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The Sources and Methods of Engineering Design Requirement

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Abstract. The increasing interest in emerging markets drives the product development activities for emerging markets. As a first step, companies need to understand the specific design requirements of a new market when expanding into it. Requirements from external sources are particularly challenging to be defined in a new context. This paper focuses on understanding the design requirement sources at the requirement elicitation phase. It aims at proposing an improved design requirement source classification considering emerging markets and presenting current methods for eliciting requirement for each source. The applicability of these methods and their adaption for emerging market is discussed.

Keywords. Design requirement source, emerging markets, classification

Introduction

Design requirement is commonly accepted as a description that defines what the product should do (not how to do) and set up the boundaries to product solution space [1]. Defining and expressing the design requirements is normally the initial step for a product development project. Design requirement identification is an iterative process which co-evolves with product development process. Deficiencies in requirements could lead to the waste time and money and even the failure of the project ([2] cited from [3]). Hence, it is important to define the requirements correctly from an early stage. Efforts have been devoted to descriptive research for understanding the practice, and prescriptive methods and theories development in terms of improving the quality of defined requirement set (specification) [4].

Jiao and Chen [5] summarized a general requirement management process (Figure 1), which included three phases: requirement elicitation, analysis, and specification. The outcome of each phase contributed to the functional requirements (product specification).

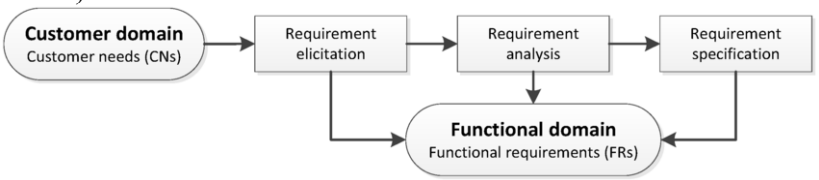

Figure 1. Customer requirement management process [5]

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In addition, the manufacturing industry's interest in emerging markets has been increasing dramatically. However, it is recognized that emerging markets (e.g. India, China, and Brazil) have different social, cultural, political and economic context from those of western companies previously established markets (e.g. [6]). Globalising a successful product development to emerging markets acquires specific design requirements from the local market. The multicultural factors can be challenging for companies to elicit requirements especially from external sources which are grounded in the local context. It makes the elicitation and management of design requirements become more critical to the success level of product development [7]. However, the literature review revealed that only a few studies investigated the sources of design requirement. Most articles referred to some sources (e.g. customer and regulation) but not complete overview of all sources. Therefore, it highlights the need for the research to understand design requirement sources for this new context.

This paper focuses on discussing the sources for eliciting design requirements. The goal is twofold. First, to propose a design requirement source classification which is based on a review of literature and improved with respect to emerging markets; second, to present current methods for eliciting requirements according to the classification. The applicability of current methods in emerging markets is briefly discussed and future studies are proposed.

1. Design requirement source from literatures

Design requirements concern complex constrains and conditions and call for comprehensive information from multiple sources. An overview of all the possible sources can contribute to the completeness of design requirement elicitation. In addition, the traceability of information sources enables the team to understand the reason for certain decisions ([8] cited from [9]).

Sudin [10] identified a list of design requirement sources based on interview analysis, in which the sources were sorted into two groups:

- *Human*: Client, end user, market analysis report, colleagues, the designers' expected solution, designer's own requirement.
- *Artefact*: semi-developed specification, proposed solution, existing product, previous project, design guideline, user guidelines.

Other studies also suggested colleagues, customer, document, other departments (i.e. sales department, marketing and manufacturing) ([11] cited from [10]), customer, user, supplier, written material (i.e. book, trade journal, technical manual) ([12] cited from [10]).

Gershenson and Stauffer [13] proposed a taxonomy that clarified four different sources from which the requirement could be generated, i.e. end user, corporate (the producer itself), technical (mother nature) and regulatory requirements (society), see Figure 2. The taxonomy could guide the development of design requirement by gathering, analysing information about each category and transforming it into design requirements [14].

