A GUIDE TO INVESTIGATING DESIGN PROCESS MODELS CONTEXT OF USE

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Abstract

Design process models are created for different purposes, which includes assisting the design team to manage a project and to perform their day-to-day activities. In both cases, process models should be development to attend needs of its users - the design personnel. A good practice to understand systems users' needs is to perform a context analysis of the intended uses. In this research, it is performed a case research which analyses the context of the use of design process model in a multinational company. User-centered techniques as contextual inquiry and empathy map were employed. Based on the application, a guide to investigating design process models context of use is proposed. Four perspectives of the context of use of design process models may be investigated: product, design process, organization, and individual. The description of the context of use of design process models may assist to verify the needs of the users of the process being represented.

Keywords: Design process, Process modelling, User centred design, Case study

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1 INTRODUCTION

Process models represent and recommend practices of a domain to support people to perform activities related to a given process (Browning et al., 2006). The adoption of design process models is considered a good design practice (Cooper and Edgett, 2012; Markham and Lee, 2013). Design process models should provide information to enable the team to execute day-to-day activities, which include the use of selected methods and tools.

A generic applicable model which adapts its content and format to be promptly used in organizations does not exist (Fettke et al., 2006; Gericke and Blessing, 2011). Indeed, products and services are developed under quite distinct environments or contexts. Thereby a generic model does not seem to be an appropriate solution. Additionally, reports inform that personnel is making less and less use of these models (Markham and Lee, 2013). It is indisputable that there is plenty of room to improve the usability of these models so that the use of design process models is enhanced. This paper describes and proposes a guide to investigating the context of use of design process models. The herein research intends to answer the following research question: How the design process context interfere on the way design process models must be developed to leverage its use?

This manuscript starts by providing a theoretical background based on the design process, business process management, and user-centered design literature. We describe the context of use of design process models in one organization, with the goal of guiding process improvement through the use of design process models. Finally, a guide is introduced to assist design personnel and researchers investigating the context of use of design process models in organizations. This case may inspire organizations to apply an user-centered approach for their process models.

2 THEORETICAL BACKGROUND

A theoretical background grounded in Design Process and Business Process Management theories is developed to introduce what concepts available in literature which deal with the context of use of process models, in particular, the ones used in the design process. User-centered design theory supports the methodological development of the context investigation guide. The theoretical background, which is further described in this session, is summarized in Figure 1.

