Identifying and Managing Engineering Design Requirements for Emerging Markets

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Identifying and Managing Engineering Design Requirements for Emerging Markets

Surveys and case studies on Denmark and China

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PhD Thesis

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Preface

This PhD project was carried out at DTU Management Engineering between December 2013 and November 2016. The project was under the principle supervision of Associate Professor Jason Li-Ying and Professor Saeema Ahmed-Kristensen (former), and the co-supervision of Assistant Professor Jaap Daalhuizen. This PhD project is conducted as a part of the Global Opportunities for Danish SMEs in Emerging Markets project, which is funded by the Danish Industry Foundation (i.e., Industriens Fond).

I wish to thank the Danish Industry Foundation for the financial support, without which the project would not have been possible.

I would like to acknowledge the guidance and efforts of my supervisor Jason Li-Ying and my former supervisor Saeema Ahmed-Kristensen. Their support and intellectual contribution to this project, as well as to my personal education, made the realisation of this project a possibility. Special thanks go to my co-supervisor Jaap Daalhuizen, for his tremendous assistance, full dedication to the project, and for always being there when I needed a keen eye.

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Lastly, and most of all, my thanks go to Weixian.

Abstract

In the last decade, emerging markets have become a significant force in the world economy. It has become increasingly important for global manufacturing companies to develop products for emerging markets, which appropriately address local needs and requirements. Therefore, it is necessary, especially for those companies originally from developed markets, to acquire an in-depth understanding of particular design requirements in emerging markets in order to adapt both company products and approaches in such contexts.

Prior studies on the identification and management of design requirements have predominantly been conducted in the context of developed countries and relatively affluent markets. Emerging markets are distinct from developed markets in terms of numerous contextual factors, e.g., regulatory environments and competitive landscapes. These factors influence the requirement identification and can lead to changes in design requirements. However, the influence of these factors have not been explicitly studied in the context of emerging markets. In addition, current studies on design requirements focus on user requirements, whereas requirements from other perspectives have received limited attention. There is a need for an overview of different perspectives in requirement identification for manufacturing companies and their corresponding assessments in the context of emerging markets.

Therefore, this research project is motivated to 1) investigate the process of identifying and managing design requirements for emerging markets, with the purpose of examining the challenges and gaps in developed-market companies' current practice and; 2) support companies in identifying design requirements for emerging markets with an efficient approach.

This research project has been performed as a close collaboration between academy and industry. Two empirical studies have been conducted with Danish and Chinese manufacturing companies employing survey and case study as research methods. These two studies demonstrate that for a developed-market company, to identify design requirements is more challenging for emerging markets than that for home markets. The key findings suggest that the process of identifying and managing design requirements, which usually apply to developed markets, should be adapted for emerging markets. In such adaptions, particular attention

should be paid to 1) understanding competitions and regulations in target markets, 2) selecting appropriate sources to gather information, and 3) being flexible in reacting to the dynamic and complex emerging-market context.

Based on the findings, the Perspective-oriented Requirement Excellence toolkit has been developed to support companies with the preparation and planning of requirement identification, especially for unfamiliar markets. This toolkit provides a structured framework to organise design requirements, which supports the identification of gaps in the existing requirement set, and assists the communication of design requirements between different stakeholders. It also provides a systematic approach to plan the process for identifying design requirements, which improves the efficiency in terms of utilising expertise and allocating resources. The toolkit has been evaluated at a workshop, which demonstrates the value of this method in supporting a real case practice.

This project has been conducted as interdisciplinary research. It supplements with a theoretical contribution to requirement engineering and engineering design, which in this case is an advanced understanding of the perspectives considered in requirement identification, and co-evolution of design requirements and product development processes in emerging markets. It also contributes to innovation management with implications that support managers in planning process, and allocating resources to identifying and managing design requirements in product development projects that target at emerging markets.

Abstract (Danish)

Gennem det seneste årti, er markederne i de nye økonomier (emerging markets) blevet en betydelig drivkraft i verdensøkonomien. Disse markeder har fået stadigt stigende betydning for globale produktionsvirksomheder, der ønsker at introducere deres produkter på disse markeder, hvor de imidlertid må tilpasse sig de lokale behov og krav. For virksomheder, der traditionelt har udviklet produkter til de klassiske, udviklede markeder, er det derfor nødvendigt, at de tilegner sig et godt kendskab til, og en indgående forståelse af specielt designkravende i de nye markeder for at kunne tilpasse såvel virksomhedens produkter som deres markedsføring til de nye og ukendte forhold.

Hidtidige studier af, hvorledes virksomheder identificerer og implementerer designkravene, har hovedsageligt taget udgangspunkt i de forhold, der er gældende for de udviklede lande, hvor der er relativt store udbud af produkter på markedet. De nye markeder adskiller sig fra de udviklede markeder på adskillige måder, afhængigt af de lokale forhold, både hvad angår lovmæssige og regulatoriske krav, og de konkurrencemæssige vilkår. Disse faktorer har indflydelse på den måde, hvorpå virksomheder identificerer produktkravene, og det vil ofte føre til ændringer i designspecifikationerne. Indflydelsen af disse faktorer er imidlertid ikke hidtil blevet studerer eksplicit for de nye markeder. Desuden har de hidtidige studier vedrørende designkrav fokuseret på brugerkrav, hvorimod der kun har været meget begrænset opmærksomhed på de krav, der hidrører fra andre perspektiver. Der er derfor et klart behov for at få indsigt i, hvorledes man i produktionsvirksomheder identificerer og vurderer designkrav ud fra perspektiver, der er afgørende for, om man kan gøre sig gældende på de nye markeder.

Dette forskningsprojekt har derfor følgende formål: 1) at undersøge identifikationsprocessen og udviklingen af designkravene i produktionsvirksomheder i de udviklede markeder og komme med forslag til, hvordan de kan håndtere de udfordringer og gab, som de står overfor i forhold til eksisterende praksis, når de ønsker at gå ind på de nye markeder, og; 2) udvikle en metode, der, på en effektiv måde, kan støtte virksomhederne i identifikationen af et komplet sæt af designspecifikationer, der kan opfylde kravene på de nye markeder.

Det foreliggende forskningsprojekt er derfor udført i et tæt samarbejde mellem universitetet og industrien, og der er gennemført to empiriske studier med danske og kinesiske

produktionsvirksomheder. Den empiriske del af forskningen omfatter dataindsamling gennem spørgeskemaundersøgelser, samt case studier i udvalgte virksomheder. Tilsammen viser de to studier, at når det drejser sig om produktionsvirksomheder i de klassiske, udviklede markeder, er identifikation af designkrav i de nye markeder en udfordrende opgave i forhold den tilsvarende opgave i hjemmemarkedet. En væsentlig konklusion er, at både identifikationen og implementeringen af designkravene for hjemmemarkederne, kræver, ofte væsentlige, tilpasninger til de nye markeder. I tilpasningsprocesserne skal der især rettes opmærksomhed på: 1) forståelse af konkurrenceforholdene og de regulatoriske vilkår på det nye marked, og 2) udvælgelse af pålidelige informationskilder, og 3) fleksibilitet og hurtig reaktion på de dynamiske og ofte komplekse forhold i de nye markeder.

Som et resultat af projektet er der udviklet "the Perspective-oriented Requirement Excellence toolkit", der kan tjene som en vigtig støtte for virksomheder i forberedelsen og planlægningen af kravidentifikationen på markeder, hvor man mangler erfaring. Dette "værktøj" er et struktureret "framework", der tjener til organisering af designkravene, og som understøtter identifikationen af de gab, der findes i den hidtil anvendte kravspecifikationsproces, og som tillige kan bistå i kommunikationen af designkravene med forskellige interessenter. Værktøjet understøtter tillige en systematisk planlægning af identifikationsprocessen af designkravene, hvilket øger effektiviteten i udnyttelsen af virksomhedens ekspertiser samt i tildelingen af ressourcer. Værktøjet er blevet evalueret i en workshop, hvor metoden beviste sin værdi gennem en praktisk demonstration på en virkelig case.

Projektet er gennemført som et interdisciplinært forskningsprojekt. Det yder et forskningsmæssigt bidrag inden for teoretisk arbejde med "requirement engineering" og "engineering design", hvilket, i det foreliggende tilfælde, giver en dybere forståelse af perspektiverne inden for kravidentifikation og co-evolution af designkrav og produktudviklingsprocesser, der er rettet mod nye markeder. Endelig bidrager projektet til innovationsledelse til støtte for ledere/managers, der er ansvarlige for planlægning og tildeling af ressourcer til opfyldelse af designkravene og implementering i produktudviklingen, der er rettet mod de nye markeder.

Content

Chapter 1. Introduction

This chapter introduces the overall background, the motivations, the scope, and the aims of this research project. It also presents the framework that was used to structure the research. The chapter is structured as follows:

- Section 1.1 introduces the background and motivations of this research project.
- Section 1.2 clarifies the scope of this project.
- Section 1.3 delineates the research aims and the research questions.
- Section 1.4 presents the methodological framework applied in this project.
- Section 1.5 outlines the structure of this thesis.

1.1 Background and motivations

Emerging markets comprise a group of fast-growing, liberalising and newly industrialising economies, with China and India as the most well-known examples. In the last decade, emerging markets have become a significant player in the world economy (Subramaniam, Ernst and Dubiel, 2015). According to the World Bank (2011), emerging markets would have an average growth rate of 4.7% a year between 2011 and 2025, while the number would be only 2.3% for advanced economies or developed markets (hereinafter referred to as developed markets) over the same period. The promising growth and attractive opportunities have enticed increasingly more companies to invest and to sell products in emerging markets. In 2012, global

corporations invested more in emerging markets than the core economies of the United States, Europe and Japan (Kenneth Rapoza, 2013). In addition, the companies originating from emerging markets (hereinafter referred to as emerging-market companies (Cogman, Jaslowitzer and Rapp, 2015)) have achieved considerable results in product development and now wield notable influence in global business. For example, China has been broadly perceived as a new centre of gravity for global R&D activities (Li and Yue, 2005; Chen and Vang, 2008). During 2000 to 2012, the foreign direct investment flows from the BRICS countries, i.e., Brazil, Russia, India, China, and South Africa, had grown from US$7 billion to US$145 billion, representing 10% of the world's overall foreign direct investment flows (United Nations Conference on Trade and Development, 2013). These emerging economies are growing into competitive rivals. It has been not only beneficial but also critical for global manufacturing companies to acquire knowledge of emerging markets.

Companies originating from developed markets (hereinafter referred to as developed-market companies (Cogman, Jaslowitzer and Rapp, 2015)) often sell existing products to emerging markets (Deloitte Touche Tohmatsu, 2006). Approximately half of the products sold by developed-market companies to emerging markets are existing products, which are more often than not outdated products at a lower price (Deloitte Touche Tohmatsu, 2006). Such a strategy without accommodating local needs into product design has been argued to be insufficient to win over emerging markets. For example, Gilroy and Traylor (2015) stated that companies fail when they attempt to thrust their brand and products on a new market with little if any adaptations. Successful companies normally reconfigure their global products to compete with consumers' preference for popular local brands, in price, services, etc. (Bloch, Shankar and Schaus, 2007). For example, in order to serve chilled drinks in regions possessing an inconsistent electricity supply in rural areas in India, Coca-Cola provided tools from solar-powered coolers to ice boxes to distributors, alongside using sachets of powder which can be

mixed with water (Warc, 2011). Successful innovations[1] should be tailored to the target market and creatively find ways to meet the requirements of a diverse customer base (Griffin, 2013). Understanding the characteristics of emerging markets and addressing their unique needs and requirements is assumed as a key success factor for developed-market companies when developing for emerging markets (Subramaniam, Ernst and Dubiel, 2015). Therefore, it requires taking a nuanced and informed approach to the analysis of design requirements in the context of emerging markets, especially of those that are distinct between emerging and developed markets.

Developed-market manufacturing companies are often confronted with challenges that are unlike anything they may have encountered in their home markets. Emerging markets have different social, cultural, political, and economic contexts compared with developed markets (Dubiel and Ernst, 2012). For example, in emerging markets, innovation is obstructed by the inadequate external institutions, which are often hindered by highly bureaucratic and corrupt legal-political governance, and weak property-right regimes (Khanna and Palepu, 1997; Zhao, 2006; Bruton *et al.*, 2010; Chen *et al.*, 2013). Companies are often forced to compete with both well-established international competitors and a large number of unbranded local competitors in emerging markets (Gu, Hung and Tse, 2008; Sheth, 2011). Eliciting requirements from users in emerging markets can be also particularly challenging. Many users in the BoP markets are not aware of certain needs (e.g., hand-washing or taking vitamins), or they are not used to think creatively about a product feature they might desire, due to a lack of education (Kramer and Belz, 2008). These users face difficulties in transferring their needs to others when personal contact and trust are lacking (Polanyi, 1966; Senker, 1993). Moreover, developed-market companies are unfamiliar with the contexts in emerging markets and detailed information

[1] Innovations are about changes that provide the opportunity for the new and different (Drucker, 1985). Innovations can take several forms: process innovations, product innovations, position innovations, and paradigm innovations (Tidd, Bessant and Pavitt, 2005). This thesis focuses on product innovations, which refer to changes in products and services offered by an organisation.

about these markets is often absent, inadequate and incomplete (UNDP, 2008). Developed-market companies need to spend more time in understanding specific problems when developing for emerging markets (Jin and Chusilp, 2006; Jagtap *et al.*, 2014). The conventional methods that have been primarily developed and applied in the context of developed markets are not necessarily suited to tackle the unique challenges in emerging markets. The evaluation, selection and implementation of conventional methods in the context of emerging markets should consider the special characteristics of these markets (Haubroe, 2015). Therefore, there is a need to evaluate and adapt current methods, or to develop new methods for emerging markets.

Research on product development in the context of emerging markets has captured increasingly more attention in recent years (Subramaniam, Ernst and Dubiel, 2015). However, prior studies on design, especially those focused on design requirements have been still predominantly conducted in the context of developed countries and relatively affluent markets (Viswanathan and Sridharan, 2012; Jagtap and Larsson, 2013; Jagtap, Larsson and Kandachar, 2013; Jagtap *et al.*, 2014). In addition, other gaps in current literature on design requirements have been identified. For example, there is limited understanding about the external causes of changes to design requirements, e.g., regulatory environments and competitive landscape, and how the changes are addressed during the product development process in the context of emerging markets. Current studies also have focused on the user perspective while other perspectives received limited attention; existing multi-perspective approaches in requirement identification have limitations. A detailed discussion of the gaps in current literature can be found in 1.5. Therefore, in an attempt at filling this void, this research project is motivated to studying the identification and management of design requirements in the context of emerging markets.

The Global Opportunities for Danish SMEs[2] in Emerging Markets project

The present research has been conducted as part of a larger research project: the Global Opportunities for Danish SMEs in Emerging Markets (GODSEM) project, which is funded by the Danish Industry Foundation (i.e., Industriens Fond). The GODSEM project aims to accelerate the growth of Danish SMEs with regard to global expansion into emerging markets, and to support the transferring of knowledge gained from this project to future start-ups. The GODSEM project would provide solutions for five practical challenges that Danish companies currently face (as listed in Table 1-1). This PhD project focuses on the three design-related challenges, i.e., Challenge 2, 3 and 5.

Table 1-1 Five practical challenges in Danish industry (Ahmed-Kristensen and Li-Ying, 2013).

Challenge	Description
Challenge 1 (Business related)	Establishing *strategies* for growth in emerging markets
Challenge 2 (Design related)	Understanding of *design requirements* for emerging markets
Challenge 3 (Design related)	Adaption/localization of the *product development process* for emerging markets with limited cost advantages when making cheap enough offerings due to a tight bottom line
Challenge 4 (Business related)	Accessing and establishing local network, including private and governmental partners
Challenge 5 (Business & Design related)	Effective Learning from emerging markets and applying knowledge back to markets in developed countries (reverse innovation)

The GODSEM project establishes a network with over 80 Danish companies and platforms that are involved with product development for emerging markets and are interested in improving their practice for such context (The GODSEM Project Team, 2015). Several companies from this network participated in the empirical studies conducted during the present research.

[2] Small and medium size companies (SMEs): companies with less than 250 employees and no more than 50 million Euro in turnover/43 million Euro in total balance sheet (European Commission, 2016).

1.2 Research scope

In order to be clear and consistent in this thesis, the scope and boundaries of this research project are specified and justified as follows:

First, this project has been conducted as interdisciplinary research. The research contributes to the requirement engineering and the engineering design domains by advancing the general understanding of the identification and management of design requirements and extending the conventional understanding generated in developed markets to emerging markets. It also contributes to innovation management by supporting managers in allocating resources for identifying and managing design requirements in the product development projects that target at emerging markets.

Second, even though many product development models suggest identifying design requirements at early stages of the process (see e.g., Ulrich and Eppinger, 2011), it is recognised that design requirements co-evolve with product development processes (see e.g., Darlington and Culley, 2002; Sudin and Ahmed-Kristensen, 2011). Managing design requirements is a continuous and iterative process. Therefore, this project investigates the entire product development process instead of only focuses on the early stages of the process.

Third, this research focuses on Denmark. This choice was made due to that: 1) this project, as part of the GODSEM project, should serve the same goal of supporting and improving Danish industry; 2) it is the most practical to conduct empirical studies by utilising the established networks and other resources where the institution is located. In addition, emerging markets are mostly represented by China in this research. This selection was based on three reasons. First, China is among the most popular and important emerging markets according to its massive size and global influence. All case companies participated in this research are either doing business in China or in the progress of doing so. Second, the project team has

collaboration with Chinese universities and has access to Chinese companies and data collected from previous relevant projects. Third, the author's Chinese background ensures the context understanding and data collection and interpretation for the study.

1.3 Research aims and questions

Derived from the challenges and needs in industry and the identified gaps in current knowledge about design requirements, two primary aims of this research project were delineated.

Research Aim 1: to understand the process of identifying and managing design requirements for emerging markets, with the purpose of examining the challenges and gaps in developed-market companies' current practice.

Research Aim 2: to support companies in identifying design requirements for emerging markets with an efficient approach.

To address these aims, four research questions were formulated. For each research question, specific objectives are clarified and presented in Table 1-2.

Research Question (1): How is the current practice of identifying and managing design requirements for emerging markets performed in developed-market companies?

Research Question (2): What challenges do developed-market companies face when they are identifying and managing design requirements for emerging markets and why do they face these challenges?

Research Question (3): How to support an effective process of identifying design requirements for emerging markets?

Research Question (4): How does the proposed method support the process of identifying design requirements for emerging markets?

Table 1-2 Objectives for each research question.

Research question	Objectives
(1) How is the current practice of identifying and managing design requirements for emerging markets performed in developed-market companies?	1.1. To analyse phases in the process of identifying and managing design requirements for emerging markets. 1.2. To analyse perspectives considered in the process of identifying and managing design requirements for emerging markets. 1.3. To analyse co-evolution of design requirements and the product development process in the context of emerging markets.
(2) What challenges do developed-market companies face when they are identifying and managing design requirements for emerging markets and why do they face these challenges?	2.1. To identify challenges for developed-market companies during the identification and management of design requirements for emerging markets. 2.2. To analyse and explain these challenges with both internal and external factors.
(3) How to support an effective process of identifying design requirements for emerging markets?	3.1. To develop a method that enhances the completeness of the identified requirements. 3.2. To develop a method that improves the efficiency of requirement identification and the effectiveness of selecting sources and methods during this process. 3.3. To develop a method that supports the identification, analysis and dealing with the potential challenges in unfamiliar contexts.
(4) How does the proposed method support the process of identifying design requirements for emerging markets?	4.1. To evaluate how the proposed method supports in improving the completeness of design requirements. 4.2. To evaluate how the proposed method supports in improving the efficiency of requirement identification and the effectiveness of selecting sources and methods during this process. 4.3. To evaluate how the proposed method supports in identifying, analysing and dealing with the challenges in unfamiliar contexts.

1.4 Methodological framework

This research project applied the Design Research Methodology (DRM) framework, because this methodology supports both the formulation and validation of models and theories about the phenomenon of design, and the development and validation of support founded on these models and theories (Blessing and Chakrabarti, 2009).

The DRM framework consists of four main stages: Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II (see Figure 1-1).

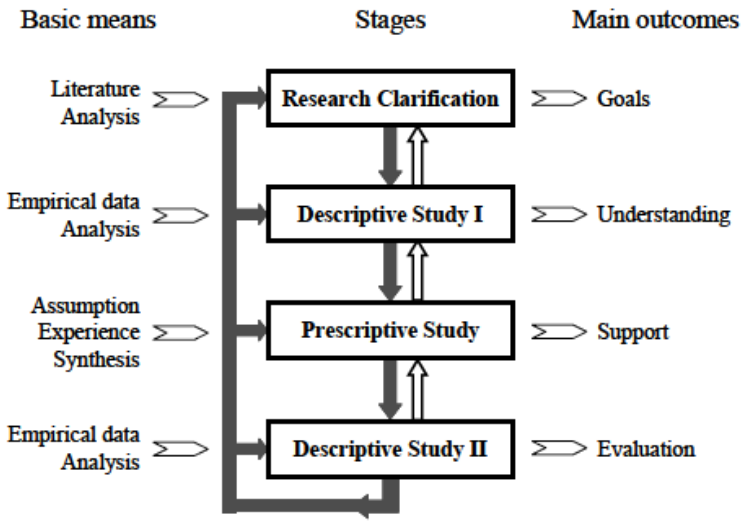

Figure 1-1 Stages of the Design Research Methodology (Blessing and Chakrabarti, 2009).

1.4.1 Research Clarification

This stage aims to support design researchers in formulating a clear, challenging but realistic goal and an overall research plan. In this project, relevant literature was reviewed with a focus on two key topics: 1) product development for emerging markets and, 2) the identification and management of design requirements. The review contributed to clarifying current understanding, determining areas of relevance and contribution, and hence formulating the aims and research questions of this project.

1.4.2 Descriptive Study I

This stage aims to increase the understanding of design through literature review, empirical studies, etc. This increased understanding should provide a sound basis on which to develop design support. In this research project, the studies conducted during the Descriptive Study I stage serve Research Aim 1 (to understand the process of identifying and managing design requirements for emerging markets, with the purpose of examining the challenges and gaps in developed-market companies' current practice).

Empirical studies conducted during Descriptive Study I

Two empirical studies were conducted during the Descriptive Study I stage. Study One investigates the process of identifying and managing design requirements for emerging markets and identifies gaps in current practice and challenges faced by developed-market companies during this process. This study analyses five phases in this process and seven perspectives considered during this process. Study One includes a survey with 64 responses from Danish industry and four case studies conducted at four Danish manufacturing companies.

Study Two compares the process of identifying and managing design requirements between developed-market and emerging-market companies, and identifies potential learnings for developed-market companies. This study analyses the co-evolution of design requirements and product development processes, and explores how various perspectives influence the differences between developed-market and emerging-market companies. Study Two includes a survey with 80 responses from the Danish industry and 165 responses from the Chinese industry as well as four case studies conducted at two Danish companies and two Chinese companies.

The results of these two studies deliver an answer to Research Question (1) (How is the current practice of identifying and managing design requirements for emerging markets performed in developed-market companies?) and Research Question (2) (What challenges do developed-market companies face when they are identifying and managing design requirements for emerging markets and why do they face these challenges?).

Reflection of research methods applied in the empirical studies

The research methods applied in the two empirical studies are similar and this section provides an overall discussion and reflection of the choices of these research methods. The specific research methods adopted in each study were described in details in Section 3.1.1 (for Study One) and Section 4.1 (for Study Two).

When planning the empirical studies, several research methods from social science were investigated. The research methods were selected based on the extent to which they fulfilled the criteria established by the research aims and research questions. In addition to this, a few issues in relation to conducting empirical studies in industry were considered (Taylor, 2016):

1) To maintain the confidentiality of the participants in the studies.
2) To keep the amount of time and involvement of the participants in the studies at a reasonable level to ensure minimal disturbance towards their day-to-day work.
3) To seek permission from the participants before recording the studies.

Surveys and case studies were selected and applied as the two major research methods. A survey collects information in an organised and methodical manner about characteristics of interest from some or all units of a population using well-defined concepts, methods and procedures, and compiles such information into a useful summary form (Statistics Canada, 2010). Conducting a survey, especially an online survey brings such advantages as reduced research

costs, enlarged sample sizes, shorter data collection-analysis-presentation cycles, better access to hard-to reach populations (e.g., the disabled), and enhanced interactivity or research material (Stanton and Rogelberg, 2001). However, in general, the quality of survey data is lower when no interviewer is used and the small samples are likely to give ambiguous, non-significant results (Sturgis, 2006). The nonresponses caused by sensitive questions, bad survey design, etc. can bias the results. Challenges can exist in an online survey study when concerning the data collection, validity and ethics, e.g., the verification of the identify of computer users, access to the internet, privacy and anonymity (Stanton and Rogelberg, 2001).

A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009). Case studies are often used when a 'how' or 'why' research question is being asked about a contemporary set of events, over which the investigators has little or no control (Yin, 2009). Case studies often require long duration for planning, testing and implementation, but can provide in-depth results and allow the use of multiple research methods.

These two research methods were applied jointly in the two empirical studies, where the surveys were used to investigate quantitative patterns and the case studies were used to interpret and analyse the survey findings. Thus, the case studies can verify the survey results and supplement them with in-depth understanding.

Using multiple sources of evidence is a principle for conducting case studies (Yin, 2009). During the conduction of the two empirical studies multiple sources, e.g., interviews and document analysis, were included to triangulate the evidence. Unfortunately, due to practical reasons, e.g., confidentiality and lack of data, not equal amount of data were collected for each case. This is considered as a limitation in this study. However, seeing the fact that these cases were used as

the supplementary data to support the interpretation and analysis of survey findings instead of as independent studies, the data collected are considered as adequate in this research project. If the time and resources allowed, observational studies could be added, e.g., observing the sessions where product managers analyse design requirements and observing the meetings where design requirements are discussed among different stakeholders. Even though direct observations requires large amount of time and money and may influence the proceed of event as being observed, the date collected by this method can cover events in real time and the context of cases (Yin, 2009). Table 1-3 presents an overview of the two empirical studies and the research methods applied.