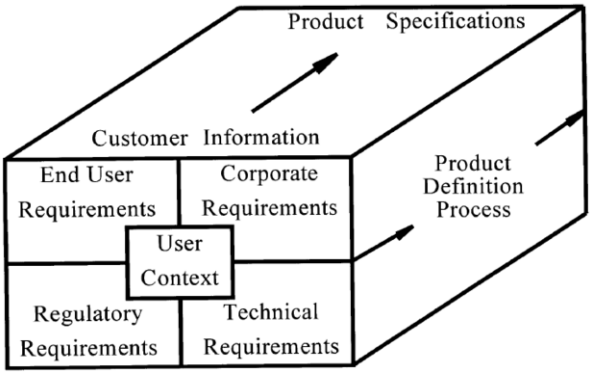

Figure 2. Requirements cube showing the various types of requirements and how the information fits into the product definition process [13]

2. Research method

The paper took the design requirement taxonomy established by Gershenson and Stauffer [13, 15, 16] as a basis. The improvement in the proposed classification was addressed by synthesizing referred sources in recent publications. 48 papers have been published since the year 2000 on journals in engineering design field, including Design Studies, Research in Engineering Design, Journal of Engineering and Concurrent Engineering-Research and Applications etc. The review started with relevant papers from those and two design requirement reviews [4,5]. Important references in above papers were also included in the review. Information about where requirements come from when a company establishes or changes design requirements was labelled and grouped in affinity diagram.

The presented requirements elicitation methods were selected based on the two reviews or from influential engineering design books (e.g. [17] and [18]).

3. Design requirement source classification

A new context of emerging markets can affect requirements. When eliciting design requirements, the project team interacts with many factors (e.g. stakeholders and documents) frequently both from the internal company mechanism and external environment in order to collect a thorough set of requirements. The quality of information that comes from the external sources is particularly challenging to be controlled due to the evident cultural, linguistic, and geographic barriers in emerging markets. Thus, it differentiates the design requirements for emerging markets from that in western context when its internal mechanism is assumed to be relatively stable.

From the review a model (Figure 3) is proposed describing the relationship between the company frame (internal/external) and three main factors (i.e. Corporate, Technology, and Society/Environment) that influence design requirements.

- *Corporate*: the company itself. It concerns the company's organisational structure, strategic vision and available resources etc.

- *Technology*: as defined by Gershenson and Stauffer [13], technology presents the knowledge of e.g. engineering principles, material properties and physical laws. These are regarded as an internal factor because the technical requirements make sense when relevant knowledge was known to the company.
- *Society/Environment*: all considerations of social and environmental aspects that out of the company's frame e.g. end users, infrastructures, and regulations. It is the most complex factor and could be extended to several subcategories.

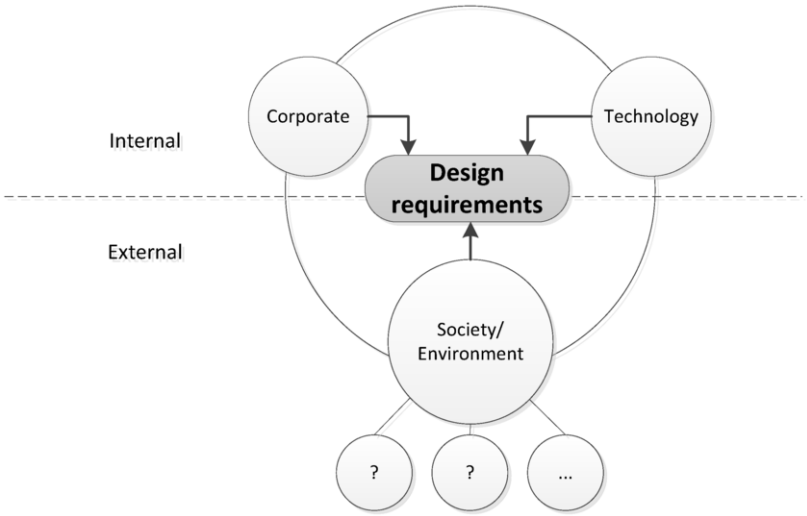

Figure 3. What influence design requirements?

It should be noticed that the distinction between internal and external is not absolute and static; instead it is relative and dynamic. For example, production may be internal or external depending on the company structure. The requirements from different sources are not isolated but interconnected with each other. The resources flow constantly between the internal mechanism and external environment e.g. a company could recruit new employees and cooperate with organisations to gain new knowledge.