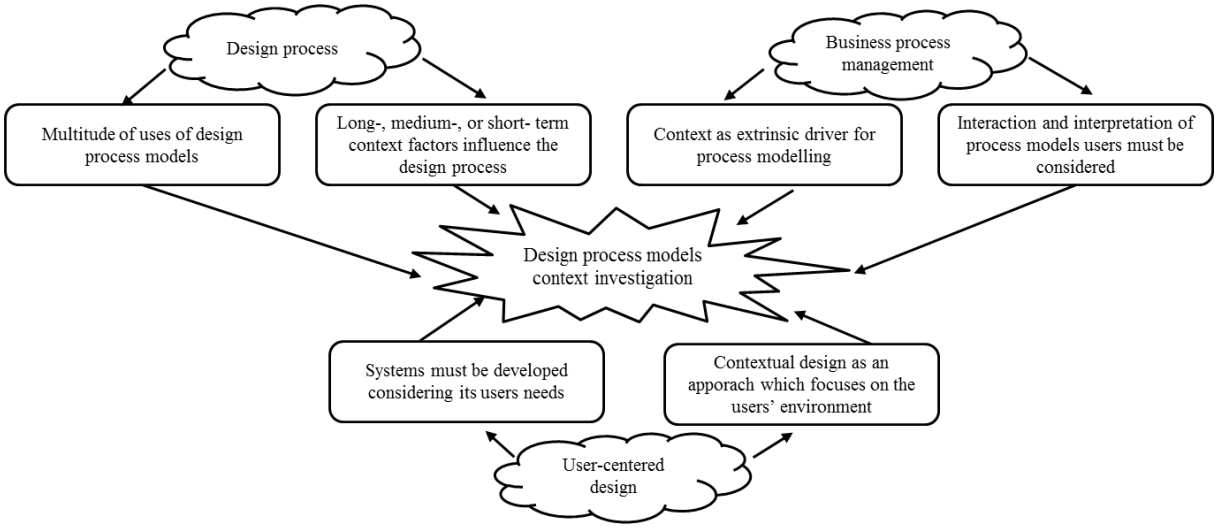

Figure 1. Theoretical background used to investigate of design process models context

Design process models represent internal or external elements of a process that are not always obvious to design personnel, such as activities, methods, deliverables and information flow. These models may exist in four different abstraction levels (Gericke and Moser, 2014, fig. 4): generic design process models, branch-specific design process models, organization-specific design process models and project plans.

In this paper, we are mainly interested in organization-specific design process models, which formalize practices adopted by an organization. These models can be created through adaptation of generic models

based on the experience of the ones involved in designing (managers, engineers, and designers). There is a multitude of users that use process models for three main applications: (a) to improve the design process, (b) to manage the design project, and (c) to perform design activities (Costa, 2016).
A structure that allows organizations to take the most out of their design process by correctly framing its context and adapting the good design practices has been envisioned by Maffin et al. (1997). Gericke, Meissner, and Paetzold (2013) provides a scheme to be used to organize context factors grounded on an extensive literature review, in which relevant context factors should be investigated for an individual purpose.
The influencing factors of using design process models are classified into long-term, medium-term, and short-term context. The less dynamic context factors are relevant to be modeled and represented for the entire organization, while the most dynamic ones may be important for the adaptation made daily by designers on each confronted design situation. The herein research stresses the long-term context factors, which are expected to generalize a fraction of the design situations to a level that can be represented for the many organization members.
From a business process management point of view, Rosemann and Recker (2006) present a context-aware process design that seeks to identify extrinsic factors for process modeling. Context is understood as information, which when changed, impacts the design and execution of the specific process. Coutaz et al. (2005) characterize this information as "reconfigurable, migratory, distributed, and multiscale." The challenge of defining which context factor to be considered, how to identify them and the impact on the specific process to be modeled is, thus, reinforced.
The interaction and interpretation of people of what is represented by process models may be considered as context as well (Saidani and Nurcan, 2007). Browning, Fricke, and Negele (Browning et al., 2006) recognize the influence of mental models of individuals as users of design process models. Eckert and Clarkson (2003) describe models used for project planning (quality plans, process plans, and product plans) making explicit some of the boundaries between the process representations and its users' interpretation. Five ways of interpreting design process models used for project management are provided by Engwall et al. (2005). There is space to investigate the interaction among users and design process models addressing longer-term factors.
Finally, from an user-centered design point of view, design process models may be understood as a system designed to be used by design personnel. Human needs and behavior should lead the development of a system so that it accommodates this identified behavior (Norman, 2013). It is expected that human-centered environments lead 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.
Contextual design can be used to support the investigation of the context and create a structured representation of users' environment exposing details that these users may not be consciously aware of and use it to improve their work practice (Holtzblatt and Beyer, 2012). The contextual design approach is adopted for this research using contextual inquiry and user profiling techniques to facilitate the comprehension and representation of the context of use of design process models. Contextual inquiry is described by Holtzblatt and Beyer (Holtzblatt and Beyer, 2012) as a technique which helps users show their environment seeking for a shared understanding of their context with researchers. User profiling is commonly applied to depict a common representation for groups of people and help the researcher to understand user needs by modeling them (Kuniavsky, 2003). These are used to help to put the researcher in the users' shoes and seek for their point of view of the organization's design process models.
The theoretical background introduced grounds the design process models context investigation proposed in this manuscript. The methodology to support this research is introduced in section 3.