1.4.3 Prescriptive Study

This research stage aims to apply the increased understanding of current practice and to develop support towards the desired situation. In this research project, a design method named the Perspective-oriented Requirements Excellence toolkit was developed based on the understanding gained from the literature review and the two empirical studies. This method was co-developed with four product development professionals. The method supports companies in preparing and planning the process of identifying design requirements for unfamiliar contexts in order to improve the efficiency of this process and to increase the completeness of identified design requirements. The development of this method answers to Research Question (3) (How to support an effective process of identifying design requirements for emerging markets?).

Table 1-3 An overview of the two empirical studies and research methods applied.

Study One					
Research objective	To understand the process of identifying and managing design requirements for emerging markets and to identify the gaps in current practice and the challenges face by developed-market companies during this process.				
Nature of the study	Observational and comparative research				
Research method and number of cases	Survey I	Four case studies conducted at four Danish companies			
	64 Danish responses	Case A	Case B	Case C	Case D
		9 interviews, Doc. analysis, 1 progress meeting	2 interviews Doc. Analysis 1 progress meeting	1 interviews Doc. analysis	1 interviews Doc. analysis
Role of researcher	Facilitator	Interviewer and meeting facilitator			
Environment	Industry				
Nature of the observed tasks	Real				
Study Two					
Research objective	To understand the differences in the process of identifying and managing design requirements between developed-market and emerging-market companies and to explore how different perspectives influence the differences between developed-market companies and emerging-market companies.				
Nature of the study	Observational and comparative research				
Research method and number of cases	Survey II	Four case studies: two Danish (DK) and two Chinese (CN) companies			
	80 Danish responses and 165 Chinese responses	Case A (DK)	Case B (DK)	Case E (CN)	Case F (CN)
		All data collected in Study One		Previous data: (3 interviews + 3 docs) 2 extra interviews	2 interviews Doc. analysis
Role of researcher	Facilitator	Interviewer and meeting facilitator			
Environment	Industry				
Nature of the observed tasks	Real				

1.4.4 Descriptive Study II

The last stage focuses on evaluating the support method. A preliminary evaluation of the proposed design method was conducted within the timeframe of this PhD project. The evaluation was conducted at a workshop with 13 industrial participants through a real-life case

exercise. This preliminary evaluation together with a full evaluation proposed for future study will answer Research Question (4) (How does the proposed method support the process of identifying design requirements for emerging markets?).

1.5 Outline of the thesis

This thesis is based on six papers that were written during this research project. Table 1-4 presents the title and reference for each paper. All papers are included in this thesis as Appendix A.

This thesis is structured following the stages of the DRM framework. Chapter 1 introduces the background and motivations of this research project, clarifies its scope and aims, and describes the research methodological framework applied in this project. 1.5 presents a review of relevant literature related to product development for emerging markets and design requirements, which provides the theoretical foundation of this research project. The literature review is also reported in all six papers. Chapter 3 and Chapter 4 describes the two empirical studies respectively, including the research methods applied, the results and discussions. Study One is reported in Paper III, IV and VI Study Two is reported in Paper V. Chapter 5 introduces the Perspective-oriented Requirement Excellence toolkit and describes the development and evaluation of this method. Chapter 6 summarises the research findings together with the main conclusions, presents the contributions and implications, and discusses possible areas for future research.

Figure 1-2 provides an overview of the studies conducted during this research project in relation to the DRM framework and research questions, and illustrates in which paper(s) and chapter(s) they are presented.

Table 1-4 The six papers written during this research project.

Paper	Title and reference
Paper I	**The Sources and Methods of Engineering Design Requirement** Reference: Li, X., Zhang, Z., and Ahmed-Kristensen, S., 2014. The Sources and Methods of Engineering Design Requirement. *In: International Conference on Concurrent Engineering*. Beijing, China, 112–121.
Paper II	**A Closed-Loop based Framework for Design Requirement Management** Reference: Zhang, Z., Li, X., and Liu, Z., 2014. A closed-loop based framework for design requirement management. *In: International Conference on Concurrent Engineering*. Beijing, China, 444–453.
Paper III	**Understand the Design Requirement in Companies** Reference: Li, X. and Ahmed-Kristensen, S., 2015. Understand the design requirement in companies. *In: International Conference on Engineering Design*. Milan, Italy, 63–74.
Paper IV	**Identifying Design Requirements for Emerging Markets** Reference: Li, X., Ahmed-Kristensen, S., and Daalhuizen, J., 2016. Identifying design requirements for emerging markets. *In: Eleventh International Symposium on Tools and Methods of Competitive Engineering*. Aix-en-Provence, France.
Paper V	**Identifying and Changing Design Requirements during the Product Development Process** Reference: Li, X., Daalhuizen, J., and Ahmed-Kristensen, S., 2017. Identifying and Changing Design Requirements during the Product Development Process, Working paper, Currently under review in *Journal of Engineering Design*.
Paper VI	**Understanding the Challenges of Identifying Design Requirements for Emerging Markets** Reference: Li, X., Daalhuizen, J., and Ahmed-Kristensen, S., 2017. Understanding the Challenges of Identifying Design Requirements for Emerging Markets, Working paper, Currently under review in *Design Science*.

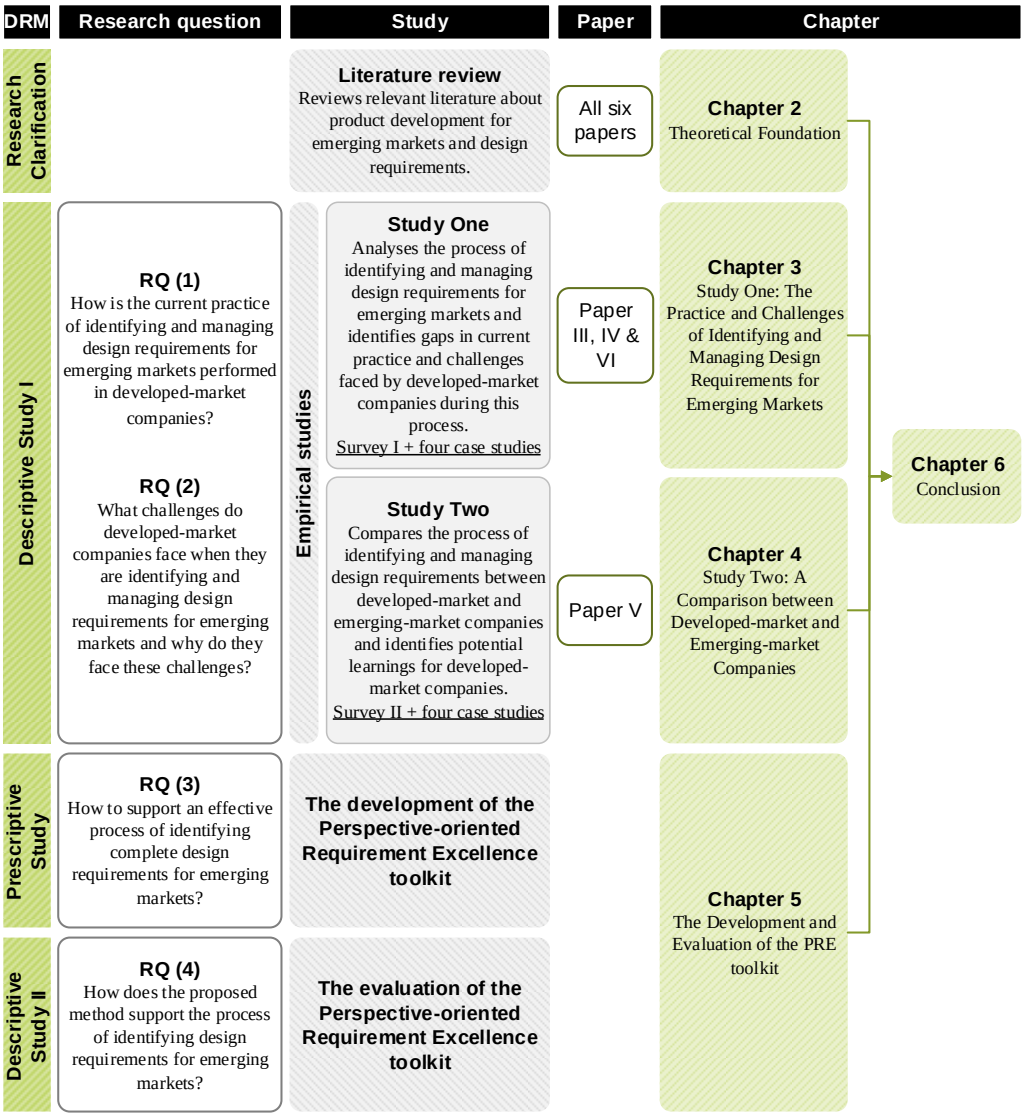

Figure 1-2 An overview of the structure of this research project and the six papers included in this thesis.

Chapter 2. Theoretical Foundation

This chapter presents current literature and summarises the main theories and studies that are relevant to this research project. Two key topics are investigated: 1) product development for emerging markets and, 2) identification and management of design requirements. Special attention was paid to the connections between these two topics. The chapter is structured as follows:

- Section 2.1 presents product development and the commonly used product development models, which provides fundamental knowledge for this project.
- Section 2.2 introduces emerging markets and discusses their influence on product development.
- Section 2.3 describes relevant studies on the identification and management of design requirements.
- Section 2.4 concludes the main points and closes with the identified gaps in current literature. These gaps serve as the base both for the qualitative and quantitative empirical studies and for the development of a design method.

2.1 Product development

Product development is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product (Ulrich and Eppinger, 2011). Identifying and managing design requirements is among the important ones of these

activities. Grasping the general knowledge about product development is the basis to study its components and the variants of product development for specific situations, e.g., product development for emerging markets.

Product development is a very challenging process with a high risk of failure (Ulrich and Eppinger, 2011). As estimated, 46% of the resources that companies devote to new product development do not go to a success in the end (Product Development Institute Inc., no date). In practice, a team can face various challenges in product development, such as the instability of technology, market, macroeconomic environment, time pressure, and the trade-off between cost and functions. Scholars have uncovered a number of factors that support successful product development, e.g., a good product innovation and technology strategy, the right climate and culture for innovation, effective ideation practices, resource allocation, portfolio management, and an effective idea to launch system (Cooper and Mills, 2005; Jaruzelski, Dehoff and Bordia, 2005; Cooper and Edgett, 2012).

A product development process prescribes the sequence of steps or activities a company employs to conceive, design, and commercialize a product (Ulrich and Eppinger, 2011). A well-defined product development process supports a company with quality assurance, team coordination, process planning, performance management, and improvement identification (Ulrich and Eppinger, 2011).

A number of product development models have been developed, which provides guidance to companies for structuring their product development processes. Product development models are generalised to be suitable for the most common situations. Adaption and modification according to a company's specific situation is often necessary. In addition, these models alone do not ensure a good result. The outcome depends on many other factors, e.g., the effectiveness of execution and the quality of decision-making.

Three commonly mentioned and widely used product development models are presented and discussed here. Ulrich and Eppinger (2011) proposed a generic product development model, which consists of six stages. The process starts with a planning stage, which clarifies the project's mission statement, then goes through a concept development stage, a system-level design stage, a detail design stage, and a testing refinement stage, and finally concludes with a production ramp-up stage. Professor Cooper has developed the Stage Gate System since the 1980s (Cooper, 1990, 2008; Cooper and Edgett, 2012). A typical stage gate process consists of one pre-stage (idea stage) and five stages, i.e., scoping, build business case, development, testing and validation and launch. Pahl *et al.* (2007) proposed a comprehensive model of the workflow for product design and development. This process starts from the planning and clarification of the task, through the identification of the required functions, the elaboration of principle solutions, the construction of modular structures, to the final documentation of the complete product.

These three models each presents a product development process that consists of a few stages with a gate in between every two stages to review the deliverables with different focuses. Pahl *et al.* (2007) focused on design and development. Those activities that come after design solutions, e.g., testing and validation, are excluded from this model. Both the generic product development process (Ulrich and Eppinger, 2011) and the stage gate model (Cooper, 2008) include a more complete process covering from planning to production ramp-up or launch. The generic product development process was developed from an engineering design perspective; it describes more and detailed steps for product design, i.e., includes a system-level design stage and a detail design stage. The stage gate model emphasises the early investigation and preparation before development and includes an idea stage, a scoping stage and a build business case in the process.

All three models note that understanding customer needs and identifying design requirements is a crucial step in a product development process. They suggest to identify design requirements

during early stages of the process, because the cost of design changes will increase dramatically if they are not implemented early (Abts and Schaudt, 2015). Ulrich and Eppinger (2011) suggested identifying customer needs at the beginning of the concept development stage, and then establish product specifications through a two-stage process: 1) determining target specifications immediately after identifying the customers' needs and, 2) establishing final specifications after a product concept has been selected (see Figure 2-1). Pahl *et al.* (2007) proposed to elaborate a requirement list during the planning and task clarification stage through activities such as defining basic market demands and defining attractive demands of the market segment (see Figure 2-2). Similarly, in a typical stage gate model, the voice of customers is identified in the second stage, i.e., the build business case stage (Cooper, 1990, 2008).

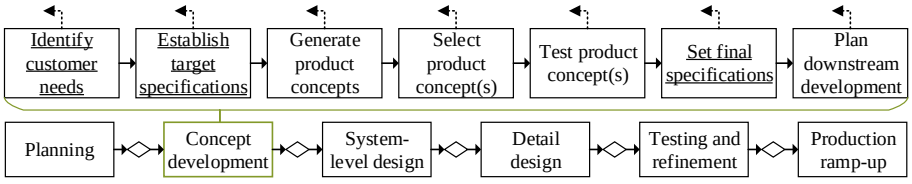

Figure 2-1 Identifying requirements during the generic process (adapted from Ulrich and Eppinger 2011).

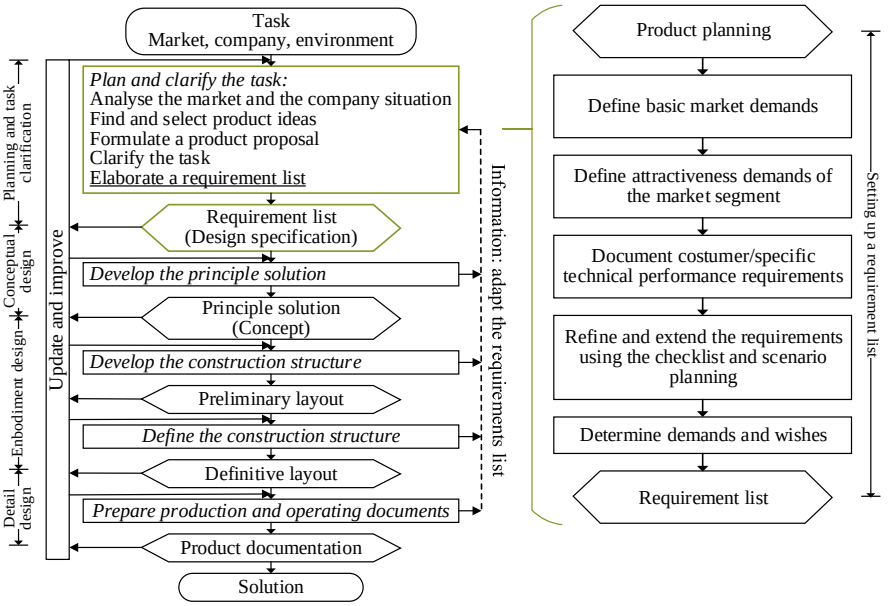

Figure 2-2 Setting up a requirement list in the design process (adapted from Pahl *et al.*, 2007).

It should be noted that in a product development process, the activities that take place during early stages (e.g., requirement identification) are different in the work nature from those that take place during later stages of the process, and should be treated differently (Koen *et al.*, 1996). Koen *et al.* (1996) compared these activities from six dimensions (see Table 2-1). Often these activates that take place during early stages are more unpredictable and more uncertain.

Despite the close attention to product development under a developed-market context, limited literature have been found addressing the implementation of these models in emerging markets, and the majority of these have been written in local languages e.g., Chinese (see e.g., Zhang, 2010). The suitability of these models in emerging markets needs further evaluation and the local practice of product development in emerging markets needs further investigation.

Table 2-1 Comparing activities that take place during early stages and later stages of the product development process (Koen et al., 1996).

Dimensions	Activities during early stages	Activities during later stages
Nature of work	Experimental, often chaotic, 'Eureka' moments. Can schedule work – but not invention	Disciplined and goal-oriented with a project plan.
Commercialization data	Unpredictable or uncertain	High degree of certainty.
Funding	Variable-in the beginning stages many projects may be 'bootlegged,' while others will need finding to proceed.	Budgeted.
Revenue expectations	Often uncertain, with a great deal of speculation.	Predictable, with increasing certainty, analysis, and documentation as the product release data gets closer.
Activity	Individuals and team conducting research to minimise risk and optimise potential.	Multifunction product and/or process development team.
Measures of progress	Strengthened concepts.	Milestone achievement.

2.2 Product development for emerging markets

2.2.1 Definitions of emerging markets

The term of '*emerging market*' was first proposed by Antoine van Agtmael from the International Finance Corporation (IFC) in 1981 with the intention to express uplift and dynamism rather than stagnation (The Economist, 2008). Several other terms, e.g., *less developed countries*, *newly industrialising countries*, *transition economy*, *developing nations*, *Third world countries* and *poor nations*, have been used or are still being used interchangeably with emerging markets (The Economist, 2006).

Numerous definitions of emerging markets have been determined in current publications. For example, Arnold and Quelch (1998) defined an emerging market as a country that has a rapid pace of economic development, government policies favouring economic liberalisation and the adoption of a free-market system. Hoskisson *et al.* (2000) defined emerging markets as low-

income, rapid-growth countries which using economic liberalization as their primary engine of growth. Kvint (2009) described an emerging market as a society, which is transitioning from a dictatorship to a free-market-oriented-economy, with increasing economic freedom, gradual integration with the global marketplace and with other members of the global emerging market, an expanding middle class, improving standards of living, social stability and tolerance, as well as an increase in cooperation with multilateral institutions. Even though these scholars paraphrased emerging markets in various ways, the key words they used were very similar, e.g., growth, liberalisation, and transition.

Different organisations or individuals have made their own lists of emerging markets and updated them over time. For example, MSCI (2016) provided an emerging market index in their market classification and the index includes 21 countries, e.g., Brazil, Chile, and China. Tarun Khanna (2010)'s list also included a few countries and districts that are often regarded as developed markets, e.g., Hong Kong and Singapore. Ian Bremmer (2015) argued that the new seven most promising emerging markets should be Colombia, India, Indonesia, Kenya, Malaysia, Mexico, Poland, and the United States based on their economic potential. India and China are among the two most popular emerging markets with higher economic growth rates than the rest (The World Bank, 2011; Mutum, Roy and Kipnis, 2014). The inconsistency and instability of these indexes of emerging markets indicates that the context of emerging markets is in rapid change, which prompts continuous research on emerging markets in order to maintain the knowledge up-to-date.

2.2.2 Major characteristics of emerging markets

Emerging markets differ from both developed markets and other developing countries in a number of dimensions (as presented in Table 2-2). More often, scholars compare emerging markets with developed markets. For example, Vladimir Kvint (2009) proposed 45 major

characteristics of an emerging market, which covered various dimensions, e.g., political, economic, and social.

Table 2-2 The distinctions between developed markets, emerging markets and other developing markets (adapted from Cavusgil, Knight and Riesenberger, 2008).

Dimensions	Developed markets	Emerging markets	Other developing markets
Representative countries	Canada, France, Japan, UK, USA	Brazil, China, India, Indonesia, Turkey	Angola, Bolivia, Nigeria, Bangladesh
Population (% of the world)	14%	62%	24%
Approx. average per capita income (US dollars, PPP basis)	33,750	13,250	6,450
Industry	Highly developed	Rapidly improving	Poor
Competition	Substantial	Moderate but increasing	Limited
Trade barriers	Minimal	Rapidly liberalising	Moderate to high
Economic and political freedom,	Free or mostly free	Moderately free or mostly not free	Mostly repressed
Economic / political system	Capitalist	Rapidly transitioning to capitalism	Authoritarian socialist, or communist
Regulatory environment	Minimal regulations	Achieved much economic liberalization	Highly regulated, burdensome
Intellectual property protection	Strong	Moderate and improving	Weak
Infrastructure	Well-developed	Moderate but improving	Inadequate

This research project focuses on comparing emerging markets with developed markets. Seven main characteristics of emerging markets are summarised along their relevance to product development.

Fast growing economy and opportunities

Fast economic growth enables emerging markets to stand out from any other markets (Hitt *et al.*, 2000; Hoskisson *et al.*, 2000; Gu, Hung and Tse, 2008). It was predicted that emerging markets would have an average growth rate by 4.7 percent a year between 2011 and 2025, while

the average growth rate for developed market would be 2.3 percent over the same period (The World Bank, 2011). The gross domestic product of emerging markets was estimated to permanently surpass that of all developed markets by 2035 (Wilson and Purushothaman, 2003). The fast growth results in an increase in purchasing power and prompts increasingly more manufacturers to sell products to emerging markets. However, a fast-changing environment can also lead to fluctuant and volatile markets (Enderwick, 2007) and challenge companies' conventional assumptions about designing, developing, and manufacturing products for these markets (Gudlavalleti, Gupta and Narayanan, 2013).

Low average per capita income

Despite their rapid growth, emerging markets still have a low to middle per capita income (Heakal, 2015; Kuepper, 2016). A large amount of the population are living in the low-income regions, which are defined as rural households or referred as the 'bottom of the Pyramid'. These inhabitants are generally illiterate and do not have the knowledge and skills regarding the use of certain products (UNDP, 2008). This fact motivates the design of suitable products this market segment with particular attention to price-performance relationship (UNDP, 2008).

Distinctive sociocultural contexts

Geographically, emerging markets include countries located in Central and Eastern Europe, Middle East, Latin America, East and Southeast Asia and Africa. These countries have different histories, cultures and social customs between each other, and are even more different from developed markets, e.g., countries in West and North Europe, and North America. Figure 2-3 illustrates an example of comparing the national cultures between a developed market (Denmark) and an emerging market (China) (Hofstede, Hofstede and Minkov, 2010).

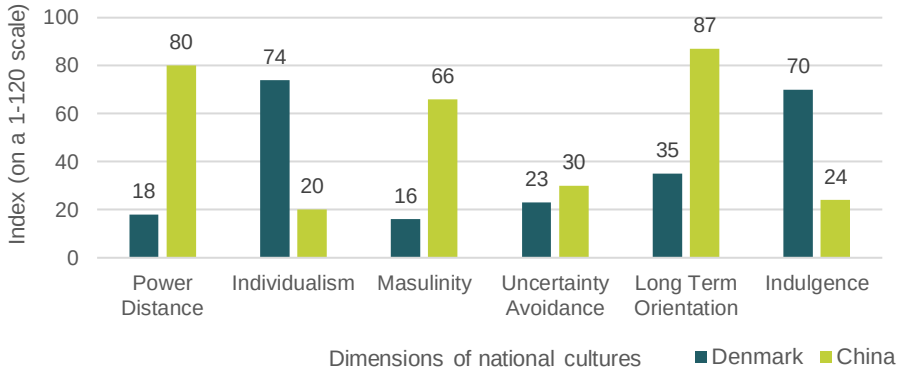

Figure 2-3 Comparing the national cultures between Denmark and China (generated from Hofstede 2016).

Culture has considerable influence on product development and it is critical that manufacturers understand these cultural differences and adapt their products and approaches accordingly (Dubiel and Ernst, 2012). For example, Salmi and Sharafutdinova (2008) determined that the Russian cultural features (e.g., high power distance, femininity, high uncertainty avoidance) affected the preferred design in the Russian mobile market. This study demonstrated that design requirements could be explained by cultural, social and economic factors. For example, the 'clear correspondence of mobile phone design to certain gender' (a design requirement) was a result of the 'clear differentiation between men and women in clothing' (a Russian socio-cultural factor).

Heterogeneous markets

Emerging markets are not homogenous but highly fragmented (Sheth, 2011). The contexts, e.g., income levels and cultures, vary even within the same country, e.g., from the East China to West

China. This characteristic challenges the attempts to study emerging markets as a whole (Hoskisson *et al.*, 2000).

Underdeveloped legal and regulatory environments

The regulatory environments of emerging markets are in general unstable and underdeveloped, and the enforcement of existing rules is insufficient (UNDP, 2008). Regulatory environments influence the market regulations, product regulations, and governance transparency, and eventually have an impact on a company's ability to earn profits in the markets (Dubiel and Ernst, 2012). Product development can be obstructed by the underdeveloped external institutions in emerging markets, which are often associated with for example highly bureaucratic and corrupt legal-political governance (Khanna and Palepu, 1997; Bruton *et al.*, 2010; Chen *et al.*, 2013). For example, Parry and Song (1994) determined that the impact of regulations on production was one of the primary constraints faced by Chinese state-owned enterprises in developing new products.

Severe competition

In emerging markets, a company competes with a large number of both local and international competitors (Gu, Hung and Tse, 2008). 60% of the consumption in emerging market is for unbranded products and services (Sheth, 2011). In addition, the competition in emerging markets is more chaotic due to relatively poorer protection of intellectual property rights and other consequences of the underdeveloped regulatory environments. Er (1997) reported that competition was the vital ingredient for the product development and design activities in the context of emerging markets. This scholar determined that a price-based competition strategy was popular in Asian emerging markets, whereas a quality-based competition approach was commonly used in developed markets. Severe competition may incite companies to closely

monitor competitors' activities and to include new information about competitors' products in their design requirements.