Based on this, a classification of design requirement sources is proposed with seven categories: corporate, technology, user, market competition, regional infrastructure, organizational infrastructure, and regulation. **Table 1** displays the categories and examples found in literatures. The seven categories are explained in the following sections with brief presentation on methods used to elicit requirements.

3.1. Corporate

Requirements generated from the corporate category form the company's space for creating product solutions. The corporate category describes internal factors within a company. It concerns both the people and activities in the company, for example departments, individuals (e.g. designers [10,22,23]), strategies and documental guidelines [10]. The corporate requirements were prioritised after safety issues and statutory regulations and customer product requirements by Lee and Thornton [21].

When entering emerging markets, the corporate is assumed to stay the same in different context unless the globalisation has an impact on its organizational structure.

Two aspects from this category have been frequently mentioned, namely platform requirements [27] and requirements from existing products [10,23]. Platform requirements (relevant research could be found in [19]) or portfolio management (e.g. [20]) outlines the strategic vision to develop the product. The requirements for developing a new product can be generated from the information accumulated from existing products [23].

Table 1. Design requirement sources classification

Category		**Term used in references (not all references were listed)**
Corporate		Corporate [13, 21]
		Designer [10, 22, 23]
		Colleague[10]
		Guideline [10]
Technology		Technical [13]
		New technology trend[23]
		Nature law [24]
Society/ Environment	User	End user [10,13,25]
		Customer [21, 26,27,28]
		Client [10]
	Market competition	Competitor situation [27]
		Marketing [10]
		Competition [23]
	Regional infrastructure	Regional infrastructure [14, 29]
	Organisational infrastructure	External stakeholder [3]
	Regulation	Regulatory[13]
		Regulation[14,21]
		Legal requirement[27]

3.2. Technology

The technology category consists of scientific and engineering knowledge, e.g. engineering principles, which can be disseminated through experience and books. These requirements keep more or less the same in different markets, which is closely related with the companies' professional expertise and knowledge learning ability.

3.3. User

This category is defined to include both end user and customer/client, i.e. all relevant individuals who would buy or use the product. It is no doubt the most critical and most frequently mentioned source for design requirement (e.g. [26], [30] and [31]). User requirements are often ambiguous and contained most obscure and latent requirements to be investigated, which become even more challenging when entering a new market. Diverse culture and social identities shape the user habits and the way users think and understand the products differently. Additionally, in emerging markets, the mid- and lower end of the market is recognised as the most significant and dynamic [37].

A number of methods have been used to study users, for example *interviews* [17,18,32,], *focus groups* [17, 18, 32,], *surveys* [18, 32], *observations* [17, 32],

brainstorm [18] *scenario* [33, 34], *ethnographic studies* [18], and *customer complaints* and *warranty data* [18].

User requirements should be weighed and prioritised to optimise the trade-off with requirements from other sources. The basic way was to rate each requirement [17] through calculating the importance based on collected data or scoring by users in new surveys [32]. Maslow's hierarchy (e.g. [35]) categorised human need into five levels: physiological needs, safety needs, love and belonging, esteem and self-actualization, which helped to define the target group in the markets. The higher level needs came up only if the lower level needs were fulfilled. Kano model illustrated three types of user needs [36], which had different prioritisations:

- *Must be need*: is the basic criteria of a product. If not fulfilled, users would be extremely dissatified; if fulfilled, users' satisfaction would not increase.
- *One-dimensional need*: user satisfaction was proportional to the level of fulfillment.
- *Attractive need*: once fulfilled, user satisfaction increased dramatically.

3.4. Market competition

This category defines requirements from the market. The competition with other competitors is one of the main concerns. It includes the perceptions gained from marketing [10] or marketer [23]. Analysing the competitor situation [27] is of particular importance in emerging markets. The competition could be even fiercer than the company's home market because of the huge number of local fast followers [37] and the globalisation barriers.

Benchmarking [38, 39, 40] was technique for gaining and maintaining competitive advantages. It enables the comparison and analysis of performance data between the new product and successful products in the market [41]. Functional decomposition supported the capture of the category, since it was more easily to design functional modular than a complete complex product [4]. Functional analysis system technique (FAST) diagram [42] supported the product function analysis by revealing its functionality as a hierarchy.