3 METHODOLOGY

The herein research proposes a guide to investigating the context of use of design process models. The guide is the result of a case research in which contextual design was applied based on Holtzblatt and Beyer (Holtzblatt and Beyer, 2012), using contextual inquiry and empathy maps as research techniques. It is noteworthy that case research was performed grounded on the argument of Voss, Tsikriktis and Frohlich (2002) that this research method should be applied to theory building, where key variables can be identified, described or linked.
The case research followed three phases: planning, data collection, and data analysis.

The planning phase comprised all activities related to research protocol preparation, organization approval, and scheduling. Aiming at investigating the context of use of design process models he human-centered network of designing proposed by Badke-Schaub et al. (2005) was the main reference to define the scope of the context to be investigated, and thus for protocol preparation. Aspects regarding the following four perspectives were investigated: organization perspective, product perspective, design process perspective, and individual perspective. The support of the organization's design process owner was quite helpful to obtain operational support, and facilitate the selection of interviewees.
Data collection was carried out in two fronts: documentary analysis and interviews. Ten in-depth interviews were conducted. Notes were made by the researcher and research assistant, and open issues were asked when convenient. If any artefact was brought to attention during interviews and when possible, photographs were taken. Interviews were audio recorded.
Data analysis occurred in parallel with the execution of the interviews. After each interview, debriefing sessions were held among research and research assistants. Researchers' notes, audio files and materials made available by the company were reviewed and organized according to the interview protocol. Patterns which fitted to each perspective were sought.
This cycle of information gathering and analysis leads to the representation of the contextual aspects of the use of the design process model of the organization. The case research and the guide proposed are following described.

4 RESULTS

4.1 Case Study Company Alpha

The case study was carried out in a multinational organization, which has implemented a cross-functional and formalized design process models more than ten years ago. The organization is part of the white goods sector as a key supplier of the air conditioning and refrigerators value chain.
It is a multinational organization, composed by a headquarter and three sites in different countries. In total, the company employs more than 10,000 employees in developing and producing its products. The investigation described in this research was performed at the subsidiary from Brazil and is hereafter called Company Alpha.
In total, ten design team members were interviewed. The average duration of each interview was 87 minutes, and they were recorded with the consent of participants. Each perspective is further described comprising the contextual inquiry and user profiling scopes.

4.1.1 Organization perspective

We identified 13 roles that make use of the design process model with different intensity through the process (Table 1). Until the scope of the project is defined (front-end and technological development scope), mainly marketing specialists and researchers are involved. It is during the concept generation that most of the roles are involved: technical leaders, product engineers, testing engineers and partner suppliers. After that, until the product launch, the following roles are involved: design engineers, process engineers, and quality specialists.
The project team structure adopted is a weak matrix structure. This structure influences the distribution of roles among members, which has an impact on the participation of individuals in the phases of the process. In the matter of fact, one team member can perform more than one role through the process in a given project, for instance, the same person can participate as a researcher and later as a product engineer. Also, this structure implies that design personnel take part in different projects at the same time and implies in a considerable workload of non-project activities as well.
As expected, product engineers have a leading role in the solution design. They direct the planning and execution of the tests. Project managers are responsible for the project as soon as the project scope is defined until the project is finished. They are in charge of deadlines and managing project needs. Executive management is periodically involved in a specific project by making go/no-go decisions. The process owner does not take action through the design project phases, his/her duties are related to improving the process itself.