Inadequate infrastructure and resources

The infrastructure, e.g., roads, logistics, power supplies, sanitation and telecommunications, are generally inadequate and underdeveloped in emerging markets (Sheth, 2011). There is also a shortage of supporting resources, such as technology, education and finance. For instance, the technology is often less mature and less invested in emerging markets compared to developed markets (Hitt *et al.*, 2000; Sheth, 2011). The customers in emerging markets are limited to purchase due to the lack of access to credits, insurance, products, and banking service. It, on one side, provides companies business opportunities to improve the situation, and on another side, requires specific attention on resource constraints when companies are developing products for emerging markets.

2.2.3 Different types of product development for emerging markets

Scholars have observed different practice of product development for emerging markets. Various types of product development for emerging markets were categorised into two groups. The first group focuses on providing affordable and suitable solutions to fulfil the specific local needs and requirements of low-income market segments, often including the adaption of the conventional resource-rich product development that originated from developed markets, to the resource-limited context of emerging markets, e.g., frugal innovation. The second group focuses on adapting the knowledge and experience developed in emerging markets back to developed markets and serving especially the low-end segment there, e.g., reverse innovation. A similar categorisation was also proposed by Agarwal and Brem (2012).

Frugal innovation describes the ability to create significantly more business and social value while minimising the use of diminishing resources such as energy, capital and time (Radjou and Prabhu, 2015). It has been developed by developed-market companies in order to cope with the general resource scarcity and to perform in emerging markets (Radjou and Prabhu, 2015). It emphasises the significance of the turbulent global market and competitive landscape, e.g., the scarcity of natural resources (Radjou, Prabhu and Ahuja, 2012).

Some other studies, e.g., low-end disruptive innovation (Christensen, 1997), cost innovation (Williams and van Triest, 2009; Williamson, 2010), bottom of pyramid (BoP) (Prahalad, 2004), and resource-constrained innovation (Ray and Ray, 2010), have the similar goal of offering suitable products that fulfil the basic needs at a low price (Zeschky, Widenmayer and Gassmann, 2011). Tiwari and Herstatt (2012) reported that frugal innovation: 1) tended to have a disruptive character (Christensen and Raynor, 2013); 2) shared features with lean innovation of effective turning knowledge into value (Sehested and Sonnenberg, 2010) and; 3) could encompass Jugaad innovation, grass roots innovation, 'bottom of the pyramid' and inclusive innovation (Gupta, 2008; Singh and Chaudhuri, 2009). Jiang, Kandachar and Freudenthal (2011) suggested that the three fields of knowledge: Bottom of Pyramid theory, social impact theory and innovation management theory are connected with each other.

These studies in the first group are often based on the traditional view that the innovation flows from developed markets to emerging markets (von Zedtwitz *et al.*, 2015). However, examples have been observed challenging the paradigm. For example, a local team from GE Healthcare built a cheap and portable ultrasound device for the poorly funded rural clinics in China. This product was then successfully introduced in developed markets (Immelt, Govindarajan and Trimble, 2009; von Zedtwitz *et al.*, 2015). Such a product development practice is described by studies in the second group, e.g., reverse innovation (Govindarajan and Trimble, 2012). Reverse innovation refers to a case where an innovation is adopted first in a poor country (an emerging

market) before being adopted in rich countries (developed markets) (Govindarajan and Ramamurti, 2011). Reverse innovation is commonly initiated by five gaps, i.e., the performance gap, the infrastructure gap, the sustainability gap, the regulatory gap, and the preferences gap (Govindarajan and Trimble, 2012). Table 2-3 summarises the different types of product development for emerging markets for each group.

Table 2-3 Different types of product development for emerging markets (adapted from von Zedtwitz *et al.* 2015).

Group	Innovation type	Definition and description	References
Group 1	Disruptive innovation	- Affordable, 'good enough' products that meet consumers' basic needs at a relatively low cost - Often destroys the value of existing technical competencies	(Hang, Chen and Subramian, no date; Christensen, 1997, 2006; Markides, 2006; Constantinos C. Markides, 2012; Wan, Williamson and Yin, 2014)
	Lean innovation	- interprets the lean thinking principles to product and process innovation and development, which eliminate all non-value-adding processes in order to achieve the goals with the lease possible efforts	(Schuh, Lenders and Hieber, 2008; Sehested and Sonnenberg, 2010)
	Frugal innovation	- Has a large cost advantage, and in some cases inferior performance, compared to existing solutions, and developed in a resource-constrained context	(Zeschky, Widenmayer and Gassmann, 2011).
	Jugaad innovations	- Innovations developed for the Indian market that responds to two Gandhian tenets: affordability and sustainability - Supports to spot opportunities in the most adverse circumstances and resourcefully improving solutions using simple means	(Prahalad and Mashelkar, 2010; Radjou, Prabhu and Ahuja, 2012).
	Grassroots innovation	- Networks of activists and organisations generating novel bottom-up solutions for sustainable development; solutions that respond to the local situation and interests and values of the communities involved	(Seyfang and Smith, 2007).
	Bottom of the pyramid/ Base of the pyramid	- Serve particularly for about four billion people who live in poverty and being economically at the bottom of the pyramid	(Kandachar and Hailme, 2008; Subrahmanyan and Gomez-Arias, 2008)

	Inclusive innovation	- Creates, acquires, absorbs and distributes knowledge targeted the fulfilment of the needs of the low-income population	(R A Mashelkar, 2014).
	Cost innovation	- Leveraging developing economies' cost advantage to develop innovation at dramatically lower costs	(Zeng and Williamson, 2007)
	Indigenous innovation	- A process of making use of technologies transferred from the developed markets to develop superior technologies at home	(Lu, 2000; Lazonick, 2004)
	Shanzhai innovation	- Chinese low-quality, low-price imitations of foreign branded products	(Peng, Xu and Lin., 2009)
	Resource-constrained innovation	- Developed in emerging economies in a context characterized by lower power of purchase, lower understanding of technology, and lower investment resource	(Ray and Ray, 2010)
Group 2	Reverse innovation	- Innovations adopted first in poor (developing) countries before being adopted in developed markets	(Immelt, Govindarajan and Trimble, 2009; Govindarajan and Ramamurti, 2011; Govindarajan and Trimble, 2012)
	Trickle-up innovation	- Innovations developed for the bottom of the pyramid that subsequently trickle up to the developed markets	(Prahalad, 2004)
	Blowback innovation	- Innovative solutions developed and adopted first in emerging markets	(Brown and Hagel, 2005)

2.2.4 Studies on product development for emerging markets

As mentioned in previous sections, the characteristics of emerging markets, e.g., the unstable and underdeveloped regulatory environments and severe competition, influence the product development for emerging markets and often increase the risks and uncertainties of product development. Several relevant studies on product development for emerging markets are discussed in this section.

A few studies directly addressed how developed-market companies develop products for emerging markets. For example, Mattson and Wood (2014) proposed nine principles for effective design for developing countries (emerging markets) by reviewing engineering literature:

1) Co-design with people from the specific developing world context encourages designer empathy, promotes user ownership, and empowers resource-poor individuals.
2) Testing the product in the actual setting is an essential part of design for the developing world, not merely a final step.
3) Importing technology without adapting it to the specific developing world context is ineffective and unsustainable.
4) Both individuals in urban and rural contexts can benefit from poverty alleviation efforts.
5) Women and children are more affected by poverty alleviation efforts than men are.
6) Project management techniques that are adapted to the specific developing world context enable a more effective and efficient design process.
7) Products for the developing world have greater impact when contextualized, developed, and implemented by inter- disciplinary teams.
8) Cooperation with governments and local influencers contextualises and enables poverty alleviation plans.
9) There are existing distribution strategies that can be used to successfully introduce products into developing world markets.

Jagtap *et al.* (2014) observed the design processes of an identical design task of four designers that designed for the base of pyramid (BoP) and four designers that designed for the top of the pyramid (ToP). Three aspects were compared between the two groups of designers: design strategy, requirement handling behaviour, and information behaviour. The findings included that the BoP designers used a problem driven strategy and the ToP designers used a solution driven strategy. It indicated the BoP designers were engaged more in the clarification of design objectives and the BoP sessions were more information intensive. These differences suggested that the market-context (e.g., BoP and ToP) could influence the design processes. One of the

main explanation provided by these scholars was that none of the eight designers came from the BoP strata and hence are unfamiliar with the design tasks in the BoP sessions. This study reflects a common challenge that developed-market companies are not familiar with emerging markets. These scholars focused on explaining the differences from the designers' own experience and background. The external factors, e.g., competitive situation and regulatory environments, were either excluded or not addressed directly in this study. The real tasks of designing for emerging markets can be much more complex, which requires extensive further research in the industry environment.

Other studies provide an understanding about product development for emerging markets by investigating the practice of the local emerging-market companies. For example, a study compared innovation between companies in Asia (Singapore, China and Korea) and in the West (Denmark) (AsiaNBC Project, 2011). This study determined that the Asian companies excelled at providing products and solutions that were suitable for a particular market and were prepared to change even radically. The Asian companies were often well organised to observe the industry leaders and first movers, and could quickly follow with similar solutions. It indicates that there are potential learnings for developed-market companies from these emerging-market companies, especially in the case of developing for emerging markets, which corresponds to the intention of reverse innovation.

Similar indications are also determined from Luo (1999)'s comparison of knowledge and its performance effects between Asian and developed-market multinational enterprises (MNEs) in China. This study reported that the Asian MNEs (e.g., from Singapore, Taiwan, and Hong Kong) were inferior in technological and organisational competencies but were superior in hosting country-specific knowledge such as marketing tactics and environmental familiarity, compared to developed-market counterparts.

Li and Ahmed-Kristensen (2014) compared product development processes between Danish and Chinese manufacturing companies. These scholars determined more controlling points during the product development process in Danish companies than in Chinese companies, especially during the early stages of the process. In addition, users were predominantly involved during early stages of the product development process in Danish companies in contrast to the Chinese companies. This study indicates possible differences in the approaches of identifying user requirements between developed-market and emerging-market companies.

Donaldson (2006) analysed the companies' design processes in Kenya. This scholar determined that in Kenyan companies, the design activities during early stages of the product development process (e.g., needs definition and conceptual design) were not standardized. The design decisions were not documented. The Kenyan engineers and technicians in the industrialised sectors lacked design expertise. These Kenyan companies did not see the need for a rigorous design process. These findings demonstrate evident differences between Kenyan companies and developed-market companies. It indicates that the product development practice in emerging-market companies is often immature. In addition, this study discussed the Kenyan market. For example, this scholar argued that the perfunctory cross-cultural application was tolerable to the consumer only in the absence of competition. This scholar also determined inadequate infrastructure to support design in Kenya. It implies the need for adapting processes and methods to address the specific needs and conditions when developed-market companies are developing products for emerging markets.

Research on product development in the context of emerging markets has captured more and more attention in recent years (Subramaniam, Ernst and Dubiel, 2015). Despite these efforts made to investigate emerging markets, prior studies on design, especially those that focused on design requirements, were predominantly conducted in the context of developed countries and relatively affluent markets (Viswanathan and Sridharan, 2012; Jagtap and Larsson, 2013; Jagtap,

Larsson and Kandachar, 2013; Jagtap *et al.*, 2014). Jagtap, Larsson and Kandachar (2013) suggested that further studies on design for the BoP to overcome the limitation in current studies (e.g., UNDP, 2008) require detailed information on the aims of different stakeholders, resources available to these stakeholders, BoP-people's need satisfied, details of different issues considered, etc. Moreover, Donaldson (2006) noted that existing design studies that address emerging markets are largely descriptive and characterise the design process and the environment differences relative to more industrialised economies. Support design methods are needed to guide companies' practice. Furthermore, a number of existing studies on emerging markets focus on large size multinational corporations (see e.g., Deloitte Touche Tohmatsu, 2006; Dubiel and Ernst, 2012; Gudlavalleti, Gupta and Narayanan, 2013). Limited effort has been made addressing SMEs, even though they are contributing considerably to the economy especially in emerging markets (Bell, 2015).

2.3 Design requirements

Often the needs or problems that the product is expected to satisfy or solve are identified in the beginning of a product development project. These initial needs and problems will then be formulated into abstract, unambiguous, traceable and validatable design requirements (Brace and Cheutet, 2012). Studying design requirements is significant and should be a central issue in design research (Chakrabarti, 1994).

Darlington and Culley (2002) categorised the research on design requirements into prescriptive research, descriptive research, and research on requirements for design automation. Such research has been conducted in multiple domains, e.g., software engineering and engineering design. This subject is a sub-discipline within software engineering generally referred as requirement engineering. In both software engineering and engineering design domains, the tasks of identifying and managing design requirements are similar. The difference between the

two domains is that the description of problem will be transformed into a description of the solution in software engineering whereas it stops at the completion of the full design requirements in engineering design (Darlington and Culley, 2002).

2.3.1 Definitions and significance of design requirements

Various definitions of design requirements have been determined in current literature. The VDI guidelines for systematic design and product development defined a requirement as the qualitative and quantitative definition of the functions and constraints to be fulfilled by a product (VDI, 1987). Chakrabarti, Morgenstern and Knaab (2004) stated that a requirement was a characteristic that a designer is expected to fulfil through the eventual design. Dorfman and Thayer (1990) defined that a design requirement was one of the following: 1) a condition or capacity needed by a user to solve a problem or achieve an object; 2) a condition or capacity that must be met or processed by a system or system component to satisfy a contract, standard, specification or other formally imposed documents and; 3) a documented representation of a condition or capacity as in 1 or 2.

A requirement and a specification are sometimes used interchangeably (see e.g., Sudin, 2012) and sometimes distinguished. A requirement can be regarded as a model reproducing the problem and the criteria for the product to be designed (Buur and Andreasen, 1989). A specification aims to determine the precise limits for the full set of requirements in the product being designed (Cross, 2006). A requirements can go beyond what is stated in the design specification, for example including issues related to style and aesthetic preferences, which may be difficult to describe in detail (Haug, 2015). For example, a customer requirement can be largely independent of any particular product developed (Ulrich and Eppinger, 2011). A specification, in contrast, depends on the concept selected. These scholars noted that the distinction between a need and a specification was subtle but noticeable. However, the

differences between these two is not the focus of this research project. In this thesis, the term *'design requirement'* is used with the broader meaning, which includes both requirements and specifications.

2.3.2 A process of identifying and managing design requirements

It is generally suggested to achieve accurate design requirements early in product development processes (Cross, 2008), because design requirements have significant influence on the whole process and the cost of design changes will increase dramatically if they are not implemented during the early stages (Abts and Schaudt, 2015).

Requirement identification is a process of gathering input of a combination of information expression of needs and information from several sources, and transforming it into a desired output as a design requirement (Brace and Cheutet, 2012). Often the process starts with gathering relevant information from a number of sources to elicit requirements. Requirement elicitation aims at identifying the needs and disparities among the various stakeholders (Brace, 2012). A number of techniques have been introduced to support the requirement elicitation, e.g., interviews, surveys, observations and brainstorming (Haubroe, 2015). The elicitation prepares informal requirements that may be overlapping, vague, conflicting etc. Such requirements must be analysed, e.g., clustered, clarified, and prioritised. The requirements that are formed in the voice of customers (and other stakeholders) need to be translated to the voice of designers (Fung, Popplewell and Xie, 1998). The translated requirements specify the precise and measurable details what the product has to do (Ulrich and Eppinger, 2011). Requirements at this level are also referred as specifications. Numerous techniques, e.g., the Quality Function Deployment (QFD) (Akao, 1990), support the analysis and specification of design requirements. In the end, in many cases, it is also necessary to validate requirements. Bahill and Henderson (2005) noted that the goal of requirement validation is to ensure: 1) the set of

requirements is correct, complete, and consistent, 2) a model can be created that satisfies the requirements, and 3) a real-world solution can be built and tested to prove that it satisfies the requirements. Requirement identification is an iterative process. Requirements might be updated and changed under certain circumstances, e.g., changes to user needs. Therefore, maintaining design requirements is a continuous process and spans the whole product life cycle (Brace, 2012). To be consistent in this thesis, five common phases in the process of identifying and managing design requirements are summarised and clarified in Table 2-4.

Table 2-4 Main phases of the process of identifying and managing design requirements.

Phase	Objective	References
Requirement elicitation	To systemically extract the requirement information from multiple sources.	(Jiao and Chen, 2006; Pacheco and Garcia, 2009)
Requirement analysis	To analyse the requirements for conflicts, overlaps, omissions, and inconsistencies.	(Sommerville and Pete Sawyer, 1997; Wood and Otto, 2000)
Requirement specification	To specify explicit and formal requirements with measurable details for development and evaluation.	(Ulrich and Eppinger, 2011)
Requirement validation	To validate whether requirements are consistent with stakeholders' intentions.	(Loucopoulos and Karakostas, 1995)
Requirement maintenance	To update, maintain and support the evolution of requirements.	(Kotonya and Sommerville, 1998; Sutcliffe, 2014)

Several models describe requirement identification processes in different ways. For example, Cooper, Wootton and Bruce (1998) defined a process of gathering and processing requirement information (see Figure 2-4) and stated that requirement information could be gathered from a large multitude of internal and external sources. They argued that the choice of sources was important and the process of selecting sources were affected by several factors, e.g., cultural influence, organisational influence and personal preference.

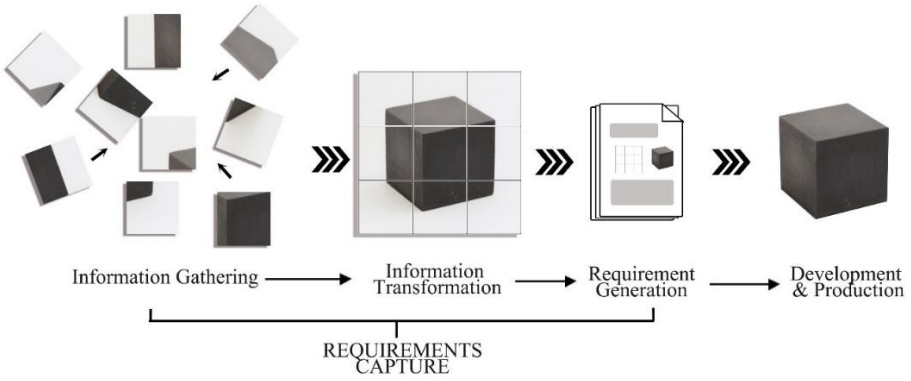

Figure 2-4 Requirement capturing process (Cooper, Wootton and Bruce, 1998).

2.3.3 Changes to design requirements

In practice, clear and unambiguous design requirements can rarely be identified at the beginning of the product development process (Haug, 2015). It is in fact increasingly recognised that design requirements co-evolve with product development processes (Darlington and Culley, 2002; Sudin and Ahmed-Kristensen, 2011). Clearly understanding problems and developing solutions are two aspects that also coevolve (Dorst and Cross, 2001). The co-evolution of design requirements and product development processes is nowadays driven by a reaction to a surprise change in environment (Dorst and Cross, 2001). Suwa, Gero and Purcell (2000) studied the design process of an architect and provided empirical evidence of the co-evolution of the problem-space and the solution-space. These scholars determined that the unexpected discoveries through the design process and the expanding of problem-space drove the occurrences of each other.

Design requirements evolves through different formats: modification or removal of existing requirements and addition of new requirements (Fernandes *et al.*, 2014). These changes can

take place during any stages of a product development process but are likely to occur during the development and prototype stage and more than likely to occur during the actual design stage before changes are documented (Ahmed and Kanike, 2007).

Both internal and external factors can initiate changes to design requirements (Morkos, Shankar and Summers, 2012). Fernandes *et al.* (2014) analysed the causes of requirement changes during the design process of a complex aerospace system developed by Rolls-Royce. These scholars observed that more than 80% of the changes had internal root causes, and the changes driven by the customer accounted for about 15% of the total. These scholars noted that the exact proportion of external versus internal change might vary across projects and industries. Almefelt *et al.* (2006) identified a few underlying factors for changes to design requirements, e.g., knowledge gained through the development work, requirements found to be conflicting, technical difficulties to meet a high specification, opportunities for function-sharing and synergies, unexpected demands for cost savings, new legal requirements, and unexpected competitor situations and customer preferences. Sudin and Ahmed-Kristensen (2011) proposed a mechanism to discover the needs to change a design requirement, considering both the internal factor, e.g., requirement analysis and solution evaluations, and external factors, e.g., technology changes, market demands changes, and customer requests changes. Vajna *et al.* (2005) determined that a requirement could be affected by the changes in technology, trends, perceptions, regulations, etc. Among these causes of changes to design requirements, the external factors, e.g., customers, regulations, and competition, are to a large extend context-dependent, i.e., differ from context to context. For example, the underdeveloped regulatory environments in emerging markets could increase the uncertainties in design requirement identification, and hence result in more changes to design requirements. Therefore, it is valuable to investigate these external factors when addressing design requirements for emerging markets.

It should be noted that even though many of the existing product development models recognise the co-evolution of design requirements and product development processes, limited methods or tools are supported in handling the co-evolution. It is still not clear at which stage(s) of product development processes, changes to design requirements should be permitted or restricted.

2.3.4 Identifying design requirements from multiple perspectives and sources

Requirement identification is a complex process, and one of the challenges is the information completeness and consistency. During this process, various perspectives should be considered and diverse sources can be used to gather information.

Perspectives considered in requirement identification

Design requirements coordinate diverse desires and provide the basis for synthesizing a solution (Darlington and Culley, 2004). Experienced requirements engineers always consider different perspectives when identifying design requirements (Sommerville, Sawyer and Viller, 1998). Chen and Zeng (2006) argued that design requirements should satisfy all players in the product's life cycle, e.g., designers, manufacturing workers, sales people, deliverers, users, maintenance workers and recycle workers. This need for a multi-perspective approach to identify design requirements across stakeholder types is commonly accepted.

A perspective, in this thesis, is defined as a combination of a group of 'actors' in the development process that shares similarities, and a 'view' that these actors maintain (adapted from Easterbrook *et al.*, 1994). These actors can be either human actors, e.g., users or suppliers, or non-human actors, e.g., constraining systems or regulatory frameworks. Current studies on multiple perspectives in design requirements are categorised into three groups:

1) Stakeholder-related studies.

The studies in this group contribute such methods as identifying stakeholders, and eliciting and analysing stakeholders' requirements, which supports requirement identification across different stakeholder types. For example, Pacheco and Garcia (2008) determined three groups of stakeholder identification methods. The first group includes methods that exclusively describe stakeholders, e.g., the Volere template that maps out the stakeholders that participated in the development (Robertson and Robertson, 2013). The second group consist of methods that focus on the interaction between stakeholders, e.g., Sharp, Finkelstein and Gala (1999)'s differentiation between 'baseline', 'supplier', 'client', and 'satellites' stakeholders. The third group comprises methods that include assessment of stakeholders, e.g., analysing stakeholders' interest in the project considering the power, legitimacy and urgency (Mitchell, Agle and Wood, 1997).

2) Viewpoint-oriented requirement identification studies.

A viewpoint is a standing or mental position used by an individual when examining or observing a universe of discourse (do Prado Leite and Freeman, 1991). Viewpoints were first used in requirement identification for aircraft industry and then developed in software engineering. Several viewpoint-oriented requirement identification methods have been developed, e.g., the PREview process (Sommerville and Sawyer, 1997) and the requirement engineering process model for software development (Pandey, Suman and Ramani, 2010).

3) Studies on the categories of design requirements.

A few categorisations of design requirements also indicate what perspectives should be considered during the requirement identification process. For example, Gershenson and Stauffer (1999) proposed a taxonomy that categorised design requirements into four types,

namely end user requirements, corporate requirements, regulatory requirements, technical requirements. This categorisation indicates that design requirements can be identified from an end user perspective, a corporate perspective, a regulatory perspective and a technical perspective. Chen and Zeng (2006) classified design requirements into eight levels: natural laws; social laws and regulations; technical limitation; cost, time, and human resource; basic functions; extended functions; exception control level; and human–machine interface, which is another example of different perspectives should be considered in requirement identification.

Table 2-5 presents a few examples of studies in each group. These studies have confirmed the significance of identifying design requirements from multiple perspectives but there are also limitations. The first group mostly focuses on human stakeholders' perspectives. Non-human actors' perspectives, e.g., a regulatory perspective and a technical perspective, are often excluded in these studies. The viewpoint-oriented requirement identification studies in the second group have been mostly developed in software engineering. The applicability of these methods in manufacturing companies have not been validated. The studies in the third group are initiated by understanding the nature of design requirements. They focus on the requirements themselves. The interaction between design requirements and the external factors, which are critical for identifying design requirements for emerging markets, are not explicitly addressed in these studies. Therefore, it is still a need to understand multiple perspectives in requirement identification in greater details and support manufacturing companies in identifying design requirements from multiple perspectives with a focus on the context of emerging markets.

Table 2-5 Examples of perspectives in existing literatures.

