP4 checklist & submit for approval	Update RP1-4 deliverables Prepare RP5 checklist & submit for approval	Update RP1-5 deliverables Prepare RP6 checklist & submit for approval	Finalize all deliverables Finalize launch plans and documentation Update RP1-6 deliverables Prepare RP7 checklist & submit for approval	Document best practices Prepare RP8 checklist & submit for approval

Courtesy of Tyco International

EXHIBIT 2-7 Key activities and the responsible functions comprising the Tyco Rally Point product development process.

(Ulrich & Eppinger, 2012, fig. 2.7)