3.5. Regional infrastructure

Regional infrastructure concerns the infrastructures needed to support product in the local using context. In many occasions, the products need auxiliary facilities in order to work, which might be out of the company's own service frame. For instance, many digital devices require Wi-Fi access and an electric car requires chargers installed, these need to be available in the infrastructure of the intended market. The regional infrastructure requirements are often considered as constraints to the product solution space.

Only very few literature have been found about generating requirements from the regional infrastructure (e.g. [29] cited from [31]). One assumption to explain this is that regional infrastructures are normally touched upon in user requirement studies due to its influence on the way users behave and use the product. However, it is meaningful to separate it as a single category because of its geographic differences. Generally, the infrastructure in emerging markets is poorer than in western countries and has identified features depending on the context. For instance, in Chinese cities most

people live in high-rises, so the fire extinguishing system should be designed able to reach the high floors.

3.6. Organizational infrastructure

This category separates the external part of the organization from the internal corporate structure. It together with the user category covers the external stakeholders [3]. It can include the suppliers, local distributors, external manufacturers (if needed) etc. The specific relevant players were depended on the company's own case.

Methodology of Organizing Specifications in Engineering (MOOSE) [13, 43] was supportive to the requirements extension for corporate and organizational infrastructure (in the methods, those two were not distinguished). It consisted of three levels of requirements: functional level (a functional group of the product lifecycle), task level (tasks that must be done to accomplish the functions), and attribute level (product attributes that effects tasks). By extending the three levels, a thorough list of requirements could be covered.

3.7. Regulation

The last category presents the regulations that made by government and authorised organizations. They are critically sensitive for product development and normally have to be fulfilled especially for certain fields such as health industry. Few methods were found to support regulatory requirements. According to Gershenson and Stauffer [16], the regulatory and technical requirements were less problematic for two reasons: 1) they were well documented and easy-access information; 2) they were context-dependent.

However, it could be discussed when think about emerging markets, especially for regulatory requirements. First, the information could be tough to find and understand due to the linguistic gaps and lack of knowledge about the local information channels. Second, it requires local network and lobbyist to negotiate on some flexible policies and rules, and get the local approvals. Third, it asks for more attention and awareness to protect the intelligent property in emerging markets. Hence, the more 'context-dependent' sources might potentially lead to focused studies under certain specific contexts.

4. Discussion

The paper indicates a lack of knowledge in design requirement elicitation for emerging markets. As presented above, user requirements has been the centre of current design requirement studies, whereas few methods have been developed for eliciting requirements from other sources, e.g. regional infrastructure and regulation. Nevertheless, some of those requirement sources are particularly problematic and sensitive when developing product for emerging markets.

In addition, the adaption and suitability of those methods require further discussions and studies. First, traditional requirement study takes a long time and a large number of resources. The main work is done before the development phase in product development process. It is particularly risky and not practical in emerging markets because the time of transition and poor protection of intelligent property,

where companies can easily be dragged into the red-sea competition with local competitors. Hence, it is worthy to study on the dynamics and rapidity of design requirement elicitation along with product development process, e.g. the closed-loop of dynamic information flow among all stakeholders through the product's life cycle. Second, unlike most western countries, one vital feature of emerging markets is the gigantic capacity, e.g. China, India, and Russia. The large database is suitable for quantitative studies and big data analysis. As described in most studies, the sample size is relatively small. However, in emerging markets, it might be possible to adapt those methods to a larger sample. Accordingly, supporting quantitatively analytic methods are requisite. Third, the cultural, social and linguistic differences and the geographical distance obstruct the collection and interpretation of design requirements. Methods are needed to bridge those gaps.

5. Conclusions

This paper reviews the source of design requirements and current methods used through a review of literature. The literature review identified a number of sources and methods. However, these were not tailored emerging markets. Therefore, a design requirement source classification with considerations on emerging markets is proposed. Relevant methods used for eliciting requirements from different sources are named and briefly presented. It suggests potential improvements and further development of design requirement for emerging markets. For future work, the proposed classification needed to be validated with industry. Studies are needed on design requirement methods generation, selection, and validation.

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