Group	Reference	Perspective	Domain
1	(Cotterell and Hughes, 1995)	A perspective internal to the project team; external to the project team, but internal to the organisation; and external to both the project team and the organisation	Software engineering
	(Pouloudi and Whitley, 1997)	A perspective of 'hubs' or 'sponsors' and a perspective of 'spokes' or 'adaptor'	Software engineering
	(Kotonya and Sommerville, 1998; Sharp, Finkelstein and Gala, 1999)	A perspective of end-users, managers and others involved in the organisational processes, engineers for development and maintenance, customers who will use the system to obtain a service, external bodies e.g., regulators, domain experts	Software engineering
	(Newman, Lamming and Newman, 2006)	A perspective of those who use the system directly or indirectly, and those who is involved in developing the system	Software engineering
2	(Kotonya and Sommerville, 1992)	Functional viewpoints and non-functional viewpoints	Software engineering
	(Kotonya and Sommeiville, 1996)	Direct viewpoints: system, operator; indirect viewpoints: engineering, regulatory, organisation, environment	Software engineering
	(White, 1997)	Operational environment view, system capabilities, system constrains, development requirements, verification and validation requirements, and specification of system growth and change	Software engineering
	(Sommerville and Sawyer, 1997)	Viewpoints associated with system stakeholders, Viewpoints associated with organisational and domain knowledge	Software engineering
	(Pandey, Suman and Ramani, 2010)	A perspective of business, customer, security, constraints, information, users, and standards	Software engineering
	(Katina, Keating and Jaradat, 2012)	A perspective of engineering, marketing, customer, production	System engineering
	(Brace and Cheutet, 2012)	Customer view (business, environment) and the engineering view (technical constraint)	Engineering design
3	(Gershenson and Stauffer, 1995)	A perspective of end users, corporates, regulatory, and technical	Engineering design
	(Bollen, 2007)	A perspective of developing and implementation	Software engineering
	(Chen and Zeng, 2006)	A perspective of natural laws; social laws and regulations; technical limitation; cost, time, and human resource; basic functions; extended functions; exception control level; and human–machine interface.	Engineering design

Despite of the recognition of considering multiple perspectives in requirement identification, conventional studies on design requirements have focused on customers and users while other perspectives have received limited attention. One explanation for this emphasis is the

significant role of customers and users in design objectives and their direct influence on design solution. A few examples of studies on customer and user requirements are presented here. Franceschini, Maisano and Mastrogiacomo (2015) introduced a technique based on the generalised Yager's algorithm to prioritise customer requirements. Haug (2015) proposed a conceptual framework that defines emergence patterns for client requirements and potential communicative problems associated with these patterns. It provides overall guidelines for addressing specific emergence patterns. Wang and Tseng (2014) reported an approach to identify emerging customer requirements by applying Bayes factor-based sequential analysis. This approach operates in the online interactive environment where customers are required to specify attribute sequentially. Jacobs and Ip (2005) investigated how user requirements are prioritised, analysed and incorporated into game design.

Sources used for gathering design requirements

A source for gathering design requirements is an information source from where the requirements information is collected. For companies, selecting sources for identifying design requirements is an important decision, because it affects the quality of the collected information and the efficiency of collecting it. For example, when gathering user requirements, directly contacting users costs more money and time but may generate more reliable information compared with gathering user feedback through distributors. However, companies often do not select sources with thorough consideration, instead, they choose the sources in an ad-hoc manner, or base on the basis of personal preferences, beliefs and other hidden cognitive influences (Cooper, Wootton and Bruce, 1998). Therefore, it is valuable to support companies' decision of selecting appropriate sources with an overview of the potential sources and guidance for selection.

Sudin, Ahmed-Kristensen and Andreasen (2010) categorised sources into two groups: 1) human sources, e.g., clients, end user, and colleagues; and 2) artefact sources, e.g., semi-developed specifications, proposed solutions, existing products, and previous projects. This categorisation recognises the non-human sources that are often excluded in stakeholder analysis and extends the information-capturing boundary beyond a single project's scope. For example, a project team can identify design requirements from existing products from both their own company and competitors (who are also often excluded from stakeholder analysis). Similarly, Wootton, Copper and Bruce (1997) separated sources into individuals (e.g., customers, users or suppliers), written materials (e.g., books, trade journals, or technical manuals), and objects (e.g., competitors' products). These scholars suggested to differentiate between internal and external sources. Table 2-6 summarises the common sources used for gathering design requirements in current literature.

Table 2-6 A list of sources for gathering requirements in current literature.

category	Source	Examples	Reference
Artefacts	Contracts and predefined requirements	Requirements imposed by the given designs (re-design only)	(Chakrabarti, Morgenstern and Knaab, 2004)
		Semi-developed specification	(Bailetti and Litva, 1995; Sudin, Ahmed-Kristensen and Andreasen, 2010)
		Given assignment	(Chakrabarti, Morgenstern and Knaab, 2004)
		Contractual agreements	(Agouridas *et al.*, 2006)
	Guidelines	Design guidelines	(Sudin, Ahmed-Kristensen and Andreasen, 2010)
		User guidelines	(Sudin, Ahmed-Kristensen and Andreasen, 2010)
	Processes	Work process	(Pa and Zin, 2011)
	Expected solutions	The designers' expected solution	(Chakrabarti, Morgenstern and Knaab, 2004; Sudin, Ahmed-Kristensen and Andreasen, 2010)
		The emergent designs	(Chakrabarti, Morgenstern and Knaab, 2004)

	Intermediate designs	Prototypes	(Bailetti and Litva, 1995)
		Simulation of end-user/product interface	(Bailetti and Litva, 1995)
		Platform simulator	(Bailetti and Litva, 1995)
	Existing products	Previous and current products	(Bailetti and Litva, 1995; Loucopoulos and Karakostas, 1995; Pohl, 2010; Sudin, Ahmed-Kristensen and Andreasen, 2010; Shuhud, Richter and Ahmad, 2013)
		Similar products in other domains	(Loucopoulos and Karakostas, 1995)
		Competitors' products	(Wootton, Copper and Bruce, 1997; Pohl, 2010)
	Market analysis	Market analysis report	(Romer, Weißhahn and Hacker, 2001; Agouridas *et al.*, 2006; Sudin, Ahmed-Kristensen and Andreasen, 2010)
	Company policies and business plans	Corporate analysis	(Agouridas *et al.*, 2006)
		Organization rules	(Pa and Zin, 2011)
		Deployment study	(Bailetti and Litva, 1995)
		Commercial specification	(Bailetti and Litva, 1995)
	Regulations and standards	Laws	(Romer, Weißhahn and Hacker, 2001; Nilsson and Fagerström, 2006; Pohl, 2010)
		Regulation	(Nilsson and Fagerström, 2006)
		Standards	(Bailetti and Litva, 1995; Loucopoulos and Karakostas, 1995; Sommerville and Sawyer, 1997; Pohl, 2010)
	Other documents	Technical manuals	(Sommerville and Sawyer, 1997; Wootton, Copper and Bruce, 1997)
		Trade journals	(Wootton, Copper and Bruce, 1997)
		Literatures	(Loucopoulos and Karakostas, 1995)
		Incident reports	(Sommerville and Sawyer, 1997)
Human	Project team	Designers	(Lin, Fox and Bilgic, 1996; Chen and Zeng, 2006; Nilsson and Fagerström, 2006; Sudin, Ahmed-Kristensen and Andreasen, 2010; Brace and Cheutet, 2012)
	Experts	Domain experts	(Loucopoulos and Karakostas, 1995; Pohl, 2010)
	Purchasing	Purchasing	(Darlington, 2002)
	Suppliers	Suppliers	(Wootton, Copper and Bruce, 1997; Darlington, 2002; Nilsson and Fagerström, 2006)

	Manufacturing	Manufacturing/managers and workers, supporters	(Gershenson and Stauffer, 1999; Romer, Weißhahn and Hacker, 2001; Darlington, 2002; Chen and Zeng, 2006; Nilsson and Fagerström, 2006)
	Assembly	Assembly	(Nilsson and Fagerström, 2006)
	Marketing	Marketing people	(Gershenson and Stauffer, 1999; Romer, Weißhahn and Hacker, 2001; Darlington, 2002; Chen and Zeng, 2006; Nilsson and Fagerström, 2006; Brace and Cheutet, 2012)
	Sales	Sales team	(Romer, Weißhahn and Hacker, 2001; Darlington, 2002; Chen and Zeng, 2006; Nilsson and Fagerström, 2006)
	Deliverers	Transportation/deliverer	(Chen and Zeng, 2006)
	User	Users	(Wootton, Copper and Bruce, 1997; Gershenson and Stauffer, 1999; Darlington, 2002; Chen and Zeng, 2006; Nilsson and Fagerström, 2006; Pohl, 2010; Sudin, Ahmed-Kristensen and Andreasen, 2010)
		Client/customers	(Lin, Fox and Bilgic, 1996; Wootton, Copper and Bruce, 1997; Romer, Weißhahn and Hacker, 2001; Darlington, 2002; Nilsson and Fagerström, 2006; Pohl, 2010; Sudin, Ahmed-Kristensen and Andreasen, 2010; Pa and Zin, 2011; Brace and Cheutet, 2012)
		Subcontractors	(Darlington, 2002)
	Service	Service	(Gershenson and Stauffer, 1999; Darlington, 2002)
	Maintenance	Maintenance/worker	(Chen and Zeng, 2006)
	Recycle	Recycle/worker	(Chen and Zeng, 2006)
	Finance	Finance	(Gershenson and Stauffer, 1999; Darlington, 2002)
	Management	Management team	(Nilsson and Fagerström, 2006)
	Governments	Governments	(Nilsson and Fagerström, 2006)
	Other groups	Government agencies, private groups	(Gershenson and Stauffer, 1999)
		Communities	(Nilsson and Fagerström, 2006)

A variety of methods and tools have been proposed to support the information elicitation from different sources, e.g., portfolio management for eliciting requirements from companies' existing products (Cooper, Edgett and Kleinschmidt, 2001), interviews, focus groups, surveys observations and ethnographic studies for eliciting requirements from users (Wood and Otto,

2000; Dieter and Schmidt, 2007; Ulrich and Eppinger, 2011), and benchmarking for eliciting requirements from competitors' products (Kumar, Antony and Dhakar, 2006). Selecting the suitable methods should consider a number of factors, e.g., time, economy, expertise needed, and the quality of the collected information (Haubroe, 2015).

The distinctions and relationship between perspectives and sources

Some studies distinguished viewpoints from concerns. Jacobson and Ng (2004) defined concerns as reflections of requirements and priorities of stakeholders in the system. Viewpoints, which represent different system perspectives, may be of different types but cross-cutting concerns (e.g., regulation, dependability, and security), while concerns generate requirements that may impact on all of the system viewpoints (Sommerville, 2011) (see Figure 2-5).

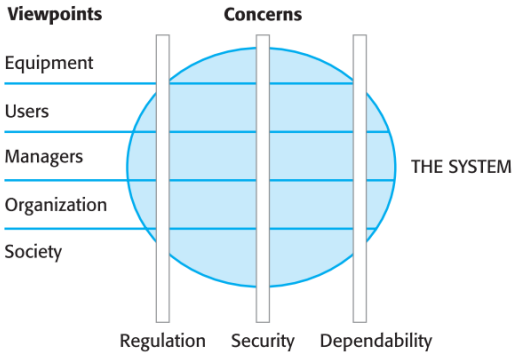

Figure 2-5 Viewpoints and concerns (Sommerville, 2011).

However, there is still confusion over perspectives and sources in current literature on design requirements. Some studies indicate that the design requirements from a perspective are gathered from certain sources. For example, Gershenson and Stauffer (1999)'s categorisation of design requirements reflects four perspectives in requirement identification: an end-user,

corporate, regulatory and technical perspectives. These scholars stated that these four types were defined based upon the sources from which requirements come, i.e., the end-users, the producer itself, society, and mother nature. However, there is not a consistent one-to-one match between perspectives and sources. In fact, a source can contribute information for multiple perspectives in the design requirement identification; meanwhile the requirements from one perspective can be collected from multiple sources. For example, the design requirements from users' perspective can be gathered directly from the users or through the feedback collected by the distributors. A distributor can also contribute to design requirements from a regulatory perspective because they are normally familiar with the local regulatory environments (as illustrated in Figure 2-6).

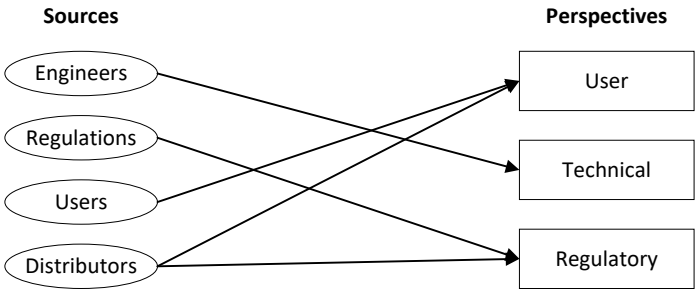

Figure 2-6 One example of the relationship between perspectives and sources in requirement identification.

2.3.5 Challenges in identifying and managing design requirements

Identifying and managing design requirements is a time-consuming and error-prone process (Jiao and Chen, 2006). Current studies have discovered a number of challenges that companies are facing during this process. The commonly discussed challenges in identifying and managing design requirements are primarily related to three topics.

First is achieving alignment in design requirements. Different stakeholders have their own unique requirements about the designed product, and these requirements are frequently conflicting. For example, the requirements from different users can differ and conflict with each other because users are heterogeneous and vary in personality, value, and a range of other characteristics (Wang and Tseng, 2014). Therefore, it is challenging to align the objectives of various stakeholders with the underlying operational arrangement when moving from ideation to commercialization (Solaimani, Guldemond and Bouwman, 2013), and to transfer these objectives in design requirements.

Second is the communication in the process of eliciting requirements. The stakeholders' knowledge about the product is not only explicit but also often tacit. Pa and Zin (2011) argued that the communication in the process of identifying design requirements was challenging as this process included cognitive aspect, personalities, techniques and tools. It is problematic to get the relevant stakeholders on board (Shuhud, Richter and Ahmad, 2013). The stakeholders can have difficulty in understanding their own requirements or they cannot explain what they do in a task with an explicit statement of requirements (Sutton, 2000; Coughlan and Macredie, 2002). This will lead to challenges such as the interpretation of imprecise stakeholder information (Nilsson and Fagerström, 2006) and the neglect of the requirements from potential users (Hull, Jackson and Dick, 2011).

Third is dealing with the changes to design requirements. These changes are challenging to manage because a change can have many undesirable side effects, can generate impact on cost, time to market, etc. (Sudin, 2012) and can initiate a series of other changes (also referred as change propagation (Clarkson, Simons and Eckert, 2004)). Katina, Keating and Jaradat (2012) argued that a major challenge of using the traditional requirements elicitation processes was the accommodation of changes in the system, the environment, and perspectives of the situation, especially in a complex situation.

2.3.6 Identifying and managing design requirements for emerging markets

Few studies that explicitly and comprehensively address the identification and management of design requirements for emerging markets have been determined. However, a few indications can be concluded based on current literature.

Firstly, studies have demonstrated the significance of adapting the content of design requirements for emerging markets. Salmi and Sharafutdinova (2008)'s study on the Russian mobile market provided a good example of that design requirements in emerging markets are different from those in developed markets due to the distinctive cultural, social, and economic factors. Another similar example showed that in Europe, a washing machine must contend with strict environmental rules that regulate the amount of electricity and water that washers can use (Cavusgil, Knight and Riesenberger, 2008). In India, customers prefer washing machines that offer superior cleaning power at a low price. In China and Latin America, customers have low spending power, but still want to buy popular models with ample features. These distinctions require developed-market companies to design products for emerging markets from the ground up based upon a deep understanding of the specific local needs and requirements (Universe Foundation, 2013). Specific approaches are suggested such as collaborating local engineers and industrial designers, simplifying product architecture, reusing platform across products, and co-creating values with prosumers (Radjou, Prabhu and Ahuja, 2012; Radjou and Prabhu, 2015).

However, studies have also indicated that companies have not made enough effort on adapting design requirements for emerging markets. Many developed-market companies are just selling the outdated products to emerging markets or simply defeaturing their high-end products for emerging markets without accommodating local requirements (Mundim *et al.*, 2012). This strategy has been argued to be inadequate to win over emerging markets. Companies fail when

they attempt to trust their brand and products on a new market with little if any adaptions (Gilroy and Traylor, 2015). A few reasons for the low motivation of adaption were determined, e.g., the products are successful enough without adapting, or companies have no time or money to engage in such activities that do not result in immediate returns (Donaldson, 2006). There is still a need to understand the challenges that companies are facing when adapting for emerging markets and to provide support from an engineering design perspective.

Second, studies have indicated the need for adapting the process of identifying design requirements for emerging markets. The challenges that developed-market companies face in emerging markets are different from or tougher than those in their home markets. For example, Kramer and Belz (2008) argued that most users in the BoP markets are not aware of certain needs (e.g., hand-washing or taking vitamins), or they are not used to think creatively about a product feature they might desire, due to a lack of education. These users face difficulties in transferring their needs to others when personal contact and trust are lacking (Polanyi, 1966; Senker, 1993). Therefore, communicating with users and eliciting users' latent requirements can be particularly challenging in emerging markets.

In addition, Jagtap *et al.* (2014) noted that the unfamiliarity about the BoP markets affects designers' behaviours of dealing with design requirements. Their findings showed that the BoP designers spent more time in dealing with requirements, while the ToP designers spent more time in dealing with solutions. The BoP designers handled the solution-neutral requirements throughout the design process with an emphasis in the early phases, while the ToP designers handled these requirements in the beginning of the process. In addition, the BoP designers placed more importance on design requirements regarding materials, energy/power, cost, etc., because of their impression about the BoP people having more survival needs. Therefore, the unfamiliarity should be taken into account in the process of identifying of managing design requirement for emerging markets.

However, few studies were determined to explicitly address how the external factors in emerging markets, e.g., the regulatory environments and cultures, influence the process of identifying and managing design requirements. Haubroe (2015) argued that when applying the methods in emerging markets , companies should consider the influence of cultural factors and infrastructural factors (because they are largely distinctive between developed markets and emerging markets) and the direct involvement of users (because it can be difficult and costly for developed-market companies to access users in emerging markets). Therefore, further studies are needed to understand the influence of the context of emerging markets on the process of identifying and managing design requirements and to support this process.

2.4 Conclusions

This chapter presents relevant literature about product development for emerging markets and the identification and management of design requirements.

Three commonly used product development models and how design requirements are identified in each model were discussed. It is noted that product development models should be adapted to the specific situations when companies apply them. The suitability of the conventional product development models and their adaption in the context of emerging markets has not been thoroughly investigated.

In addition, this chapter explores how the different characteristics of emerging markets affect product development and summarises current studies on product development for emerging markets. It determines that the practice of product development is different between developed-market and emerging-market companies, and indicates that developed-market companies should adapt their products and approaches when developing for emerging markets. There is a need for a deep understanding of product development for emerging markets, especially an

understanding of how to support companies in designing products for emerging markets and how the practice of developing for emerging markets is in SMEs.

Furthermore, this chapter presents relevant literature on the identification and management of design requirements. The co-evolution of design requirements and product development processes has been increasingly recognised. The external causes of changes to design requirements, e.g., regulatory environments and competitive landscape, and how the changes are addressed during the product development process should be further investigated in the context of emerging markets. The significance of considering multiple perspectives in requirement identification is demonstrated. However, current studies have focused on the user perspective while other perspectives received limited attention; existing research on the multi-perspective approaches in requirement identification has limitations. Further studies that provide a comprehensive overview of different perspectives, and support the requirement identification from multiple perspectives and the selection of appropriate information sources are needed, especially in the context of emerging markets. The review also demonstrates the need to adapt both the content of design requirements and the process of identifying and managing design requirements for emerging markets. Consequently, further studies, with a focus on the challenges that developed-market companies face during this process and the influence of external factors on this process, are required to support the adaption.

Chapter 3. Study One: The Practice and Challenges of Identifying and Managing Design Requirements for Emerging Markets

Study One aims to understand the process of identifying and managing design requirements for emerging markets and to identify the gaps in current practice and the challenges faced by developed-market companies during this process. The understanding was built up upon a comparison between how developed-market companies identify and manage requirements for home markets (i.e., developed markets) and for emerging markets.

This study has three primary objectives. First, to gain a deeper understanding of the significance of design requirements in product development for emerging markets. Second, to analyse different phases in the process of identifying and managing design requirements i the context of emerging markets. Third, to analyse different perspectives considered during the process.

This chapter describes the research methods applied in this empirical study, and presents and discusses its results[3]. The chapter is structured as follows:

- Section 3.1.1 describes the survey and four case studies conducted for this study.
- Section 3.2 present the survey results.
- Section 3.3 assesses and discusses the results with the data from the four case studies.
- Section 3.4 concludes Study One.

[3] The description of Study One presented in this chapter is adapted from Paper III, IV and VI.

3.1.1 Research methods

In Study One, a survey conducted in Danish industry was used to determine the general patterns. In addition, four case studies conducted at four Danish manufacturing companies were used to support the interpretation and analysis of the survey findings.

The developed-market context was represented by Danish industry in this study for three reasons. First, Denmark is a developed country with sufficient infrastructure and advanced innovation capacity; it fulfils the criteria of a developed market at which this project targets. Second, it is practical for the author to access the data from the Danish industry by utilising the project's established network. Third, this project, as a part of the GODSEM project (see a detailed description in Section 1.1), was initiated by the intention of improving the Danish industry. This selection has its limitations. Further studies across multiple countries should be conducted to apply the knowledge gained from this study to other developed markets beyond Denmark.

This study analysed five phases in the process of identifying and managing design requirements, which were summarised from current literature and are listed in Table 3-1. A more detailed description of the requirement identification process can be found in Section 2.3.2.

Table 3-1 Main phases in the process of identifying and managing design requirements.

Phase	Objective	References
Requirement elicitation	To systemically extract the requirement information from multiple sources.	(Jiao and Chen, 2006; Pacheco and Garcia, 2009)
Requirement analysis	To analyse the requirements for conflicts, overlaps, omissions, and inconsistencies.	(Sommerville and Pete Sawyer, 1997; Wood and Otto, 2000)
Requirement specification	To specify explicit and formal requirements with measurable details for development and evaluation.	(Ulrich and Eppinger, 2011)
Requirement validation	To validate whether requirements are consistent with stakeholders' intentions.	(Loucopoulos and Karakostas, 1995)
Requirement maintenance	To update, maintain and support the evolution of requirements.	(Kotonya and Sommerville, 1998; Sutcliffe, 2014)

The seven perspectives investigated in this study were summarised from current literature based upon their relevance to emerging markets. These perspective were clarified as follows:

- *A user perspective*: customer needs and users' expectations about the product's capabilities, experience, aesthetics, usability, etc. (Gershenson and Stauffer, 1995).
- *An organisation and business perspective*: business concerns that affect the product design, such as the strategic plans, business situations, financial status, and marketing (Gershenson and Stauffer, 1995).
- *A competition perspective*: the concerns about competition situation and competitive landscape in the target market (Tseng and Jiao, 2007).
- *A regional infrastructure perspective*: the condition of the services and facilities in the region that are necessary for the product to function, e.g., roads, electrical grids, water supply and telecommunications (Rounds and Cooper, 2002).
- *A technical perspective*: the technical aspects that a product must fulfil, e.g., technical functions, technical performance and engineering requirements (Gershenson and Stauffer, 1995).
- *A regulatory perspective*: the governmental regulations, certifications, and international and regional standards on issues such as safety/health, environment/ ecology, disposal and polity (Gershenson and Stauffer, 1995).
- *A perspective of other external stakeholders*: expectations concerning the product from external stakeholders involved in the product life cycle, excluding users but including suppliers, manufacturers, distributors, business partners etc. (Nilsson and Fagerström, 2006).

3.1.2 Survey I: Product development and design requirements for emerging markets

Survey I[4] was conducted for Study One to investigate different phases and perspectives in the process of identifying and managing design requirements in developed-market companies and how these companies understand about emerging markets.

Survey design and instrument

This survey was designed in English by two researchers in several iterations. It was first tested at a workshop with more than 20 industrial participants in Denmark. Feedback was collected at the workshop and used for improving the survey design. The revised version was then evaluated and improved together with three academic experts for clarity and unambiguity.

The survey included of following three sections:

1) Background information of the respondent and the respective company.

This section included the respondent's position, background, and experience with product development and with emerging markets as well as the respective company's name, size, and industry sector. In addition, the survey collected the company's business status in emerging markets, i.e., whether they were selling existing products to emerging markets without any changes in design, adapting products for emerging markets with some changes in design, or developing new products for emerging markets.

[4] Survey I is included in this thesis as Appendix B.

2) The process of identifying and managing design requirements for home markets.

First, the survey investigates the five main phases in this process: elicitation, analysis, specification, validation, and maintenance, in the case of developing for home markets. The participant was asked to rank the five phases with respect to how challenging they were. The ranking of each phase was coded with the value that equalled to its rank in the analysis. For example, if requirement elicitation was ranked as the second most difficult, it would be coded as 2 in the analysis.

Second, the survey investigated seven predefined perspectives: the user, organisation and business, competition, regional infrastructure, technical, regulatory, and other external stakeholder perspectives. This was measured by asking how difficult it was to identify design requirement when considering each of these perspectives. A five-point Likert scale was applied for these measurements. The scale ranged from "not at all difficult" to "extremely difficult", which was coded as 1-5 in the analysis (as presented in Table 3-2).

Table 3-2 The code scheme for how difficult it was to identify design requirements considering each perspective.

Code Option	1 Not at all difficult	2 Slightly difficult	3 Somewhat difficult	4 Very difficult	5 Extremely difficult

3) The process of identifying and managing design requirements for emerging markets.

This section investigated the same five phases and seven perspectives in the case of developing for emerging markets. They were measured in the same way as that for home market.

4) Main obstacles to product development for emerging markets.

This section investigated the main obstacles in the way of developed-market companies developing products for emerging markets. The survey asked the respondent to choose the three most serious obstacles from a predesigned list, which was established through two steps. First, a preliminary list was prepared upon literature review and; second, this preliminary list was revised based on the feedback collected at the testing workshop. Table 3-3 presents the final list. In the survey, respondents were allowed to add additional obstacles beyond the list and justify their choices in an open question.

Table 3-3 Main obstacles of product development for emerging markets.

Obstacles	Reference
Unstable political and regulatory environment	(Arnold and Quelch, 1998; UNDP, 2008; Tracey and Phillips, 2011; Dubiel and Ernst, 2012)
Difficult to reach and understand the local regulation	Workshop feedback
Poor intellectual property right protection	(Arnold and Quelch, 1998; Khanna and Palepu, 2010)
Overcome the impediments to distribute can be frustrating	(Arnold and Quelch, 1998; Khanna and Palepu, 2010)
Special constraint under the using context, e.g., a lack of supportive infrastructure and space	(UNDP, 2008; Tracey and Phillips, 2011)
The shortage of financial support	(UNDP, 2008)
High level of product diversion within or between countries	(Arnold and Quelch, 1998)
Insufficient understanding of market needs	(Arnold and Quelch, 1998; UNDP, 2008)
Possibility of watering down a premium brand	(Dubiel and Ernst, 2012)
Different business culture of deeply embedded networks and personalised exchange	(Tracey and Phillips, 2011)
Difficult to develop affordable products with sufficient features for local consumers	Workshop feedback

Sampling process

The survey was distributed among representatives of Danish industry. The sampling was performed in two steps. First, an initial list was extracted from a database of Danish companies provided by Bisnode (a professional business information provider) with 7723 Danish companies using the following three criteria:

- The company operated in Denmark (an option provided by the database),
- The company developed or manufactured products, or provided product design services to other companies (filtered by the NACE code (Eurostat, 2016)), and
- The company was making a profit (an option provided by the database).