Table 1. Roles involvement through the process, where '+' represents intensity

Roles	Project Scoping	Concept generation	Solution detailing
Researcher	+ + +		
Marketing Specialist	+ + +		
Technical Leader	+ +	+ + +	+
Project Manager		+ + +	+ + +
Product Engineer		+ + +	+ +
Testing Engineer		+ + +	
Partner Supplier	+	+ + +	
Design Engineer			+ + +
Process Engineer			+ + +
Quality Specialist			+ + +
Supplier		+	+ + +
Executive Management	+	+	+
Process Owner			

Researchers, product engineers, design engineers and technical leaders belong to specific engineering knowledge areas (mechanical, electrical, and electronic engineering).
Important rituals for project progression and portfolio review are part of the organization's design process. Weekly meetings and managerial and technical gates are carried on for project evaluation. The gates evaluation system leads to the possible following project decisions: progression, cancel, freeze or iterate on the phase under evaluation. Monthly global design review meetings address the whole design project portfolio of the organization. Each type of meeting requires the participation of variate roles: executive management are mainly involved in decision-making events, project managers in meetings for planning and monitoring issues, and technical leaders and engineering designers when technical inputs are necessary.
Regarding the workplace, the company has two sites in Brazil. Researchers, technical leaders, project managers, product engineers, and testing engineers are located on the main R&D building in site one. The location of roles involved in manufacturing varies according to where each system is produced. Electric motors are produced in site one, where the design engineers specialized in this knowledge area work. Mechanical parts are produced in site two; thus, mechanical design engineers are located there. As the company does not manufacture electronic systems, there are no design engineers in the electronics team. The assembly line is in site two, so process engineers are located there as well.
There are specifics rooms to gather information of product representations (sketches, prototypes, specifications). This information is sometimes virtually presented and sometimes presented through physical artefacts. Ideas are discussed in the meeting rooms, virtual concepts prototypes are mainly developed in the offices of each knowledge area. In the development workshop spaces, the prototypes are built and, they are later tested to exhaustion in the testing facilities. Manufacturing process maps and quality standards are developed in the engineering support area next to the manufacturing area leading to pilot production. The information of each product representation is made available in the information system.
Headquarters and subsidiaries are located in different countries, which present diverse maturity level of the knowledge areas, as well as different manufacturing capability, and seniority of teams and members. Technical leaders and product designers nurture their professional network according to available expertise in the different sites. When managing specific projects, they are split among sites according to expertise, work capacity and manufacturing capabilities. Cultural differences among design personnel from different countries bring some special challenges to manage projects and to coordinate efforts.

4.1.2 Product perspective

Engineering knowledge areas are associated with the systems of the main product. These are: (a) electric engineering - accountable for electric motor and power transmission; (b) mechanical engineering - accountable for thermodynamics and casting; and (c) electronic engineering - accountable for automation and control. These knowledge areas represent the functional areas within the organization.

Common guidance must guarantee the integration of different knowledge areas, while specific representations should provide specific guidance for monodisciplinary work. If a new area of knowledge emerges from product evolution, guidance may be provided to design personnel of this area as well.
As early mentioned, Company Alfa is an important supplier in the white goods industry on a B2B setting. Their products are part of more complex products assembled in other organizations. Product requirements are mainly defined by customers in the value chain (white goods manufacturing companies) instead of the end-user of the white goods. The interaction between companies must be clearly represented in the organization process models.