A link to the survey was sent to these 7723 companies by an email. Two screening questions were added in the email to further narrow down the target companies, because these two criteria could not be filtered with the database:

- The company had experience in selling to emerging markets, or
- The company had an interest in selling to emerging markets.

A total of 131 respondents were collected, which provided a response rate lower than 2%. Three reasons explained the low response rate. First, only approximately 10% of the companies on the initial list passed the two screening questions, according to the export ratio in Denmark (Hennigan, 2015). Second, the email addresses generated from the database and used to contact companies were mostly general email addresses (e.g., information or customer service) and not always up to date. Third, a low response rate is expected and is often the case when the self-enumeration method was applied, i.e., where the respondent completes the questionnaire without the assistance of an interviewer (Statistics Canada, 2010).

Sample characteristics

Unfortunately, not all respondents finished the whole survey. All 131 respondents finished part 1, which requested the basic background information and the company's business status in emerging markets. 64 responses were complete with an answer to all questions and were used in the analysis. Table 3-4 presents the distribution of these 64 responses by company size.

Table 3-4 Company size of the 64 responses.

Size (number of employees)	Micro (<10)	Small (10-49)	Medium (50-249)	Large (>249)	Total
Count	15	29	10	10	64
Percent	23.4%	45.3%	15.6%	15.6%	100%

Of these 64 companies, 45 (70.3%) were conducting business in emerging markets, including 21 (46.7%) were selling existing products, 14 (31.1%) were adapting products for emerging markets and 8 (17.8%) were developing new products for emerging markets. The rest 19 companies were interested in doing business in emerging markets. This results is corroborated by similar findings from another report (Deloitte Touche Tohmatsu, 2006), which provided an extended view from the Danish industry to a broader range of companies all over the world, and specified data for each emerging market (see Table 3-5). This alignment between this report and the results from Survey I verifies the representativeness of the sample collected by Survey I.

Table 3-5 How are the products sold by emerging-market companies compared to products sold in home markets? (Adapted from Deloitte Touche Tohmatsu, 2006).

Emerging market	Very different	Somewhat different	Very similar
Indonesia	12%	41%	47%
India	16%	32%	52%
Russia	11%	43%	46%
China	14%	36%	50%

The most common backgrounds of these 64 respondents were engineering (42 respondents), management (30 respondents), and business (28 respondents) (multiple choices were allowed). The respondents' experience in product development and emerging markets are presented in Table 3-6.

Table 3-6 The experience of the 64 respondents in product development and emerging markets.

Years of experience in	None	<1 year	1-3 years	3-5 years	5-10 years	>10 years	Total
Product development	2 (3.1%)	2 (3.1%)	4 (6.3%)	10 (15.6%)	9 (14.1)	37 (57.8%)	64 (100%)
Emerging markets	8 (12.5%)	4 (6.3%)	13 (20.3%)	11 (17.2%)	14 (21.9%)	14 (21.9%)	64 (100%)

3.1.3 Case studies

Four case studies were included in this study for two primary objectives. First, to gather qualitative data about how the process of identifying and managing design requirements is structured and how this process is integrated in the product development process. Second, to gain a better understanding of how and why different sources are selected and used for gathering requirements. These data will support the interpretation and explanation of the findings of Survey I.

The four case companies were recruited from the network previously established by the GODSEM project with 77 Danish companies and seven Danish business platforms. These participants were characterised by their involvement with product development for emerging markets and interest in improving their practice for such context. The criteria for selecting case companies for Study One were based on the fulfilment of the research objectives and practicality, as well as:

- the company was a manufacturing company that operated in Denmark,
- the company had sold products to emerging markets or was in the process of planning to do so, and
- the company identified and managed design requirements during their product development process.

In order to triangulate the data, the case study evidence was collected from multiple sources: interviews, progress meetings, and document analysis.

Company background

The four Danish case companies include one large-size company and one small-size company and two micro-size companies, which provides an understanding across different size segments.

Company A is a medical device producer. It was founded in 2001 and now has over 500 employees including approximate 150 non-production employees. The company develops medical devices for professional users, e.g., doctors. By the time this study was conducted, their biggest sales share came from the United States and followed by China.

Company B is also a medical device producer, which was founded in 1986. By the time this study was conducted, the company had 30 employees, including about 20 non-production employees. The company has established distribution network in over 60 countries. The major emerging markets they serve are China, Russia and India.

Company C produces laboratory equipment for academic researchers. It was founded in 2012 and had eight people including full-time, part-time employees and internships. Their customers are mostly in Europe. By the time of conducting this study, Company C was expanding to China and other emerging markets.

Company D produces medical devices. It was started in 2012.It is a micro size company with three employees and three freelancers. They design health care products and sell to both healthcare organisations and private users. By the time of conducting this study, the company's first product was still under development and would be launched in 2015. This version was

mainly tested in the Danish market. Company D was planning to enter emerging markets, e.g., China.

Except Company C customising products for each customer, Company A, B and D were all selling or planning to sell existing products to emerging markets,. This is acknowledged as a limitation in the study. However all case companies did considered the requirements from emerging markets in their design. In addition, seeing that around half of developed-market companies were selling existing products to emerging markets, the investigation on these four case companies can provide an understanding of the most common scenario and are hence valuable. Therefore, these four cases were considered as adequate for the purpose of this study. Table 3-7 summarises the four case companies' business statuses in emerging markets.

Table 3-7 The four case companies' business statuses in emerging markets.

Status	Company A	Company B	Company C	Company D
Products are primarily developed for	European and US markets	European and US markets	Customised products	Nordic markets
Major target emerging markets	China, India, Russia, Latin America, Middle East	China, Russia, India	China	Preparing to extend to Asian market
Products sold in emerging markets	Existing mature products	Existing mature products	Customised products	Plan to sell existing new products

Interviews

Interviews provide in-depth first-hand information and allow follow-up questions and clarifications (Eckert and Summers, 2013). They are useful for capturing data about more than one cases that are retrospective in nature (Ahmed-Kristensen, 2001). Interviews were used as the primary method to collect data for case studies in Study One.

Interview participants were selected from those who were involved in the process of identifying and managing design requirements, e.g., product managers, project managers, or in some cases the directors, to ensure that they had enough knowledge to answers the questions. In total, eight interviewees participated in this study and nine interviews were conducted. Table 3-8 provides the list of the interviewees from each company.

The nine interviews were conducted in two rounds. The first round included seven interviews that aimed to understand the general practice of identifying and managing design requirements in each case company and their considerations about emerging markets. The first round interviews were conducted at all four companies. These interviews were semi-structured, which allowed the interviewee to expand on answers and hence gives room for clarification (Kvale and Brinkmann, 2009).

Table 3-8 An overview of the interview participants in Study One.

Company	Interviewee	Years at the company	Role in the process of identifying design requirements	Interview participated
A	Product manager	4 years	Collected and validated design requirements, particularly concerning business aspects	A1
	Project manager	11 years	Specified requirements	A2
	Technologist	12 years	Collected and validated requirements primarily from users and customers	A3, A4
	Regulatory affairs manager	7 months	Collected and validated regulatory requirements	A5
B	Managing director	6 years	Converted business strategy into requirements and approved requirements	B1
	Product manager	2 years	Collected, specified and validated requirements	B2
C	Director & Co-founder	2 years	Collected, specified and validated requirements	C1
D	Director & Co-founder	2 years	Collected, specified and validated requirements	D1

An interview guide[5] was prepared and applied in each interview with modifications. The key issues addressed in the interviews were:

- The product development process used in each case company and where in the process design requirements were identified and changed,
- The processes, sources and methods adopted for identifying and managing design requirements,
- The perspectives considered when identifying and managing design requirements, and
- The differences of requirement identification and management for developed and emerging markets and the challenges faced in emerging markets.

In addition, two second round interviews were conducted at Company A. Other companies did not participate in the second round due to the lack of relevant people available to be interviewed. The second round interviews were unstructured (also known as open-ended). In an unstructured interview, the interviewer acts as an informant and directs the interviewee within topics; it is good for exploring an area where the investigated themes are still unknown (Kvale and Brinkmann, 2009). The second round interviews verified and clarified the data collected from the first round and provided supplementary information. All interviews were conducted in English, audio-recorded with the permission from the interviewees and transcribed. Notes were taken during the interviews. Table 3-9 shows an overview the nine interviews.

[5] This interview guide is included in this thesis as Appendix C.

Table 3-9 An overview of the interviews conducted in Study One.

#	Type	Length	Recorded	1st round	2nd round
A1	Semi-structured	120 m	Yes	√	
A2	Semi-structured	75 m	Yes	√	
A3	Semi-structured	120 m	Yes	√	
A4	Unstructured	90 m	Yes		√ To gain supplementary understanding on requirement processes and sources
A5	Unstructured	50 m	Yes		√ To gain supplementary understanding on the regulatory requirements
B1	Semi-structured	150 m	Yes	√	
B2	Semi-structured	90 m	Yes	√	
C1	Semi-structured	90 m	Yes	√	
D1	Semi-structured	90 m	Yes	√	

Document analysis

Relevant documents were reviewed to gather extra information related to the research question(s) in addition to interviews.(Hancock and Algozzine, 2006). Compared with other sources of evidence, documentations are stable (can be reviewed repeatedly), unobtrusive (not created as a result of the case study), exact (contains exact names, references, and details of an event) and have a broad coverage (long span of time, many events, and many settings) (Yin, 2009). The documents from each company that were analysed for this study are listed in Table 3-10.

For all cases, the information from their websites, e.g., company history and facts, product catalogue, and press releases, were reviewed to understand the companies' background. Additional relevant documents, e.g., product development process descriptions and design requirement documents, were obtained from three case companies: Company A, B, and D. No documents were obtained from Company C due to confidentiality.

Table 3-10 An overview of the documents analysed for Study One.

Company	Documents
Company A	- Product development process - Requirement templates - Requirement doc for Project A1 (2 versions) - Project A1 demo - Company website
Company B	- Product development process - Requirement change doc - Requirement doc for Project B1 (6 versions) - Requirement doc for Project B2 - Company website
Company C	- Company website
Company D	- Requirement doc for Project D1 - Product catalogue - Company website

Progress meetings

In addition to the interviews and document analysis, two progress meetings (presented in Table 3-11) were held at two case companies, i.e., Company A and B. At the progress meetings, the author presented the data collected from their company and discussed the data with the meeting participants. The progress meetings verify the data and provide supplementary information to support the understanding.

Table 3-11 An overview of the progress meetings conducted for Study One.

Company	Participants	Language	Length(min)	Recorded
Company A	Product manager	English	90	Yes
Company B	Managing director and product manager	English	60	Yes

3.2 Results of Survey I

3.2.1 The significance of design requirements in product development for emerging markets

Survey I explored challenges in product development for emerging markets and analysed how they are related to design requirements. Respondents were asked to select the three most difficult obstacles to product development for emerging markets from a predefined list (see Table 3-3 in Section 3.1.2). Table 3-12 presents the five obstacles that were selected most frequently by the respondents.

Table 3-12 Five main obstacles faced by Danish companies when developing for emerging markets (n=64).

Obstacles	Counts	%	Relevance to design requirements
Difficult to reach and understand the local regulation and to get local approvals	28	43.8%	A lack of understand of regulatory requirements
Different business culture of deeply embedded networks and personalised exchange	27	42.2%	Difficulty in communication when eliciting design requirements from local stakeholders
Insufficient understanding of market needs	22	34.3%	A lack of understand of design requirements, particularly user requirements
Unstable political and regulatory environment	22	34.3%	Difficult to handle the change in regulatory requirements
The shortage of financial support	21	32.8%	Limited resource can be used for identifying design requirements

These main obstacles to product development for emerging markets are highly relevant to design requirements. It reveals that developed-market companies generally lack sufficient understanding about the local requirements and needs, particularly about the requirements from the regulatory and user perspectives, due to the inherent differences of users and regulatory environments between emerging and developed markets. This lack of understanding can lead to misinterpretation and missing information in requirement identification; and is

likely to result in inappropriate products to the markets. This result testifies to the importance of making effort to understand the design requirements for emerging markets.

In addition, the result demonstrates specific challenges for developed-market companies to identify and manage design requirements for emerging markets. For example, the differences in business cultures can hinder the communication with and requirement gathering from the local stakeholders. The shortage of finance and other support restricts the resources, e.g., budgets and expertise, spent on identifying design requirements. In fact, in the survey, 40 respondents (62.5%) reported that it was more challenging to identify design requirements for emerging markets; 16 (25.0%) stood neutral; and only 8 (12.5%) disagreed with this statement. This result testifies to that developed-market companies are facing more and unique challenges in requirement identification for emerging markets. These challenges are related with external factors, e.g., culture, regulatory environments, and users in the markets.

3.2.2 Phases in the process of identifying and managing design requirements

To understand the process of identifying and managing design requirements for emerging markets in greater detail, Survey I investigated five phases in this process: requirement elicitation, analysis, specification, validation and maintenance. These five phases were compared in terms of how challenging they were in the context of home markets (i.e., the Danish market or other developed markets) and emerging markets. Respondents were asked to rank the five phases according to their difficulty with respect to home and emerging markets.

The ranking among these five phases were significantly different for both home markets [χ^2 (4)=57.338, p=.000] and emerging markets [χ^2 (4)=23.350, p=.000] (tested by Friedman's tests[6]).

Each phase's rank was compared between home and emerging markets (tested by a Wilcoxon signed-rank test[7]). The results are presented in Table 3-13. The mean rank of requirement analysis phase was significantly higher in emerging markets than in home markets, indicating that analysing design requirements was less difficult in emerging markets relative to other phases. In contrast, the mean value of requirement maintenance was significantly lower in emerging markets than home markets, which indicates that maintaining design requirements was viewed as much more difficult in emerging markets relative to other phases.

Table 3-13 Comparing fives phases for identifying and managing design requirements (n=63).

Phase	Home markets			Emerging markets			Differences between the home and emerging markets	
	M	Mdn	SD	M	Mdn	SD	z	p (2-tailed)
Eicitation	2.49	2	1.435	2.30	2	1.433	-.403	.687
Analysis	2.14	2	1.189	2.62	2.5	1.250	-2.577	.010*
Specification	3.19	3	1.216	3.57	4	1.228	-1.417	.157
Validation	3.16	3	1.208	3.10	3	1.329	-.489	.625
Maintenance	4.06	5	1.243	3.41	4	1.455	-2.641	.008**

* p < .05, **p < .01, ***p < .001

3.2.3 Identifying design requirements from multiple perspectives

To understand seven perspectives (i.e., the user, organisation and business perspective, competition, regional infrastructure, technical perspective, regulatory, and other external stakeholder perspectives) in identifying design requirements for emerging markets, Survey I

[6] Friedman's test is a non-parametric test that compares several conditions when the same participants take part in each condition (Field, 2014). Non-parametric tests were used here because the ranking data are not normal distributed.

[7] Wilcoxon signed-rank test compares sets of scores that come from the same participant. It is the non-parametric equivalent of the paired-samples *t*-test (Field, 2014).

measured the difficulty of defining design requirements considering each of these perspectives for home and emerging markets.

Paired sample *t*-tests[8] were conducted to compare the differences between the two contexts (i.e., home and emerging markets). Table 3-14 displays the descriptive statistics of each context, the compared means and the p values.

Table 3-14 Comparing the difficulties of identifying design requirements considering the seven perspectives in for both home and emerging markets (n=62).

Perspective	Home markets		Emerging markets		Compared means	SD	p (2-tailed)
	M	SD	M	SD			
User	2.35	.907	2.89	1.073	-.53	1.18	.001**
Organisation and business	2.06	.885	2.44	.917	-.37	1.18	.016*
Competition	2.53	.970	2.85	.956	-.32	1.14	.030*
Regional infrastructure	1.94	1.069	2.32	.845	-.39	1.12	.009**
Technology	2.44	.985	2.42	.915	.02	1.08	.907
Regulation	2.44	1.081	3.03	1.055	-.60	1.21	.000***
Other external stakeholders	2.15	.921	2.80	.822	-.65	1.14	.000***
Average of all perspectives	2.27	.668	2.68	.609	-.41	.77	.000***

* p < .05, **p < .01, ***p < .001

Six perspectives, i.e., the user, organisation and business, competition, regional infrastructure, regulatory, other external stakeholder perspectives, were rated as significantly more challenging for emerging markets than for home markets. No significant difference was found in technology between the two contexts. The difficulty of three perspectives, i.e., the other external stakeholder, regulatory and user perspectives, increased considerably more than other perspectives. The results confirm the challenges in requirement identification for emerging markets are highly related with the user and regulatory perspectives, which corresponds with the main obstacles to product development for emerging markets. The results also suggest the

[8] The paired-sample *t*-test compares two means that have come from the same entities (Field, 2014).

need for particular attention to the perspective of other stakeholders, which supplements the previous findings of analysing the main obstacles.

3.3 Results assessment and discussion

The survey conducted for this study demonstrated that the main obstacles to product development for emerging markets are highly relevant to design requirements. It determined that the process of identifying and managing design requirements for emerging markets is more challenging than for developed markets. These challenges are reflected in different phases and various perspectives considered in this process. This section analyses and discusses why and how developed-market companies face these specific challenges when identifying and managing design requirements for emerging markets. This extensive assessment brought in the data of four case studies.

3.3.1 Gaps in the current practice of identifying and managing design requirements for emerging markets

Data collected from the case studies indicated that it is more challenging for a developed-market company to identify and manage design requirements for emerging markets than for developed markets. Further analysis of the case studies reveals a few gaps in the current practice.

First, developed-market companies in general have limited knowledge about emerging markets, e.g., knowledge about the users and regulations in these markets. The following quotes serve as examples:

- 'The challenge is that it's so difficult to predict because you don't know or you don't have this history that you can simply extrapolate.' (Product manager, Company A)

- 'The biggest challenge for us has been of course cultural issues, understanding the market, understanding the regulations in the markets…' (Managing director, Company B)
- 'I would be a little afraid that we might run into some regulations regarding [the product] that we do not know.' (Director, Company C)

It is natural for companies to know less about foreign markets than their home markets. In particular, information about emerging markets, e.g., informal rules, social rather than legal contracts, shared use of assets dominate, and accurate knowledge about the consumer, is often absent, inadequate and incomplete (Arnold and Quelch, 1998; UNDP, 2008). However, companies' effort to identify and manage design requirements for emerging markets may be insufficient. For example, Company A had few local employees collecting requirements in emerging markets, and product managers or other relevant team members rarely travelled to emerging markets to collect requirements (Product manager and Technologist, Company A). Hence, a large amount of the requirement information is gathered through a third party, often a distributor, which also increases the risk of missing information and misunderstandings. In addition, companies often sell the same products (older versions) to emerging markets and are not prepared to adapt their approaches for emerging markets. The Technologist from Company A also noted that it was not adequate just to sell cheap versions in emerging markets, as the challenges were obviously much bigger in the emerging markets than in lower segments in developed markets. This Technologist provided an example: 'even if we have a low segment in Europe, they all have Wi-Fi and they all have power that works 24 hours and running water and all that, whereas those challenges, will be different in a different country'. This example indicates a lack of infrastructure in emerging markets; and this difference in infrastructure between developed and emerging markets should be reflected in design requirements and may have an impact on requirement identification approaches.

Second, developed-market companies are not clear about the specific differences between developed and emerging markets. Six out of the eight interviewees generally referred to these differences as cultural differences, as seen in the following quotes:

- '[The key differences between the Danish market and emerging markets are the] cultural differences, and… how things are done in the emerging markets.' (Project manager, Company A)
- '[The difficulty with emerging markets] is all the basic stuff with culture and language and all that.' (Product manager, Company A)
- 'I can sense that it is a level which can be tricky if you do not know the culture.' (Director, Company D)

These cultural differences cover a large range of aspects, including business and consumer culture (Iyer, Laplaca and Sharma, 2006). These cultural differences challenge the routine and best practice that are believed as the truth in the developed-market context. It testifies to the fact that developed-market companies do not have enough knowledge about emerging markets. Additionally, with only a vague impression about the differences between developed and emerging markets, it is not sufficiently clear to the companies what aspects they should investigate and how.

Third, the understanding of emerging markets varies among employees. Seven out of the eight interviewees reported that they faced challenges in identifying requirements for emerging markets that they did not experience in developed markets. One interviewee, the Product Manager from Company B, noted no differences between the two contexts when identifying design requirements. The given arguments was that the company competed with same competitors worldwide and the users they served required same products. However, this

argument conflicted with another comment gathered from the same company saying that competition with local competitors in the Chinese market was increasing.

These gaps indicate that when companies examine the situation in emerging markets, they may overlook or underestimate certain aspects, which confirms the need for a systematic framework to compare across developed and emerging markets, and to support the requirement identification for emerging markets.

3.3.2 Challenges in identifying and managing design requirements for emerging markets

This study analyses the challenges in identifying and managing design requirements for emerging markets from two aspects: the phases in the process and the perspectives considered during the process.

Phases in the process of identifying and managing design requirements

In Survey I, five phases in the process of identifying and managing design requirement were compared for home and emerging markets with respect to how challenging they are. The relative difficulty (how difficult the phase is relative to other phases) of requirement analysis was lower for emerging markets than for home markets, whereas the relative difficulty of the maintaining requirement was higher for emerging markets than for home markets, indicating that the influence of emerging markets on the process of identifying and managing design requirements varies across each phase. One explanation is that identifying requirements for emerging markets has a greater impact on those activities that require more interaction with the external context, e.g., communication with local stakeholders and gathering information from the local context. According to the Technologist from Company A, information gathering

was easier in home markets, as they could physically reach different stakeholders and understand culturally what they said. The Technologist noted that the challenges in information gathering and understanding influence the entire requirement identification process, because information gathering was normally the initial step in the process and dictates everything.

Identifying design requirements from multiple perspectives

Survey I indicates that identifying design requirements is more challenging for emerging markets when considering the perspectives of the organisation and business, competition, and regional infrastructure, and particularly so for users, regulations and other stakeholders. This section discusses how challenges in identifying and managing design requirements for emerging markets are related to these perspectives.

1) The user perspective.

The challenges in identifying design requirements for emerging markets from the user perspective can come from three aspects. The first aspect is the identification of users. Existing studies have discussed the identification of different stakeholders in business (Pouloudi and Whitley, 1997; Reed *et al.*, 2009) and specifically in design requirements (Pacheco and Garcia, 2008). Users are often the relatively obvious and direct stakeholders in a project. However, it can be very challenging for developed-market companies to identify target users and establish communication with them in emerging markets. For instance, Company D was familiar with users in the German market, which were both the public healthcare and private insurance, but the healthcare system in China was unknown. Identifying the right people to talk to and obtaining such information was both challenging and crucial for Company D.

The second aspect is an awareness of the differences between users in emerging markets and those in developed markets. Users in different cultural contexts can have diverse expectations about the same products. Company C provided such an example. Their customers in developed-market countries, e.g., Germany and Sweden, cared mostly about scientific results when using their laboratory equipment in studies, while the Chinese customers insisted upon a commercial end goal. Similar results were supported by Salmi and Sharafutdinova (2008). These scholars determined that the Russian users have unique requirements for mobile phones. Several socio-economic factors influence the users' preferences, e.g., low average income, concentration of money in the capital region, sharp distinctions between the poor and the rich, social structures not corresponding to income distribution, high levels of street crime, and underdeveloped fixed telephone lines.

The third aspect is the access to local users in emerging markets. The lack of information from emerging markets results in high information asymmetries between companies and users (Kramer and Belz, 2008). Moreover, due to limited resources allocated in emerging markets, many developed-market companies do not have the possibility of directly collecting requirements from local users in emerging markets. Instead, they often collect user requirements through distributors (noted in Company A, Company B and Company D). On the one hand, this approach saves lots of time and money for the company in terms of setting up their own sites in emerging markets. It also reduces language and cultural barriers in communication by involving local people in the process. On the other hand, it involves higher risks and more uncertainties as the information processed by distributors or other third parties can be biased based on their own interest and knowledge. This indirect communication with users is against current advice of involving locale users in the design process (see e.g., Mattson and Wood, 2014).

2) The regulatory perspective.

As shown by the survey, regulations are one of the most challenging issues for developed-market companies when identifying design requirements for emerging markets, though researchers have not focused on them in terms of addressing design requirements. According to Gershenson and Stauffer (1999), regulatory and technical requirements receive less attention in research for two reasons. First, they are often well-documented and easy to find for the design team. Second, they are more context-dependent compared with other perspectives. Studies on these two perspectives could be either too broad or specific and hence of lesser value.

The survey indicated the significance of addressing regulatory requirements for emerging markets. In the interview, only two out of seven first-round interviewees mentioned regulations in design requirements spontaneously. However, after the interviewer specifically asked about regulations, all interviewers agreed that the regulatory perspective in identifying design requirements was critical. The role of regulations in design requirements may have been overlooked, as regulatory requirements are of high importance for certain industries, e.g., medical devices, but can be of low concern in others. The design teams' attitude towards the perspectives is critical. Designers' failure to realise the importance of capturing requirements is one possible causes of problems in design requirements (Ward, Shefelbine and Clarkson, 2003). According to the Regulatory affairs coordinator from Company A, companies have not focused much on allocating resources to regulatory affairs and are just starting to do so.

Context-dependency is actually one of the reasons that the regulatory perspective is more challenging for developed-market companies to identify and manage design requirements for emerging markets. Companies have to make an effort to investigate the situation for each country or each region. The specific challenges in each country are different. For example, China requires special tests and verifications to approve products. The requirements should consider how the product is to be tested. The registration process takes up to two years before the products can be sold, which challenges the validity of requirements over a long period. In

other countries, e.g., Brazil, India and Indonesia, standard international certifications are accepted, so it is easier for companies to sell existing products there (Regulatory affairs coordinator, Company A). Considering the significance of regulatory requirements, the current approaches applied by many companies in emerging markets (e.g., collecting regulatory requirements through distributors and online databases) are inadequate (Regulatory affairs coordinator, Company A).

3) The perspective of other external stakeholders.

The perspective of other external stakeholders (e.g., suppliers and distributors) is not negligible, particularly when considering the underdeveloped external institutions in emerging markets. Developed-market companies in general face high level of uncertainty and risk in collaborating with supply chain partners in emerging markets, where the legal institutions, including intellectual property rights and contracts, provide little governance or protection for firms' innovation outputs (Jean, Sinkovics and Hiebaum, 2013). This gives a good example that a regulatory perspective and other external stakeholders' perspectives affect each other.

The distributors received significant attention in the interviews conducted for this study. They can have specific requirements about the product (Managing director, Company B), but more often they act as the intermediary that connects the company and many other information sources in emerging markets, e.g., users and regulations. For example, Company B collected user feedback through distributors without knowing the names of specific users in emerging markets (Product manager, Company B). This indicates that the user perspective and other external stakeholders' perspectives are interrelated, as the distributing mechanism affects the user understanding.

It is of particular importance to build and maintain a trustworthy relationship with stakeholders in emerging markets in order to collect high quality requirements. For example, in China, personal relationships and reputation are highly recommended; they affect how companies establish collaboration with business partners and hence gather requirement information from them (Director, Company D).

4) The competition perspective.

Competition is one of the major causes for changes to design requirements (Fricke *et al.*, 2000) though it has been rarely studied in relation to identifying design requirements. It is more critical to understand a competition perspective in requirement identification for emerging markets. Er (1997) identified competition as the vital ingredient to design in emerging markets. Unlike the developed-market context, which seeks quality-based competition, companies in the emerging Asian markets largely employ the price-based competition strategy (Er, 1997). For developed-market companies, competition in emerging markets is fiercer compared to that in their home markets (Sheth, 2011). However, this study presented cases in which developed-market companies attach limited attention or act passively to the local competition in emerging markets. For example, Company B realised that the competition in the Chinese market was increasing and affected their performance in the market. This action shifted focus to the Indian market, where the company observed an opportunity for growth, as a competition-oriented approach seems to contradict their innovation strategy

Benchmarking competitors' products is a common practice in requirement identification (Technologist, Company A). Often, basic user requirements are also discovered by studying competitor products during benchmarking (Dieter and Schmidt, 2007), which shows that the user perspective is connected with the competition perspective.

5) Other perspectives.

The other three perspectives: the technical, organisation and business, and regional infrastructure perspectives, are not discussed in detail in this study for two reasons. First, the technical perspective was not significantly differentiated between the two contexts and hence it was not interesting in this study, and second, the regional infrastructure perspective and the organisation and business perspective were not explicitly described in the interviews. The regional infrastructure perspective was determined to be often considered together with user perspective since it constrained the use of the product. The organisation and business perspective, e.g., concerning about company strategies and financial status, was often addressed before identifying design requirements, e.g., at the planning phase (Ulrich and Eppinger, 2011).

Sources used for gathering requirements

The case studies determined that it was not only critical to identifying design requirements from multiple perspectives, but also important to gather information from multiple sources. This is particularly true in emerging markets due to the constraint resources. For example, Company B did not have direct communication with the end users in emerging markets. User feedback were collected through distributors (Managing Director, Company B). Consequently, there are higher risks of identifying incomplete or inaccurate design requirements.

Table 3-15 presents the main sources used to gather information for identifying design requirements at each case company. These sources were used for both home and emerging markets since case companies did not differentiate their process for emerging markets.

Table 3-15 Main sources used to gather requirement information at each case company.

Company	Sources used to gather information
Company A	Management team, R&D team, sales and service, users and customers, competitors' products, manufacturers and suppliers, regulations, external experts
Company B	Management team, R&D team, sales and service, users and customers, competitors' products, suppliers, regulations, exhibitions, scientific articles
Company C	Management team and other employees, users and customers, suppliers, regulations
Company D	Management team and other employees, users and customers, external consultancies, regulations

There were a few sources that were commonly used across different case companies, e.g., management team, R&D team, users and customers, and regulations. These four common sources often contributed requirements from four common perspectives, i.e., the organisation and business, technical, user and regulatory perspectives, which reflects Gershenson and Stauffer (1995)'s taxonomy of design requirements.

The sources used for gather information for each perspective differed from case to case. Take the user perspective as an example. In Company A, requirements from the user perspective were collected through directly customer visits, sales and service's feedback, competitors' products analysis and R&D employees' brainstorm. Company B also gathered user requirements when attending exhibitions in addition to using the same sources as Company A. In Company C and D, a user requirement either directly came from the customers or was proposed internally by the team.

The choice of sources depended on a variety of factors. First, large-size and mature companies in general have access to more sources than small and young companies do. In this study, Company A and B were able to gather information from more sources than Company C and D. Second, the industry sector the company operates in affects the choice. For example, medical device companies, e.g., Company A, B and D, relied more on regulations than Company C.

Third, other personal or company cultural factors have an influence on the choice. For example, Company A held focus groups with both internal and external experts to discuss design requirements based upon their experience. For Company B, attending exhibitions was an important source to gather design requirement, where they would direct communicate with competitors. In all four cases, the sources and the methods applied to gathering information from each source were selected with an ad-hoc manner or based on personal experience and preferences, meaning no guidelines or methods were adopted to support the selection. These findings correspond with Cooper, Wootton and Bruce (1998). These results proposes the need for companies to understand their own situations and have an overview of the available resources in order to select appropriate sources to identify design requirements. Instead of only concentrating on the user perspective, an awareness of the existence of different perspectives in requirement identification is critical. For instance, a regulatory perspective may only contribute to a very limited part to the final requirements but it can be crucial dependent on the industry sector, e.g., medical devices.

This analysis also indicated that employees at the same company would not have the same level understanding of sources. For example, in Company A, the Project Manager noted the major sources for design requirements were only customers and management team without being aware of other sources. In addition, most interviewees did not know the distinctions between a perspective and a source in design requirement identification. These results indicate the need for recognising available sources. Mapping out the available internal and external sources can support companies in systematically planning the information gathering for each perspectives. For example, large companies might have plentiful internal sources as well as experience and knowledge, whereas small companies can take advantages of more external sources, such as partners and consultancies. In addition, effective methods need to be selected and applied appropriately to elicit requirement from different sources.

3.4 Conclusions

Study One analyses the process of identifying and managing design requirements for emerging markets, and identifies gaps in current practice and challenges that developed-market companies face during this process. This study includes a survey with 64 Danish responses and four case studies conducted at four Danish manufacturing companies. This study contributes to advanced knowledge about different phases of this process and various perspectives considered during this process in the context of emerging markets.

This study demonstrates that it is more challenging for a developed-market company to identify design requirements for emerging markets than for home markets. Developed-market companies in general have limited knowledge about emerging markets and often do not have a thorough understanding of the specific differences between emerging and developed markets. In addition, even though certain amount of companies start to recognise the necessity of differentiating for emerging markets, they make only a limited effort and only limited resources are allocated to investigate emerging markets.

The results indicate that the influence of emerging markets varies across different phases in the process of identifying and managing design requirements. The context of emerging markets has a stronger impact on those phases that require more interaction with the external context, e.g., communicating with and gathering information from the local stakeholders.

The results also reveal that the process of identifying and managing design requirements is more challenging for emerging markets than for developed markets particularly considering the user, regulatory and other stakeholder perspectives. These challenges include a lack of knowledge about local users' specific needs, a lack of access to local stakeholders, difficulties in understanding a variety of regulations in different markets, difficulties in dealing with the volatile regulatory environments, and difficulties in establishing a trustworthy relationship with

stakeholders with different cultural backgrounds. Moreover, the results imply that a competition perspective is critical in requirement identification for emerging markets but has received inadequate attention from companies.

This study also indicates that perspectives are interrelated with each other. For example, regulations, like the protection of IP rights, affect how companies compete in the market. Therefore, studies on identifying and managing design requirements should comprehensively cover multiple perspectives and consider the interaction between perspectives. Particularly, in the context of emerging markets, design requirements from the regulatory, competition and other stakeholders perspectives should be studied in greater detail due to limited understanding in current literature and their significance in emerging markets. Furthermore, the study indicates the importance of selecting appropriate sources for gathering requirements in emerging markets. It also suggests a need for further investigation on the relationship between perspectives and sources in the identification and management of design requirement and practical guidance to support the selection process.

Chapter 4. Study Two: A Comparison between Developed-market and Emerging-market Companies

Study Two aims to understand the differences in the process of identifying and managing design requirements between developed-market and emerging-market companies and to identify potential learnings for developed-market companies.

This study has two primary objectives. First, to investigate the co-evolution of design requirements and product development processes in the context of emerging markets by analysing at which stage(s) the design requirements are identified and changed during product development processes. Second, to analyse how the user, competition and regulatory perspectives influence the differences between developed-market and emerging-market companies.

This chapter describes the research methods applied in this empirical study, and presents and discusses its results[9]. The chapter is structured as follows:

- Section 4.1 describes the survey and four case studies conducted for this study.
- Section 4.2 presents the survey results.
- Section 4.3 assesses and discusses the results with the data from the four case studies.
- Section 4.4 summarises Study Two.

[9] The description of Study Two presented in this chapter is adapted from Paper V.

4.1 Research methods

The data for this study were collected using two methods from Danish and Chinese manufacturing industries. A survey questionnaire collected 80 responses from Danish manufacturing companies and 165 responses from Chinese manufacturing companies. It was used as the primary data to specify quantitative differences between companies in developed and emerging markets. Four case studies were performed to gather secondary data for gaining a detailed understanding and determining any possible explanations for the survey results.

This study chose Danish industry to represent the developed-market context for the same reasons as presented in Study One (Section 3.1.1). Moreover, emerging markets were represented by China in this study for two reasons. First, China is one of the most representative emerging markets. China has maintained a considerably high economic growth rate and is amongst the most popular emerging markets (Mutum, Roy, and Kipnis 2014). Second, the author was able to utilise the department's previously established network with Chinese universities and companies, which supported the data collection.

This study investigated two scenarios for companies identifying and managing design requirements in: 1) home markets (i.e., the Danish market for Danish companies and the Chinese market for Chinese companies) and, 2) foreign markets, which provides an understanding of how companies adapt for unfamiliar contexts.

4.1.1 Survey II: Identifying and changing design requirements in the product development process

Survey II[10] was conducted to gain quantitative data for comparing the process of identifying and managing design requirements between developed-market and emerging-market companies.

Survey design and instrument

Survey II was originally designed in English by the research team. The English survey was evaluated by five academic experts for clarity and unambiguity, then revised in several iterations based on the feedback. A native-speaking researcher on the research team translated the survey into Chinese using the same structure and questions to ensure comparability (Leeuw, Hox and Dillman, 2008) and to capture both commonalities and differences in and across the two cultures (Kumar, 2000). Three independent native Chinese speakers (one academic expert and two industrial experts) checked the Chinese version for clarity and unambiguity.

The survey included four sections:

1) Background information of the respondent and the respective company.

This section included the respondent's position, background, and experience with product development and with foreign markets; and the companies name, size, and industry sector. In addition, with the intention of knowing about the products that companies sold to foreign markets, the frequencies of three statuses of a company's business status in foreign markets were

[10] Survey II is included in this thesis as Appendix D.

measured. The three status are: 1) selling existing products to foreign markets without any changes in design, 2) adapting products for foreign markets with some changes in design, 3) developing new products for foreign markets. The measuring was done by a five-point Likert scale: never, rarely, sometimes, frequently and every time.

2) Product development processes used in the company.

The product development processes used by the companies were investigated with reference to the generic product development model that was developed by Ulrich and Eppinger (2011). To document the product development process that was used by the company, respondents were asked if their own processes included stages that were the same or similar to those in the model. The survey included an open-ended questions: "If your product development process involves other stages, please specify", enabled respondents to specify activities that were not included in this model.

3) Processes of identifying and managing design requirements.

This section investigated: 1) at which stage(s) of the product development process that design requirements were identified; and 2) at which stage(s) in the process changes to design requirements were permitted. The question was asked for home and foreign markets respectively.

4) An evaluation on three perspectives considered during the process of identifying and managing design requirements.

Three perspectives were analysed to understand the external reasons for the differences between developed-market and emerging-market companies. The three perspectives are:

- *A user perspective*: customer needs and users' expectations about the product's capabilities, experience, aesthetics, usability, etc. A user perspective is generally considered to be the basis for product development (Wang and Tseng, 2014). Users are important because they directly influence the identification of design requirements (Chen, Khoo, and Yan 2003).
- *A competition perspective*: the concerns about competition situation and competitive landscape in the target market. These concerns should be assessed when companies identify design requirements because of the risk of institutionalising old and non-competitive designs (Tseng and Jiao, 2007). Competition is one of the primary external reasons for requirement changes (Fricke *et al.*, 2000).
- *A regulatory perspective*: the governmental regulations, certifications, and international and regional standards on issues such as safety/health, environment/ ecology, disposal and polity. New legal requirements are among the factors that lead to changes in requirements for projects (Almefelt *et al.*, 2006). Specifically, the regulatory environment is different for developed-market and emerging markets.

These three perspectives were selected for two reasons. First, according to Study One (presented in Chapter 3), these three perspectives are considerably different between developed and emerging markets. The investigation on these three perspectives will provide an explanation for the differences between developed-market and emerging-market companies. In particular, as indicated in Study One, the competition perspective and the regulatory perspective are critical in the context of emerging market but may be underestimated in both practice and research. Second, these perspectives are among the major reasons for changes to design requirements. Such an investigation can support the understanding of changes to design requirements.

In Survey Two, these three perspectives were measured by their contribution to product development, which is defined as the amount of design requirements identified from the

perspective in the product development project. A five-point Likert scale was used for the measuring (as presented in Table 4-1). The measurement was done for home and foreign markets respectively.

Table 4-1 The code scheme for the contribution of each perspective to product development.

Code Responses	1 No contribution	2 Slight contribution	3 Moderate contribution	4 Significant contribution	5 Essential contribution

Sampling process

The survey was distributed online and used different sampling processes in Denmark (English version) and in China (Chinese version). In Denmark, the research team conducted the sampling. In China, the sampling was outsourced to a third party service agency because the contact information for Chinese companies was not available; this approach has also been adopted by other researchers (Zhou *et al*., 2013; Chen, Cheng and Urpelainen, 2015). The sampling process used for each country is described in detail in the following section.

In Denmark, the companies were recruited from multiple sources to minimise sample homogeneity (Sawang and Unsworth, 2011). The first source, Bisnode (a professional business information provider), provided a list of companies that was extracted from a database of Danish companies. From this database, companies were selected using two criteria: 1) manufacturing companies were selected by using the NACE code (category C) (European Commission, 2010) and 2) firms that exported to foreign countries (an option provided by the database). The list included 1726 companies, and 1570 companies provided a valid company email address. The second source was a list of Danish subsidiaries in 17 foreign countries (e.g., Argentina, Brazil, Chile, China, and Portugal) that was provided by the Ministry of Foreign Affairs of Denmark. From this list, the research team identified 366 additional manufacturing

companies. Among these, 239 companies provided valid email addresses for specific individuals (managers and product development related positions, e.g., product managers, were prioritised), and 127 companies provided valid general company email addresses.

The survey was submitted to all 1936 companies with an email invitation that was followed by two reminders. In total, 119 responses were collected from the two sources. A total of 46 responses were obtained from the first source, with a 2.5% response rate, and 73 responses were obtained from the second source, with a 19.9% response rate. Although the response rate for the first source was low, this was expected because the email addresses that were extracted from the database were often for general information or customer service and were less likely to generate interest in supporting academic research or reach an individual who possessed the necessary knowledge to respond to the survey. The low response rate was also expected and often occurs when the self-enumeration method is applied, i.e., a respondent completes a questionnaire without the assistance of an interviewer (Statistics Canada, 2010).

In China, the survey responses were collected by a paid sampling service that is provided by a generally acknowledged online survey platform: Sojump, which has been used by other research studies (Zhou *et al.*, 2013; Chen, Cheng and Urpelainen, 2015). This platform has a user base of more than 2.6 million voluntary users and is similar to a crowdsourcing platform, e.g., the Mechanical Turk (Kaufmann, Schulze and Veit, 2011). The study used three criteria to recruit participants from the user base. First, the participants worked in a manufacturing company (controlled by the survey platform). Second, the company was located in the Yangtze (Changjiang) River Delta in China. The Yangtze River Delta includes the Shanghai municipality, the Zhejiang province and the Jiangsu province. It was selected because it is a centre of the Chinese economy (Marton, 2000) and numerous manufacturing companies operate in the Yangtze River Delta. Third, the company exported products to foreign countries (controlled by the survey platform).

A total of 23113 surveys were submitted, and 252 responses were collected, which resulted in a 1% response rate. This response rate was low but can be explained by the following three reasons. First, the Sojump service did not screen participants for their suitability prior to submitting the survey and therefore resulted in a large percentage of unsuitable participants. Second, reminders were not sent, and third, the respondents did not receive assistance from an interviewer to complete the survey (self-enumerated) (Statistics Canada, 2010).

Validity check

The process resulted in 371 total responses from both Denmark and China that were reviewed and checked for validity. All incomplete, repeated and invalid responses were removed. Incomplete responses were those that did not complete all the compulsory questions. Repeated answers were submitted from the same IP address more than once. Invalid answers were noted when a participant responded that they did not understand the survey, responded with meaningless random letters for the optional open questions or selected the same option for all the questions. A total of 125 responses were removed from the analysis, which reduced the total valid responses to 246 (66.3%) Table 4-2 counts the deleted responses for each reason.

Table 4-2 An overview of deleted responses from China and Denmark.

	Denmark	China	Total
Total responses	119	252	371
Deleted answers	39	87	126
- Invalid answers	1	86	87
- Incomplete answers	36	1	37
- Repeated answers	2	0	2
Valid answers	80 (68%)	165 (65.5%)	245 (66.3%)

An additional validation was conducted by the research team; 25 (10%) of the 245 valid answers were randomly selected to confirm the company name, size and contact information (participants were permitted to voluntarily provide their information for future contact after

the survey). All 25 responses were valid; the company name represented an existing company, and the contact information (if provided) was valid and consistent (i.e., the company name and size matched the public information).

Sample characteristics

The final sample included 165 responses from China and 80 responses from Denmark. The sample included a wide spectrum of company sizes that ranged from micro to large. Both the number of total employees (as presented in Table 4-3) and the number of non-production employees that were not directly engaged in the production process (as presented in Table 4-4) were recorded during the survey. This information increased the equivalency between China and Denmark, because many Chinese manufacturing companies employ a large number of production employees, but Danish companies often outsource their manufacturing processes to other countries (Hansen and Ahmed-Kristensen, 2010).

Table 4-3 Distribution of companies for total number of employees.

	Size class (total number of employees)						
	<10	10-49	50-199	200-499	500-1000	>1000	Total
Number of Danish companies	6 (7.5%)	26 (32.5%)	24 (30.0%)	11 (13.8%)	3 (3.8%)	10 (12.5%)	80 (100%)
Number of Chinese companies	1 (0.6%)	3 (1.8%)	27 (16.4%)	49 (29.7%)	44 (26.7%)	41 (24.8%)	165 (100%)

Table 4-4 Distribution of companies for total number of non-production employees.

	Size class (total number of employees)						
	<10	10-49	50-199	200-499	500-1000	>1000	Total
Number of Danish companies	21 (26.3%)	30 (37.5%)	18 (22.5%)	3 (3.8%)	2 (2.5%)	6 (7.5%)	80 (100%)
Number of Chinese companies	5 (3.0%)	66 (40.0%)	50 (30.3%)	22 (13.3%)	11 (6.7%)	11 (6.7%)	165 (100%)

The differences in company size for Denmark and China were compared (tested by independent-sample *t*-tests[11]). Chinese companies were significantly larger than Danish companies in terms of both the number of total employees [M(China)=4.55, SD(China)=1.123; M(Denmark)=3.11, SD(Denmark)=1.432, *t*(243)=-8.537, and p=.000)] and the number of non-production employees [M(China)=3.01, SD(China)=1.237; M(Denmark)=2.41, SD(Denmark)=1.384, *t*(243)=-3.386, and p=.001].

The survey collected information regarding the positions held by the respondents in their company. Respondents held various positions, including business owners, top managers, mid-level managers, and employees. Respondents were involved in various functions of the company's product development activities (e.g., R&D, production, management and marketing), and their diverse backgrounds provided insights from several perspectives. The survey included a question about the respondents' experience in product development and experience with foreign markets(see Table 4-5). Compared to the Danish respondents, the Chinese respondents had significantly less experience in product development [M(China)=1.97, SD(China)=.768; M(Denmark)=2.33, SD(Denmark)=.897, t(243)=3.043, and p=.003] as well as less experience with foreign markets [M(China)=1.58, SD(China)=.742; M(Denmark)=2.18, SD(Denmark)=.952, t(243)=4.949, and p=.000].

Table 4-5 Respondents' experience in product development (tested by independent-sample *t*-tests).

Country	Experience	Years of experience in product development		
		<5 years	5-10 years	>10 years
Denmark (n=80)	In product development	23 (28.7%)	8 (10.0%)	49 (61.3%)
	With foreign markets	30 (37.5%)	6 (7.5%)	44 (55.0%)
China (n=165)	In product development	51 (30.9%)	68 (41.2%)	46 (27.9%)
	With foreign markets	95 (57.6%)	45 (27.3%)	25 (15.2%)

[11] The independent-samples *t*-test compares two experimental conditions that come from different participants (Field, 2014).

4.1.2 Case studies

Four case studies were included in Study Two to support the results of Survey II with a qualitative analysis. The four cases were conducted with four companies: two Danish companies and two Chinese companies. The criteria of selecting case companies for this study were:

- The company was a manufacturing company, which operated in Denmark/China,
- The company have applied a standard product development process, which is comparable to the generic product development process from Ulrich and Eppinger (2011), and
- The company were selling products to foreign markets.

In order to triangulate the data, the case study evidence was collected from multiple sources: previous data, interviews, and document analysis.

Company background

The two Danish case companies (Company A and B) used in Study Two also participated in Study One. The background of these two companies is presented in Section 3.1.3. The background of the two Chinese case companies, i.e., Company E and Company F, is introduced in this section.

Company E is a lighting products producer. It was founded in 2007 in Shenzhen, China. It has about 1300 employees with approximate 500 non-production employees. It is one of the leading companies that produces lighting products in China. The company has a global scope, selling its product to more than 100 countries and districts in Europe, America, Australia, Middle East, and Southeast Asia.

Company F is a consumer electronics manufacturer. The business was incorporated in 1994 and it has around 5000 employees including approximate 4000 non-production employees. Their products are primarily sold in China and other more than 20 countries, e.g., Japan and America.

Data collected from previous studies

The data used for the cases in Study Two were primarily collected from previous studies. These included:

1) All the data about Company A and B that were collected in Study One, i.e., data from interviews, progress meetings and document analysis.
2) The data about Company E that were collected during a master project (Li, 2013). This master project investigated product development processes in Danish and Chinese companies with a focus on decision-making, user involvement, and product strategy, which is highly relevant to this PhD project. Three interviews and document analysis were conducted at Company E during the master project (as listed in Table 4-6). These data were included in Study Two with permission from the company. The data cover the following key issues: 1) the company's background information, 2) the product development process implemented in the company and the design methods applied along the process and, 3) the challenges the company faced in the product development process.

Table 4-6 The data collected from previous studies of Company E used in Study Two.

Documents	Product development process Requirement doc for one project Company website					
Interviews	Interviewee	Type	Conducted	Length	Recorded	Transcribed
	Quality manager	Semi-structured	Face to face in Chinese	80m	Yes	Yes
	R&D manager			60m	Yes	Yes
	Co-founder/director			60m	No	No

Interviews

Four additional interviews were conducted at the two Chinese companies for the specific aims of Study Two. An interview guide[12] were prepared and addressed the following key issues:

- The product development process used in the company,
- At which stage(s) in the product development process design requirements were identified and changes were permitted, and
- Justified the influence of the three perspectives (i.e., the user, competition and regulatory perspectives) on the process of identifying and managing design requirements.

All interviews were conducted in Chinese based on the interviewees' preference. An overview of the four interviews is presented in Table 4-7.

[12] This interview guide was prepared in Chinese as all interviewees only speak Chinese. It is included in this thesis as Appendix E.

Table 4-7 The interviews conducted at the two Chinese case companies for Study Two.

Company	Interviewee	Years at the co.	Interview type	Length	Recorded
Company E	Co-founder and director	6	Semi-structured	45	Yes
	Marketing manager	5	Semi-structured	75	Yes
Company F	Product designer	1	Semi-structured	60	Yes
	Product manager	2	Semi-structured	45	Yes

Document analysis

In addition to the documents collected from previous studies for Company A, B and E, the company website and other public information about Company F were used in Study Two to support the analysis. Unfortunately, no documents were obtained directly from Company F due to confidentiality.

4.2 Results of Survey II

4.2.1 Comparing the identification of design requirements during the product development process for home markets

Danish companies and Chinese companies were compared to determine for home markets at which stage(s) of the product development process the design requirements were identified. The generic model from Ulrich and Eppinger (2011) was used as the reference to present the product development process in the survey. Figure 4-1 illustrates the percentage of Danish and Chinese companies that identified design requirements at each stage of the product development process (self-reported).