4.1.3 Design process perspective

The design process is referred as New Product Development (NPD) by organization members. NPD is a process structured in phases and gates and indicates mandatory deliverables for each phase. Design process interfaces two other processes: Marketing (Front-End of Innovation - FEI) and New Technology Development (NTD). The main goal of Front-End of Innovation process is to seek for opportunities. New Technology Development (NTD) was recently introduced and still does not have a structured process model.
Company Alpha's NPD process is a flexible process. Ideas and suggestions with considerable marketing opportunities and proven technical maturity are formalized into projects, following a project typology, which indicates the required customization of the design process. Innovative projects or projects that comprise major changes on existing products goes through all the phases of the NPD process. Even that a project typology is followed, changes of priorities and scope among the portfolio became evident during interviews. Additionally, interviewees reported that lack of technical maturity in projects under development caused major impacts on development lead time.
Emails, conference calls, and meetings are used for day-to-day communication and decision-making about the project. Each one is used according to convenience and specific need for the event. A workflow solution is used for communication with areas outside the site. Integration among communication channels is of utmost importance to facilitate decision-making.
The design process is composed of phases, gates, and main deliverables for each NPD phase. In addition to the process model itself, a second relevant artifacts, are the technical standards that the team must use. The technical standards indicate acceptance criteria and methods that should be used to meet the requirements of the different markets.
Organization practices are also available, use as benchmarking deliverables from analogous projects acting as a guide for a specific project situation. These practices can be related to project management or engineering knowledge areas. The notion of good practice is collectively created in the organization and shared among design personnel according to the design situation.
A third important artifact is the Project plan. This artifact is a project deliverable that must comprise the product scope and the project schedule. Product scope is the document representing market requirements, which directs the project progression and decision-making. The project schedule is represented by activities and deliverables organized according to the NPD based on the type of project to be developed. Scope and priorities among projects may change, influencing the project plan.
Finally, Product representation can be considered the fourth artifact. CAD/CAE/CAM tools are used to develop the virtual product representation artifacts, which can also be identified in the form of prototypes of different development levels. Post-concept definition information as the bill of materials, manufacturing process maps and quality control maps are kept available on the ERP solution. For management purposes, the product representation is only taken into consideration during gates.
Design teams manage the project information using a shared server. A structure of folders in this server is used to store and make available all design process related information. Each knowledge area has a specific folder, e.g. electric folder, mechanical folder, where all technical information is held. The Project management folder has specific files and sub-folders for all project deliverables, according to the design process phases structure. Documents on these folders are mainly consolidations of the activities performed and pieces of evidence of the achieved results for decision-making purpose. Sharing design data with areas from outside of the project team as marketing personnel happens mainly through the ERP solution.

4.1.4 Individual perspective

Empathy maps (Plattner, 2010) were created to represent the design process model user profiles (Figure 2). Three profiles were elaborated representing the three roles:

- Product Engineer: Defines and designs functionalities of systems, sub-systems and components. May be specialists in different knowledge areas;
- Project Manager: Plans and monitors the design project. Project managers focus to maintain task progress and team member interaction; and
- Technical Leader: Maintains technical knowledge related to products. Participate in technical decision-making and helps assigning the design team members. May be specialists in different knowledge areas.