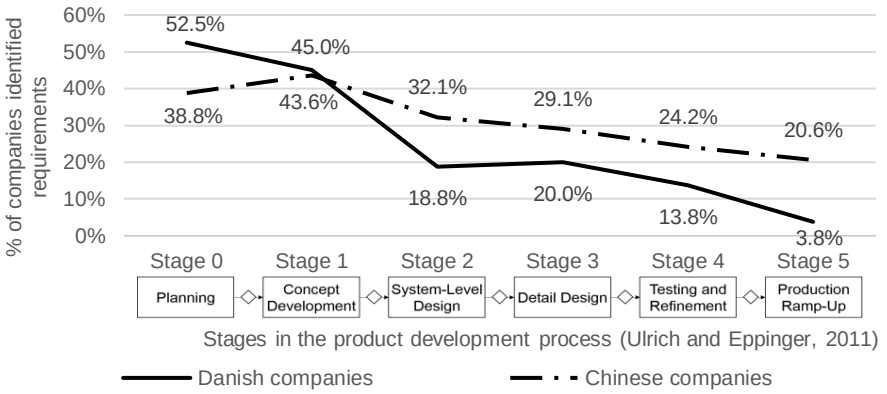

Figure 4-1 At which stage(s) did companies identify design requirements.

A large percentage of Danish companies identified design requirements during the first two stages: the planning stage (52.5%) and the concept development stage (45.0%). Fewer than 20.0% of the Danish firms reported that they identified design requirements during any of the remaining stages (i.e., system-level design, detail design, testing and refinement, and product ramp-up). The highest percentage (43.6%) of Chinese companies identified design requirements during the concept development stage, followed by 38.8% during the planning stage. Still more than 20% of Chinese firms identified design requirements during the later stages; even this was less than for the first two stages. These results indicate that on average, more Chinese companies were still identifying design requirements during later stages of the product development process, as compared to Danish companies.

The average percent for each stage between Danish and Chinese companies were compared (as reported in Table 4-8). The results demonstrate significantly more Danish companies identified design requirements during the planning stage, and significantly more Chinese companies identified design requirements during the system-level design, testing and refinement, and production ramp-up stages.

Table 4-8 The differences of identifying design requirements at each stage between Danish and Chinese companies (tested by independent-sample *t*-tests).

Stage	Danish (n=80)		Chinese (n=165)		Difference between Danish and Chinese	
	M	SD	M	SD	t (243)	p (2-tailed)
Planning	.53	.503	.39	.489	2.040	.042*
Concept development	.45	.501	.44	.497	.201	.841
System-level design	.19	.393	.32	.468	-2.343	.020*
Detail design	.20	.403	.29	.456	-1.587	.114
Testing and refinement	.14	.347	.24	.430	-2.049	.042*
Production ramp-up	.04	.191	.21	.406	-4.420	.000***

* p < .05, **p < .01, ***p < .001

4.2.2 Comparing the changes to design requirements during the product development process for home markets

A similar comparison between Danish and Chinese companies was conducted on the changes to design requirements during the product development for home markets. Respondents were asked at which stage(s) of their product development process they changed design requirements. Figure 4-2 illustrates the percentages of Danish and Chinese companies that changed design requirements at each stage in the product development process.

The largest number of Danish companies (35.0%) changed requirements during the concept development stage. The largest number of Chinese (47.9%) changed requirements during the testing and refinement stage. It appears that more Danish companies identified and addressed changes early in the product development process, whereas more Chinese companies identified changes during the later stages.

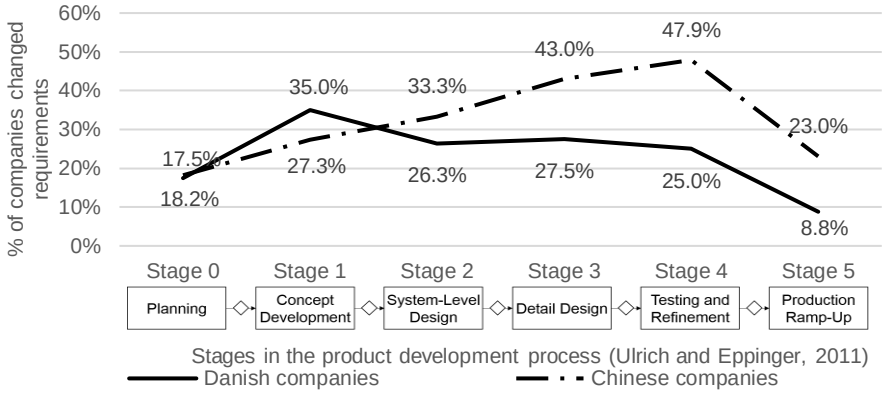

Figure 4-2 At which stage(s) did companies change design requirements?

The differences of the average percent for each stage were compared between Danish and Chinese companies (as reported in Table 4-9). The results demonstrate that significantly more Chinese companies changed design requirements during later stages of the product development process (i.e., the detail design stage, the testing and refinement stage and the product ramp-up stage) than Danish companies (as reported in Table 4-9). However, no significant difference was determined for the concept development stage.

Table 4-9 The differences of changing design requirements at each stage between Danish and Chinese companies (tested by independent-sample *t*-tests).

Stage	Danish (n=80)		Chinese (n=165)		Difference between Danish and Chinese	
	M	SD	M	SD	t (243)	p (2-tailed)
Planning	.18	.382	.18	.387	-.130	.897
Concept development	.35	.480	.27	.447	1.208	.229
System-level design	.26	.443	.33	.473	-1.148	.253
Detail design	.28	.449	.43	.497	-2.450	.015*
Testing and refinement	.25	.436	.48	.501	-3.666	.000***
Production ramp-up	.09	.284	.23	.422	-3.123	.002**

* p < .05, **p < .01, ***p < .001

4.2.3 Comparing the contribution of three perspectives to product development

In order to understand the context of the origins of companies, i.e., developed and emerging markets, and to analyse the differences between developed-market and emerging-market companies, this study analysed three perspectives considered when identifying and managing design requirements: 1) a user perspective, 2) a competition perspective, and 3) a regulatory perspective. Survey II measured the contribution of each perspective to product developments, which is defined as the amount of design requirements identified from the perspective in the product development project.

Table 4-10 presents the descriptive statistics of the three perspectives and the differences for the Danish and Chinese companies. No significant differences were observed for the user and regulatory perspectives between the Danish and Chinese companies. However, the contribution of the competition perspective was rated significantly higher in Chinese companies than in Danish companies. This difference reflects that the competition perspective in requirement identification was more useful in the Chinese companies' perception than in the Danish companies'.

Table 4-10 The differences in the contribution of three perspectives to product development between Danish and Chinese companies (tested by independent-sample *t*-tests).

Perspective	Danish		Chinese (n=165)		Difference between Danish and Chinese	
	M	SD	M	SD	t	p (2-tailed)
User	3.61 (n=80)	1.355	3.62	.836	-.071 (243)	.943
Competition	2.76 (n=78)	1.197	3.69	.867	-6.171	.000***
Regulatory	3.42 (n=78)	1.419	3.39	1.057	.161	.872

* p < .05, **p < .01, ***p < .001

One-way repeated-measures ANOVA tests[13] were conducted to test the differences between the three perspectives respectively in the Danish context and the Chinese context. For Danish companies, the Mauchly's test indicated that the sphericity could be assumed [$\chi^2(2)=5.433$, p=.066] and the contribution was significantly different among the three perspectives [F(2,129.641)=21.991, p=.000]. For Chinese companies, the Mauchly's test indicated that the assumption of sphericity had been violated [$\chi^2(2)=6.652$, p=.036], therefor Greenhouse-Geisser corrected tests are reported (ε=.962). The results also show that the contribution was significantly different among the three perspectives [F(1.923,315.389)=6.727, p=.002]. Table 4-11 reports the results of the *post hoc* tests, which demonstrates the differences in contribution for each pair of these three perspectives.

Table 4-11 The difference of each pair of the three perspectives (post hoc test for the repeated-measures AVOVA).

Comparison of the perspective	Among Danish companies (n=78)		Among Chinese companies (n=165)	
	Mean differences	p	Mean differences	p
User vs. competition	.949	.000***	-.067	1.000
User vs. regulatory	.282	.234	.230	.032*
Competition vs. regulatory	-.667	.000***	.297	.003**

* p < .05, **p < .01, ***p < .001

The results demonstrate that among Danish companies, design requirements identified from a competition perspective contributed significantly less to product development than a user or regulatory perspective. The analysis did not determine any significant difference between the user and regulatory perspectives. For Chinese companies, design requirements identified from both the user and competition perspectives contributed more than the regulatory perspective, and the analysis did not determine any significant differences between the user and competition perspectives (as illustrated in Figure 4-3). These results indicate that Chinese companies focus

[13] One-way repeated-measures ANOVA test compares several means that have come from the same entities (Field, 2014).

more on competition and users, and Danish companies focus on users and regulations when identifying design requirements.

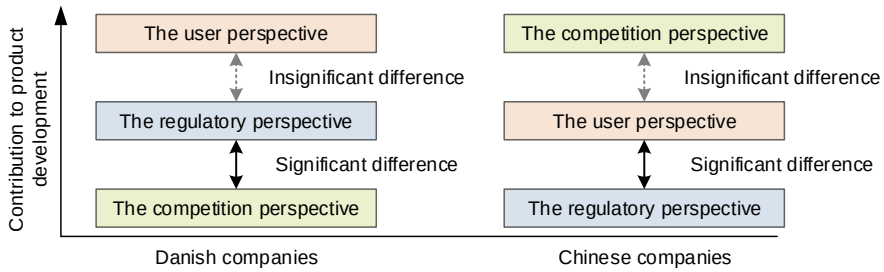

Figure 4-3 The contribution of the user, competition and regulatory perspectives.

4.2.4 Comparing the adaption for foreign market

In order to identify potential learnings of product development for emerging markets for developed-market companies from the local emerging-market companies, Study Two compared the adaption of design requirements for foreign markets between developed-market and emerging-market companies.

Adapting products for foreign markets

Companies generally utilize three strategies for developing products for foreign markets: 1) selling existing products to foreign markets without changes in design, 2) adapting products for foreign markets with changes in design, and 3) developing new products for foreign markets. The survey results determined that the Chinese companies more often adapted their products for foreign market; whereas the Danish companies more often sold existing products to foreign markets (see Table 4-12).

Table 4-12 The differences of strategies in foreign markets between Chinese and Danish companies (tested by independent-sample *t*-tests).

Strategies in foreign markets	Danish (n=80)		Chinese (n=165)		Differences between Danish and Chinese	
	M	SD	M	SD	t(243)	p(2-tailed)
Selling existing products	3.70	1.226	3.01	.950	4.819	.000***
Adapting products	2.90	1.259	3.35	.902	-2.832	.005**
Developing new products	3.01	1.297	3.28	.947	-1.636	.104

* p < .05, **p < .01, ***p < .001

Adapting the process of identifying and managing design requirements for foreign markets

To compare the adaption across home and foreign markets, the research team coded if the company identified/changed design requirements at different stage(s) when developing for foreign markets as they did for home market. The results showed that 119 Chinese companies (72.1%) identified design requirements at different stage(s) for home and foreign markets and 119 (72.1%) changed design requirements at different stage(s). Only 17 Danish companies (21.3%) identified design requirements at different stage(s) for home and foreign markets and nine Danish companies (11.3%) changed design requirements at different stage(s). The results were compared across countries and the differences were significant across the two countries (tested by one way ANOVA tests and reported in Table 4-13). It indicates that more Chinese companies adapt the process of identifying and managing of design requirements for foreign markets in comparison to Danish companies.

Table 4-13 The differences in the adaption of the process of identifying and managing design requirements for foreign markets (tested by independent-sample *t*-tests).

Adapt for foreign markets the process of	Danish (n=80)		Chinese (n=165)		Differences between Danish and Chinese	
	M	SD	M	SD	t(243)	p(2-tailed)
Identifying requirements	.21	.412	.72	.450	-8.797	.000***
Changing requirements	.11	.318	.72	.450	-12.199	.000***

* p < .05, **p < .01, ***p < .001

4.3 Results assessment and discussion

Survey II demonstrates that there were design requirements identified and changed during the later stages of the process development process in both Danish and Chinese companies. It confirms the co-evolution of design requirements and product development processes, which have been studies by several other scholars (see e.g., Dorst and Cross, 2001; Sudin and Ahmed-Kristensen, 2011). The results also demonstrate evident differences in identifying and managing design requirements for Danish and Chinese companies. It determines that these differences exist in when companies identify and change design requirements during the product development process and how companies adapt the identification and change of design requirements for foreign markets. This section brings in the secondary data of the case studies and extensively discusses why there are these differences.

4.3.1 The differences between Danish and Chinese companies for home markets

For Danish companies, most of the requirements were identified during the early stages of the product development process, (i.e., the planning stage and the concept development stage); this trend was less evident in the Chinese companies. Jagtap *et al.* (2014) analysed the design process for BoP and ToP and addressed similar issues. Their results indicated the BoP designers were

more engaged in clarifying design objectives, and the BoP designers were more information intensive. These differences suggested that the market-context (e.g., BoP and ToP) could influence the design processes. These scholars provided one explanations for this difference: the BoP designers were less familiar with the design tasks because none of them were from the BoP strata. Compared with their study, Study Two conducted the comparison in a number of manufacturing companies operating in developed and emerging markets, which provides a broader view by analysing across companies and extends the focus from designers to external perspectives, i.e., the user, competition, and regulatory perspective.

Changes to design requirements were noted for the Danish firms. Most of these changes occurred during the concept development stage and the amount of changes decreased along the process. The experiences reported by the Danish companies are similar to other studies that were conducted in a developed-market context. For example, Chakrabarti, Morgenstern and Knaab (2004) observed in a design experiment that requirements were identified primarily during the task clarification phase and increasingly less during the subsequent phases. Ahmed and Kanike (2007) determined that changes to design requirements were likely to occur during the development and prototype phase and more than likely to occur during the design phase, before changes were documented.

For Chinese companies, the majority of design requirements are identified during the early stages of the product development process. However, significantly more design requirements are identified later in the product development process for Chinese companies than for Danish companies. In addition, many Chinese companies permitted changes to design requirements at later stages of the product development process, which appears to contradict developed-market practices and models. Changes in design requirements that occur late in the product development process were noted in both Chinese cases. For Company E (Chinese), around 10% of the projects accepted late changes in the requirements (Managing Director, Company E). For

Company F (Chinese), requirements were changed for 20% of the projects and these changes were permitted during any stage of the product development process, and modifications were permitted even after the product had been delivered to the market (Product Manager, Company F).

Three explanations for these differences are provided. The first explanation relates to the organisation and the processes for identifying requirements in Chinese companies. For the two Chinese case companies (Company E and F), the information collection and requirement specification processes were separated and conducted by different teams. Information related to the requirements was first collected by an independent team (often from the marketing department) and then delivered to product managers. Then, the product manager compiled the information into design requirements for a specific project. Conversely, only one person was responsible for both the information collection and requirement specification in both Danish cases (Company A and B). The Chinese product managers who manage the design requirements may have a limited understanding of the collected data, since the information is collected by another department, i.e., the marketing department. In addition, when requirements are formulated by a variety of experts, designers have more difficulty in fully understanding the precise meaning or implications of the information (Haug, 2015). However, a short physical distance between the employees (e.g., marketing professionals, product managers, designers and engineers) can enhance communication.

For the Chinese companies, the data collected by the marketing department were used for specifying design requirements for multiple projects. Therefore, in each project, the requirement elicitation phase and the planning stage is often excluded from the product development process. This explains why significantly fewer Chinese companies identified design requirements during the planning stages.

Second, the sources that provide requirement information affect the requirement identification process. The case studies indicated that end users were typically used as a crucial source of requirements for Danish companies. For Company A (Danish), the four primary sources that were used to identify design requirements included customer visits, focus groups with professional experts, using competitors' products as a benchmark and management decisions. For Company B (Danish), the most important sources for design requirements were customers (either through direct contact or feedback through sales or distributors), internal R&D teams and regulations. In contrast, Chinese companies more often generated design requirements by benchmarking competitors' products and learning from best practices. Company E (Chinese) primarily benchmarked their design requirements against competitors' products, particularly from advanced competitors in Northern America. Company F (Chinese) combined benchmarking and sales data (e.g., sales records) and additional data from user studies to develop design requirements. In general, Chinese companies place less importance on field studies, which allows them to spend less time identifying requirements early in the process. However, companies may make changes in requirements late in the process when they are highly dependent on benchmarking and sales data, particularly in a highly competitive market such as China. For instance, requirements may be changed late in the process because a competitor launched a new product. One problem is that marketing data may be too general to provide designers with accurate information regarding a specific user's situation and experience; this may result in a design that fails to adequately target end users' needs (McGinley and Dong, 2011; Haug, 2015). Furthermore, it was noted that for Company E (Chinese), the development team informally interacted with users during the development process, and customers were invited to the testing and refinement stage to validate the end product. The involvement of users in the testing and refinement phase in Chinese companies (Li and Ahmed-Kristensen 2014) can also result in changes to design requirements late in the process.

Third, Chinese manufacturing companies in general spend more time on the later stages than the early stages of the product development process. This was noted during the analysis of the product development processes for the four case companies. The product development processes applied in each case company are illustrated in Figure 4-4 according to company documents and interviewees' descriptions. For the Chinese cases, the testing and refinement stage and production ramp-up stage actually occurred during several stages of the process (more detailed steps than for Danish companies). The designed product is tested and refined in several formal rounds (e.g., as engineering samples or in pilot production). The product development processes of the Chinese companies differed from many product development models (e.g., the stage gate system (Cooper 2008)), for which the early stages are planned in greater detail. This indicates that Chinese companies strongly focus on correcting errors, which results in changes late in the process of product development, whereas product improvement is often the motivation for changes during the earlier stages (Sudin and Ahmed-Kristensen 2011; Ahmed and Kanike 2007). Although costs increase when changes are made late in the process, late changes are also more feasible because Chinese companies own their manufacturing facilities and utilise relatively cheaper human resources.

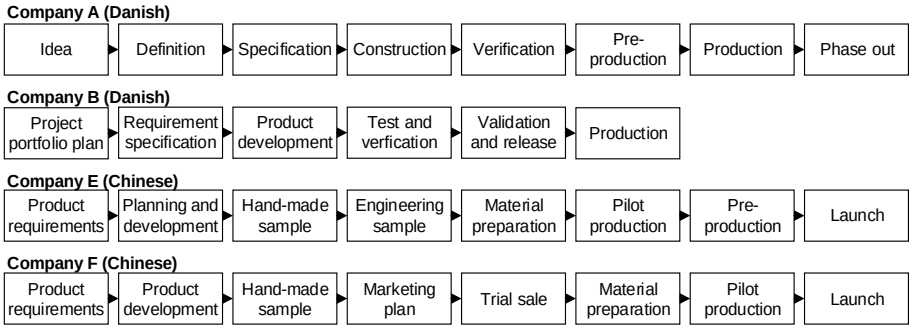

Figure 4-4 The product developed processes applied in each case company.

4.3.2 The influence of the three perspectives on the differences between developed-market companies and emerging-market companies

The survey results indicated differences in perceiving three perspectives, i.e., the user, competition and regulatory perspectives, between Danish and Chinese companies. This section discusses the influence of these differences on the identification and management of design requirements during the product development process.

Significant differences were noted for the contribution of each perspective to product development in both Danish and Chinese markets. Specifically, competition contributed the least for Danish companies but contributed the most for Chinese companies. The competition perspective was perceived significantly more valuable among Chinese companies than among Danish companies. It appears that Chinese companies focused more on competition when they identified design requirements.

This strong focus on competition among Chinese companies may be a result of inherent features of the Chinese market. The large number of competitors in the Chinese market, and particularly local unbranded competitors, result in incredibly severe market competition (Sheth, 2011). Furthermore, the majority of emerging markets have a low per capita income (Heakal, 2015; Kuepper, 2016) and are considered low-end or middle-end markets. In this study, both Danish cases (Companies A and B) targeted the high-end market; their products were specialised for a small group of users. The products of both Chinese cases (Companies E and F) targeted the middle and low-end markets. Middle and low-end markets are generally larger, particularly in China. This makes it easier for Chinese companies to meet customer needs. Conversely, the lack of significant barriers stimulates the development and production of a large number of competitive products and substitutes, which drives companies to prioritise competition during the product development process. Companies that compete in a

competitive market with mass products should carefully observe customers' reactions and make improvements to products accordingly (Fricke *et al.*, 2000).

As a consequence, competition pressures Chinese companies to respond quickly. The response time is of great importance, and speed becomes important during the product development process. Therefore, the process for identifying design requirements should be effective and conducted as quickly as possible. Unlike the developed-market context that is engaged in quality-based competition, companies in Asian emerging countries generally employ a price-based competition strategy (Er, 1997). Rather than focusing on product differentiation and adding considerable value to products, Chinese companies generally launch products that are similar to existing products with only minor modifications, which requires less time and effort spent on identifying requirements, particularly during the early stages of the product development process.

In addition, for the Chinese companies, a regulatory perspective contributed significantly less to product development than a user or competition perspective. This result indicates that Chinese companies may be less concerned about regulations and may have less problems with regulations when addressing design requirements.

Compared to developed markets, emerging markets are, in general, less regulated. Having less regulation allows companies to operate with more freedom and less control. Conversely, this type of environment may make competition more chaotic. Less effective intellectual property right protections and imitators in the markets may discourage companies from engaging in fundamental innovation, which strengthens the focus on competition among Chinese companies.

In a well-regulated market, a well-formulated product development process is often required, particularly for certain industries such as medical devices. For example, both Danish case

companies that were analysed in this study had implemented a stage-gate product development model for more than 10 years, which requires more standardised methods of identifying design requirements. In contrast, companies operating in emerging markets often believe that a formal product development process is not necessary (Donaldson, 2006). The Chinese manufacturing industry, in general, is less knowledgeable and has less experience with product development models. For example, the two Chinese companies had structured their engineering product development processes within the last five years. Company E stated that they implemented the Integrated Product Development (IPD) model with support from an external consultant. However, the internal employees from Company E did not well understand the model. This indicates that the product development process (including the process of identifying and managing design requirements) in Chinese companies is generally less standardised, which provides another explanation for the differences between the Danish and Chinese companies.

4.3.3 Adaption for foreign markets

Survey II determines that Chinese companies adapted both their products and their processes of identifying and managing design requirements for foreign markets more than Danish companies did. One example was provided by Company E and is illustrated in Figure 4-5.

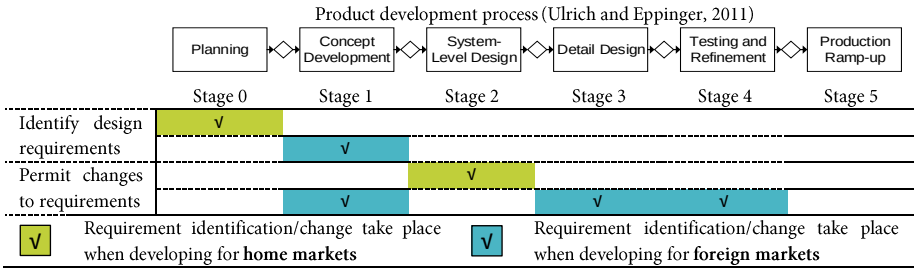

Figure 4-5 The adaption of the identification and management of design requirements for foreign markets in Company E.

In Company E, design requirements were both identified and changed later for foreign markets than for home market. The Marketing Manager explained that Company E was very familiar about its home markets and could easily access to large number of end users. They were experienced with the users and had more knowledge about the market than most of their customers. Therefore, they could identify design requirements early at the planning stage, and could recognise most problems at the concept development stage and modify the design requirements there. However, when they were developing for foreign markets, most of the requirements information was captured through their customers, which were the retailers. Normally the information could not be confirmed until the concept development stage. It was necessary to keep communicating with customers later at the stage in order to understand how the products were used in the markets, which would result in requirement changes at later stage in the process.

This result shows that when developing for foreign markets, the unfamiliarity about the context affects the process of identifying design requirements. Specifically, the unfamiliarity requires more time and effort in dealing with design requirements (Jagtap *et al.*, 2014), which in this case prompts delays in identifying design requirements and late changes to requirements.

The differences in adapting for foreign markets between developed-market and emerging-market companies demonstrate that emerging-market companies are likely to be structured and to operate in way that is more flexible to external changes. This flexibility is a potentially effective approach for contexts that are volatile, e.g., emerging markets.

4.4 Conclusions

Study Two compares the process of identifying and managing design requirements between developed-market and emerging-market companies and identifies potential learnings for

developed-market companies. It includes a survey with 80 Danish responses and 165 Chinese responses as well as case studies conducted at two Danish companies and two Chinese companies. This study contributes to advanced knowledge about the co-evolution of design requirements and product development processes in the context of emerging markets.

This study demonstrates noticeable differences in the process of identifying and managing design requirements between developed-market and the emerging-market companies. The developed-market companies identified and changed design requirements throughout the product development process with a relatively strong focus during the early stages of the process. In contrast, the emerging-market companies more often identify design requirements and permit changes to design requirements during the later stages of the product development process. A few explanations of these differences were discussed using the case studies: the processes of identifying and managing design requirements, the person or team that is responsible for design requirements, the selection of sources for gathering information, and the overall structure of product development processes. In addition, the results indicate that the differences between developed-market and emerging-market companies are consequences of companies' reactions to the distinctive competitive landscapes and regulatory environments between developed and emerging markets.

Moreover, this study determines that emerging-market companies more often adapted their products and processes of identifying and managing design requirements for foreign markets than developed-market companies do. It indicates potential learning for developed-market companies to structure their process of identifying and managing design requirements in a way that is more flexible to external changes, so they are more prepared for the fast-changing markets such as emerging markets.