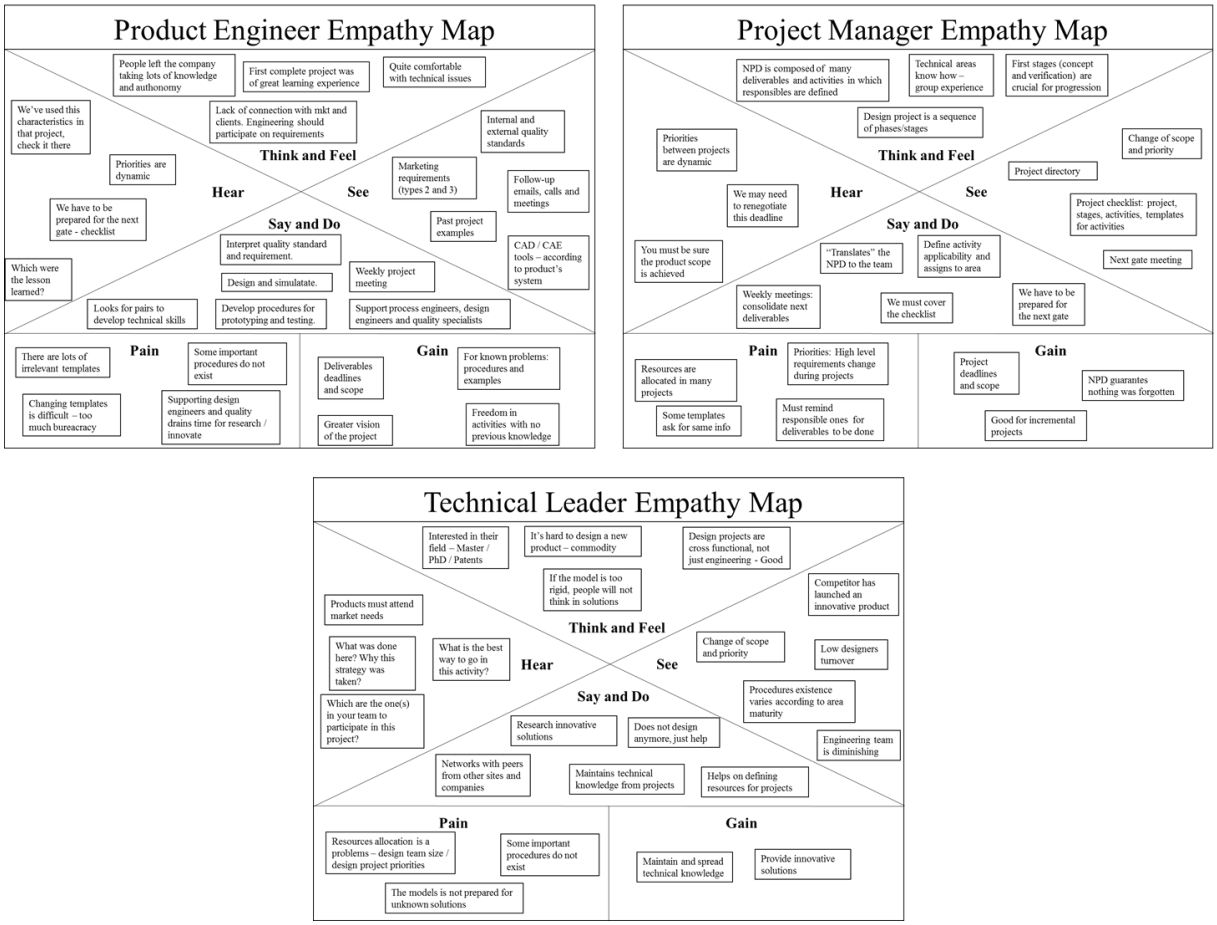

Figure 2. Empathy maps developed for the three roles: Product Engineer, Project Manager, and Technical Leader

Product engineers enjoy talking about the technical features of the product and are open and motivated to develop skills in their areas. On their daily work, these engineers are highly used to be guided by internal and external technical standards available. After interpreting these standards, product engineers iterate designing and virtually simulating the product behavior to develop procedures for prototyping and testing. They are open to collaborating with people from other roles and knowledge areas towards a better solution.

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. They 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.

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. Managers act as "translators" of the organization 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 NPD process and procedures used by the company. The idea of

completing the phases towards project completion gives an extra motivation to them. They enjoy being in contact with people from other areas. Projects, priorities, deadlines, meetings are constantly in their vocabulary.
Technical leaders are concerned with process model flexibility, which, in their point of view, promote 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. They 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 these three roles are performed by personnel with an engineering background, it could be perceived significant differences among each other. The individual perspective concludes the description of the context of use of design process models in Company Alpha.

4.2 Guide to investigating the context of use of design process models

Results of the presented case research motivated the development of the guide to investigating the context of use of design process models. As illustrated in Figure 3 and on section 4.1, the four perspectives to be investigated are Organization, Product, Process and Individual.

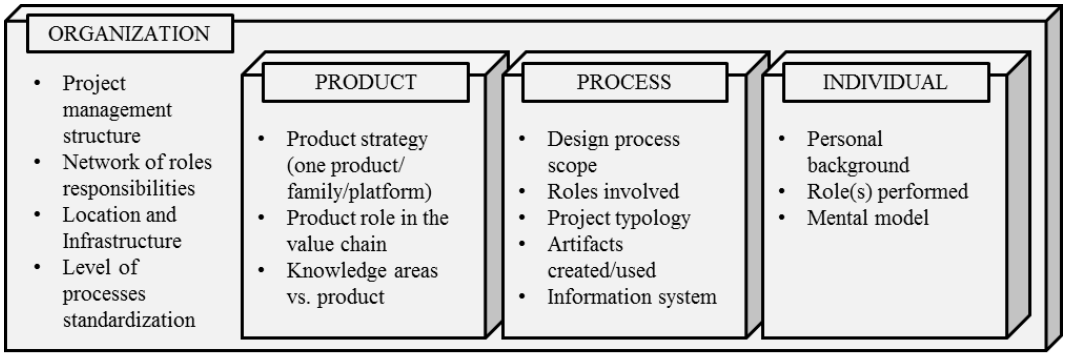

Figure 3. Guide to investigating the context of use of design process models.

The **organization perspective** is the broadest. This perspective provides indications/pieces of evidence about aspects that can influence not only the design process but all other processes within the organization. Aspects related to the composition and management of project teams within the organization are highly important. As design personnel can be assigned to different roles, an issue to mind is the way responsibilities of each person influence the ones taken by others' activities/responsibilities. Location and existence of different sites of the organization as well as the infrastructure available perform a significant impact on the use of process models and should be considered as well. Finally, another aspect that must be investigated is the level of process standardization.
The **product perspective** is intended to investigate aspects regarding product strategy (e.g. one product, family, platform), the role of the product development by the organization in the general supply chain (e.g. OEM), and specific knowledge areas required by the products or services developed.
The **process perspective** should investigate aspects as the scope of the design process, which highly influences the design of the process model. The roles performed through the design process should be as well identified. Another aspect is regarding the existence of a formal (or informal) project typology. It is important to recognize different projects types, and how they must be represented by the design process model. Also, artifacts created or used must be listed and analyzed in term of frequency, the obligation to use, and how much information one must have to execute it properly. Lastly, the information system available for the design team shall be investigated.
Lastly, the **individual perspective** is intended to investigate the personal needs of those involved in the process. It must comprehend the background and the mental model of personnel. This difference can influence how one can experience the use of process models. Finally, it is important to understand the

many roles one individual is performing, for instance, project managers also perform product engineering roles? This might influence how she/him will use design models.

5 REMARKS

In this research, a guide to investigating the context of use of design process models is introduced. It is supported by literature review and a case research using contextual design methods. The description provided consisting on four perspectives of the context of use of design process models may support replication in other organizations.

The guide should be used following steps similar to the ones taken in this research. If the organization is planning to investigate the use of its process models and seek for improvement opportunities, the contextual approach may be of help. Each perspective should be investigated taking the point of view of the users, i.e. the ones involved in the process. People from the many areas and taking different roles in the process should be involved. Iterative data collection and analysis is expected to provide a description of the context of use of design process models in an organization which may lead to requirements of a to-be version of the model.

Organizations should seek for a common comprehension of process models use among design personnel and ensure process models are adapted to their necessities. The scope of the process (including NPD, FEI, and NTD) must be clear to design personnel. The interfaces should be formalized to coordinate the ones taking different roles in the design process. Both levels (generic, branch-specific, organization-specific, and project plans) are used as guides for the design situations, and design personnel should have access to them and be aware of the adaptation effort to be done. Process models of each level should be designed, updated and discontinued considering the frequencies of change and triggers for the change of contextual factors relevant for each process representation.

The human-centered network of designing proposed by Badke-Schaub et al. (Badke-Schaub et al., 2005) was useful to determine the perspectives of the context of use of design process model. Along with it, the application of contextual inquiry to investigate the environment of use and empathy maps to represents the individual perspective led to a valuable description of the use of these models in one organization. Thus, the application of contextual design techniques to investigate models use before focusing on modelling methods is regarded as a contribution of this manuscript.

Comprehension of the context of use of design process models by academia would help to define approaches to achieve adaptable process models to be used in organizations. This study may be applied in different organizations to seek for common needs. A planned step is to perform them in different organizations of a similar complexity of a single branch. The procedure to comprehend the context of use of design process models is expected to evolve as well.

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