This study testifies to some of the findings in Study One and supplements them with additional understanding. It demonstrates the particular importance of taking competition and regulation into account when identifying and managing design requirements for emerging markets. Study One and Two together indicate that competition in emerging markets might be underestimated in certain amount of developed-market companies, which is very risky. In addition, Study Two discussed the context of developed and emerging markets and compared current adaptions for foreign markets between developed-market and emerging-market companies, which testifies to Study One's indication of adapting the process of when identifying and managing design requirements for emerging markets. Study Two also indicates such adaptions for emerging markets should focus on understanding the competition and regulation in the markets and dealing with the unfamiliarity with these markets. The user perspective is also important in emerging markets, and it has already received much attention in both research and industry.

Chapter 5. The Development and Evaluation of the PRE toolkit

Based on the literature review and empirical studies, a design method was developed during this research project to support companies in preparing and planning the identification of design requirements for unfamiliar markets. This chapter introduces this design method as well as its development and evaluation. The chapter is structured as follows:

- Section 5.1 identifies the gaps in current methods for identifying design requirements.
- Section 5.2 describes the gaps and challenges in current practice of developed-market companies identifying design requirements for emerging markets.
- Section 5.3 describes the development of the method.
- Section 5.4 provides a step-by step introduction of the method.
- Section 5.5 presents the evaluation of the method.

5.1 Current methods for identifying design requirements

Methods and tools make a significant contribution to the process of identifying and managing design requirements (Dorfman and Thayer, 1990). Though a number of methods and tools have been developed to support the identification of design requirements, there are still gaps and limitations in current solutions. The needs for methods and tools that collects, structures and formulates design requirements in an efficient and consistent manner still exist.

Many methods focus on user issues, which can lead to incomplete design requirements (Kotonya and Sommeiville, 1996). It is important to consider multiple perspectives when identifying and managing design requirements. In the software engineering domain, several methods have been developed to support the identification and consideration of multiple perspectives in the process of identifying and managing design requirements. A well-known example is the Viewpoint-Oriented Requirements Definition method (VORD) (Kotonya and Sommerville, 1996). This method provided a model that covered from initial requirements discovery to detailed system modelling. The process prescribed by this model consisted of three iterative steps: viewpoint identification and structuring, viewpoint documentation, and viewpoint requirements analysis and specification (see Figure 5-2). This method proposed two classes of abstract viewpoints: the direct viewpoints (e.g., a system viewpoint and an operator viewpoint) and the indirect viewpoints (e.g., an engineering viewpoint, a regulatory viewpoint, an organisation viewpoint, and an environment viewpoint). This classification allowed the project team to take into account both end-user and organisational considerations.

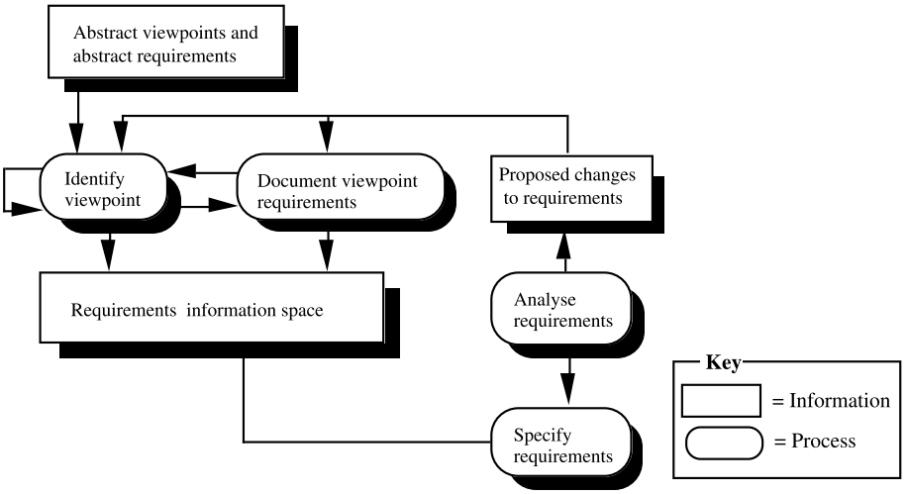

Figure 5-1 The VORD process model (Kotonya and Sommerville, 1996).

However, directly implementing such a model in a manufacturing company can be problematic. First, it is not clear how this process can be integrated into engineering product development processes and where the interfaces are. Second, the viewpoints proposed in the method are from a software engineering perspective. Their suitability for engineering products has not been evaluated. Third, this method dose not clearly distinguish viewpoints from sources. It lacks support in selecting information sources and approaches and allocating resources in identifying design requirements, which is particularly important for manufacturing companies. Therefore, a method that supports in identifying design requirements from multiple perspectives with a particular focus on manufacturing companies is still in need.

In addition, numerous methods and tools have been developed to support the elicitation and analysis of design requirements, but companies have difficulties of selecting the appropriate ones for their own practice. For example, the scenarios building method supports designers to create thought-up scenarios to simulate situation the users can experience (Hasdoğan, 1996) and is used to elicit and analyse user requirements (Haubroe, 2015). The quality function deployment (QFD) (Akao, 1990) supports the analysis of customer requirements, design attributes, trade-offs and other information focused on meeting customer needs (Gershenson and Stauffer, 1999). Being offered with so many methods, it is important for companies receiving guidance on selecting from these methods and planning the process of identifying design requirements. However, few methods have been determined to serve this purpose.

Moreover, most of the methods (including those mentioned above) were developed in a context of developed markets, which developed-market companies are relatively familiar with. However, there is a lack of support of identifying design requirements when companies are dealing with unfamiliar contexts, e.g., emerging markets.

5.2 Gaps and challenges in current practice

Based on the two empirical studies conducted during the Descriptive Study I stage (presented in Chapter 3 and Chapter 4), the author identifies the main gaps in developed-market manufacturing companies' practice and key challenges for these companies when identifying design requirements, particularly for emerging markets.

First, developed-market companies do not often adapt their process of identifying and managing design requirements for emerging markets, which is inadequate considering the inherent distinctions between developed and emerging markets. It is valuable to support developed-market companies in gaining an overview of requirement identification and planning this process, so they can consciously address these distinctions and actively adapt their approaches.

Second, companies do not often consciously consider multiple perspectives when identifying and managing design requirements. Companies are more likely to identify incomplete design requirements if any main perspectives are overlooked. It is particularly critical and challenging in emerging markets because certain perspectives (e.g., the competition and regulatory perspectives) can be considerably different from those in companies' home markets and are often underestimated. Therefore, it is important to support companies in covering the key perspectives and analysing the challenges with each perspective during the process of identifying and managing design requirements for emerging markets.

Third, companies often select the sources for gathering information in an ad-hoc manner. Even though various methods have been developed, companies rarely systematically select and apply these methods in their practice. Companies are often not aware of all available sources and the most effective methods. This is particularly challenging in emerging markets due to the lack of resources and access to certain sources. Therefore, it is valuable to support companies in

selecting the appropriate sources and methods to gather information during the process of identifying and managing design requirements for emerging markets.

5.3 The development of the support method

Based on these main gaps in current literature and practice, solutions were sought towards:

1) To enhance the quality of the identified design requirements, specifically to improve the completeness of identified requirements;
2) To improve the efficiency of the requirement identification process and the effectiveness of selecting sources and methods during this process and;
3) To support companies in identifying, analysing, and preparing solutions for the potential challenges that they will face in the requirement identification process for unfamiliar contexts.

As a result, a design method named the Perspective-oriented Requirements Excellence toolkit (hereinafter also referred to as the PRE toolkit) was developed. According to the DRM framework, the development of this design method contributes to the Prescriptive Study stage and answers Research Questions (3) (How to support an effective process of identifying design requirements for emerging markets?).

This method was developed in several iterations since continuous testing should be involved during the development of the design support so that it is developed to such an extent that is can be evaluated in the Descriptive Study II stage (Blessing and Chakrabarti, 2009). The development involved collaboration with four professionals who are also potential method users through reviewing meetings. One reviewing meeting was held with each professional (see Table 5-1).

Table 5-1 The professionals that participated in the development of the support method.

Company	Participants	Experience in product development	Reviewing process
Danish manufacturing company (Case Company A)	Technologist	More than 10 years	90 min, face to face
Danish manufacturing company (Case Company A)	Product manager	More than 10 years	60 min, face to face
Danish manufacturing company	Project manager	Three years	90 min, face to face
Chinese telecommunication company	Industrial designer (In China)	Three years	60 min, via Skype

Each review meeting was organised as an unstructured interview, where the interviewer acts as informant and directs interviewee within topics (Kvale and Brinkmann, 2009). The key issues covered in each review meeting include:

1) An introduction of the background, motivation and expected outcome of the method;
2) A description of the process of the PRE toolkit and each step in the process and;
3) Feedback of the method.

Experts were allowed to interrupt and make comments during the meeting. Hence, feedback was collected from both the simultaneous comments along the meeting and the overall discussion in the end of the meeting; the feedback was implemented in the development of the method.

5.4 The Perspective-oriented Requirements Excellence Toolkit

The Perspective-oriented Requirements Excellence toolkit is a set of tools and processes, which supports companies in preparing and planning the process of identifying design requirements. This PRE toolkit can be used for any product development projects but has the most of value when applied in projects that target at unfamiliar markets. In such these project that target at

unfamiliar markets, companies are more likely to overlook some important perspectives and have more restricted resources.

In a generic product development model (Ulrich and Eppinger, 2011), design requirements are identified early at the concept development phase. The traditional process of identifying design requirements is an iterative process consisting of activities such as requirement elicitation, analysis, specification and validation. The PRE toolkit suggests having a workshop (named as the PRE workshop) at the planning stage to prepare and plan the process of identifying design requirements before it actually starts. Figure 5-2 illustrates the PRE toolkit in relation to the product development process.

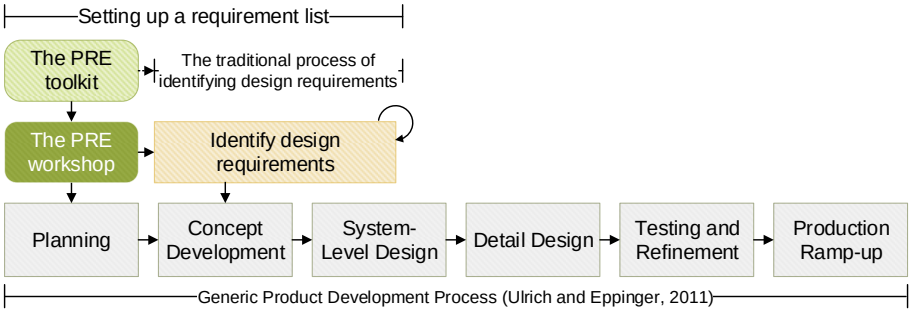

Figure 5-2 The PRE toolkit supports the preparation and plan of the process of identifying design requirements.

The PRE workshop is organised through three phases (as illustrated in Figure 5-3). Phase 0 clarifies the objectives and prepares input for discussion. Phase 1 categorises the initial design requirements and identifies additional design requirements and gaps. Phase 2 defines specific tasks for requirement identification and formulates a feasible plan.

Figure 5-3 The three phases for organising a PRE workshop.

By holding the PRE workshop, a company can expect a structured list of existing design requirements and gaps as well as an action plan to guide the requirement identification process.

5.4.1 Phase 0: Collect input

Phase 0 aims at setting up the workshop and preparing the supportive materials. To be effective, this phase is ideally prepared prior the workshop. Often a product manager or a person/team that is responsible for identifying design requirements initiates a PRE workshop. It is suggested to invite participants from different functions, e.g., management, marketing, sales, development, manufacturing and service, in order to minimise the risk of missing important insights or being biased with the information. There are three key steps during this phase:

Step 1: clarify the timeframe and resources allocated for identifying requirements in the project and the objectives for the workshop.

Step 2: specify the redefined perspectives for the project and create simple personas for each perspective. A list of general perspectives are predefined to support this step (see Table 5-2). In the PRE toolkit, *a perspective* refers to the combination of a group of 'actors' in the development process that shares similarities, and a 'view' that these actors maintain (adapted from Easterbrook *et al.*, 1994). The actors affect or are affected by the product; they include both human actors, e.g., users and distributors, and non-human actors, e.g., regulations and

technology. These general perspectives are important and should be considered in most cases when identifying design requirements. Companies should specify the meaning of these perspectives according to their own situation.

Table 5-2 The general perspectives defined for the PRE toolkit.

Perspective	Definition
User	The customer needs and users' expectations about the product's capabilities, experience, aesthetics, usability, etc.
Organisational and business	Includes such concerns as the strategic plans, business situation, financial status, and marketing that affect the product design.
Competition	The concerns about competition situation and competitive landscape in the target market.
Regional infrastructure	The condition of the services and facilities in the region that are necessary for the product to function, e.g., roads, electrical grids, water supply and telecommunications.
Technical	The technical aspects a product must fulfil, e.g., technical functions, technical performance and engineering requirements.
Regulatory	The governmental regulations, certifications, and international and regional standards about such issues as safety/health, environment/ ecology, disposal and polity.
Other external stakeholders	The expectation of the product from external stakeholders involved in the product life cycle except users, including suppliers, manufacturers, distributors, and business partners.

The PRE toolkit also suggests thinking of concrete actors and creating simple personas for each perspective in order to empathise with them. Persona is a technique that is often used by practicing designers in interaction design (Chang, Lim and Stolterman, 2008). A persona is a precise description of a user's characteristics and what he/she wants to accomplish (Cooper, 1999). In this step, it is sufficient to use the simplified personas with the essential characteristics of an actor, e.g., the occupation, gender and expectations of the product. A template name as *the Perspective Table* was developed to support the documentation of the perspectives and personas (included in this thesis as Appendix F-1).

In addition to the perspectives, when companies are developing for an unfamiliar market, the culture in the target market should be explicitly considered in comparison to the companies' home markets. Culture is a factor that differs from market to market and can influence how the

users perceive and use the product (user perspective) or what the manufacturers expect from the product (other external stakeholders' perspective).

Step 3: collect existing design requirements, including the requirements established for previous projects, generated from previous experience, etc. These existing requirements will be used as the starting point to generate new requirements.

5.4.2 Phase 1: Categorise requirements and identify gaps

Phase 1 aims at gaining an overview of existing design requirements and identifying new requirements and gaps. Three steps are suggested for this phase:

Step 1: categorise the initial design requirements to each perspective. The PRE toolkit suggests categorising the existing design requirements according to the seven predefined perspectives. By doing so, companies can gain an overview of the perspectives and the requirements under each perspective, which indicates the aspects that that might have been overlooked. The overview also supports the communication of design requirements with different stakeholders. *A Requirement Table* was developed to support the categorisation (included in this thesis as Appendix F-2).

It should be noted that a design requirement can match more than one perspectives for two reasons. First is that the requirement is too broad, which should be broken down into a few more specific requirements. Second is that the requirement is connected to multiple perspectives. For example, a requirement of safety can be a concern from both a user perspective and a regulatory perspective. In this case, the requirement can be categorised to the most relevant perspective.

Step 2: propose additional requirements, especially those that are special for the new context. The PRE toolkit suggests participants discussing the existing design requirements under each perspective and come up with additional requirements utilising the participants' diverse experience and knowledge at the PRE workshop. These additional requirements should also be documented in the Requirement Table.

A list of supporting questions is developed for each perspective to support the understanding of the perspectives and the identification of additional requirements (see Table 5-3).

Table 5-3 The supporting questions for each perspective.

Perspective	Supporting questions
User	– Who are your customers/users in the target market? How do they perceive/use your product? – Do your target customers/users in the new markets have different demands and wishes for the products compared with the customers/users in your home market? – How does the cultural differences between the target market and your home market influence your target customers/users? – How do the competitors' products in the target market influence customers' choices? – Is the infrastructure in the target market adequate to support the use of the product?
Organisational and business	– What is your strategies for the target market? – How would your strategies affect the design?
Competition	– How is the competitive landscape in the target markets? Who are the key competitors? Are there many unbranded local competitors? – How would the competition affect the design?
Regional infrastructure	– What infrastructure is needed in order for your product to function? – Is the regional infrastructure in emerging markets adequate to support the distribution and operation of your product? How would this affect the design?
Technical	– Are there any special technical requirements required due to the condition of the infrastructure and environment in the target market?
Regulatory	– Does your target market require any special regulations or standards? – Do you have access to all the relevant regulatory documents? Are the documents in the language that you can understand? – Is there any space for negotiation? If so, how do the cultural differences influence the negotiation?
Other external stakeholders	– Do you involve any new stakeholders when designing the product to the target market? – Do the external stakeholders (e.g., suppliers, manufacturers, and distributors) have special demands and wishes for the product? – How does the cultural differences influence those external stakeholders? – Is the infrastructure in the target market adequate to support the production and distribution of the product? How does it influence the stakeholders' expectations?

The PRE toolkit also suggests differentiating the design requirements between those the company is certain about and those that are based on assumptions. As McGrath and MacMillan (1995) explained in their discovery-driven planning approach, undertaking without careful up-front identification and validation of assumptions can lead to failures, especially in new and unfamiliar contexts. Therefore, it is valuable to intentionally document the assumptions including the unconscious assumptions separately to ensure that these assumptions are checked.

Step 3: identify gaps (missing information) for each perspective. The PRE toolkits suggest identifying what information is missing for each perspective based on the existing and additional requirements, and documenting these gaps in the Requirement Table. These gaps form the basis to plan the specific tasks of requirement identification.

5.4.3 Phase 2: Make an action plan

Phase 2 aims at defining the tasks of identifying design requirements and making a feasible action plan for the execution. It consists of three steps:

Step 1: cluster the requirements that need to be validated and the missing information. Clarify and define the clusters into doable tasks. *A Task Table* is provided to support the documentation of each task (included in this thesis as Appendix F-3). It should be noted that validating existing requirements and identifying new requirements are two different types of activities.

Step 2: identify the sources where you can collect information for each task. The PRE toolkit encourages the identification of multiple information sources for each task, so the company can compare these sources and prepare backup solutions for emergent situations. The identified

sources should also be documented in the Task Table. A list of commonly used sources in requirement identification is provided for inspiration (see Table 2-6 in Section 2.3.4).

Step 3: evaluate and select sources, and make a feasible plan. Companies should evaluate the sources according to their available resources and determine the appropriate sources and corresponding methods. The PRE toolkit suggests organising the tasks following the sources, so it is clearly from each source what information is needed and all relevant questions for one actor can be asked together. Companies can consider assessing the time needed to gather information from each source, prioritising the sources and assigning a responsible person for gathering information from each source. This planning supports companies in optimising the use of their restricted resources. *An Action Plan* template was developed to support the planning and is included as Appendix F-4 in this thesis.

An overview of this three-step process of organising a PRE workshop is illustrated in Figure 5-4.

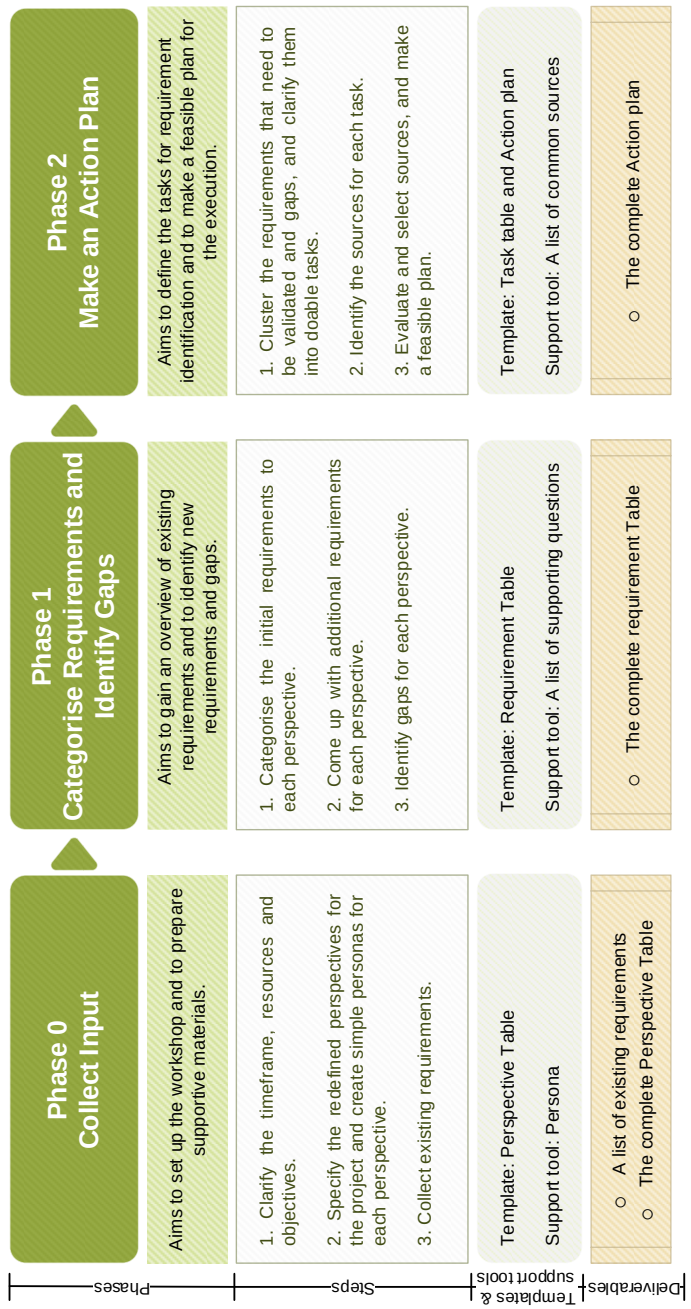

Figure 5-4 An overview of the three phases for organising a PRE workshop.

5.5 The evaluation of the support method

The impact of the proposed support method should be evaluated during the Descriptive Study II phase (Blessing and Chakrabarti, 2009). A preliminary evaluation of the PRE toolkit was conducted during the PhD project. A full evaluation in greater details is proposed for future studies. These evaluations together will answers Research Question (4) (How does the proposed method support the process of identifying design requirements for emerging markets?).

5.5.1 Research methods applied in the evaluation

The PRE toolkit was evaluated in relation to the verification for supporting in 1) improving the completeness of the identified design requirements, 2) selecting appropriate sources and methods and, 3) identifying, analysing, and preparing solutions for the potential challenges in the context of unfamiliar markets.

The methods was evaluated at a one-hour workshop with 13 industrial participants in Denmark. The evaluation was organised with three sessions during the workshop.

Session 1 (15 min): the author presented the background and motivations of developing this method, and introduces the PRE toolkit step by step with examples.

Session 2 (30 min): the participants worked on an exercise of applying the PRE toolkit. The exercise was designed based on a real case provided by a Danish manufacturing company. A description of this exercise is presented in Table 5-4. For this exercise, three groups were randomly formed with four to five participants in each group. Due to time limitation, the participants conducted only Phase 1 of the process for the PRE workshop. Phase 0 was prepared by the author prior the workshop and Phase 2 was presented by the author with example answers after the exercise.

Table 5-4 The description of the exercise used for the PRE toolkit evaluation.

Characteristic	Description
Product	An inhaler for sucking in micronized salt
Goal of the project	To redesign the inhaler for the Chinese market
Tasks defined for the excise	(Phase 1 of the process for organising a PRE workshop) Task 1: categorise the initial requirements (given) to each perspective. Task 2: come up with additional requirements for each perspective, especially those that are special for the Chinese market. Task 3: identify gaps for each perspective.
Materials provided for each group	A prototype of the inhaler (current design). Initial design requirements (provided by the company) The definition, description, examples and supporting questions for each perspective. The Requirement Table template for categorising the initial requirements, and identifying additional requirements and gaps.
Deliverables	A completed Requirement Table

Table 5-5 demonstrates a few examples of the answers produced during the exercise.

Table 5-5 The examples of answers produced during the exercise used for the PRE toolkit evaluation.

Perspective	Initial requirements (given)	Additional requirements	Identified gaps
User	It is easy to handle and no harm can be done even if it is not handled correctly.	The product should be hygienic.	The size of product (may need a compact design for the Chinese market).
Technical	When the inhaler is activated and ready for use, only three holes are exposed to the surroundings.	It should be designed to protect against higher humidity.	n/a
Regulatory	A specific justification must be provided for the patient groups of children and pregnant or nursing women.	Warnings should be added to the device.	The Chinese regulation about medical device is unknown.

Session 3 (15 min): a plenary discussion was held, where the participants shared their results of the exercise and their learnings. Potential improvements for the method were also proposed and discussed. Qualitative feedback about the PRE toolkit was collected through the discussion.

5.5.2 Results of the evaluation

The collected feedback from the evaluation workshop was structured following Kirkpatrick's methods extended by Ahmed-Kristensen (2001):

1) Reaction: this is evaluated by testing the usefulness and applicability of the PRE toolkit. The participants reported that they understood the method and were able to apply it to the exercise. In general, they thought the method was useful and applicable. Feedback for further improvement included providing a more visualised instruction in details, templates to support the framing of design requirements and gaps, and a guidance of how to integrate the PRE toolkit with existing methods, e.g., product portfolio management.
2) Learning: this is evaluated by investigating the increased understanding towards the multiple perspectives in requirement identification. The participates reported that the seven predefined perspectives supported them in gaining a better understanding about the multiple perspectives in requirement identification and recognising the perspectives that were often overlooked.
3) Results: this is evaluated by comparing the differences between requirements identified prior to and post the implementation of the PRE toolkit. By thinking through each perspective, the participants were able to identify design requirements and gaps that are often overlooked. In addition, several design solutions were generated during the exercise, which is a result of the co-evolving nature between problems and solutions (Dorst and Cross, 2001). A design experiment is proposed for future study to compare the design requirements identified with and without applying the PRE toolkit in greater details, e.g., comparing the numbers of design requirements identified.

4) Validation: this is evaluated by examining whether the PRE toolkit provides the required improvements. The participants noted that the PRE toolkit was able to facilitate the identification of additional design requirements and gaps, which supports in improving the completeness of design requirements and identifying the potential challenges companies may face in unfamiliar markets. A case study with a real product development project that targets at unfamiliar markets is proposed for future study to validate how the PRE toolkit can improve the efficiency of the requirement identification process and the effectiveness of selecting sources and methods during this process.
5) Behaviour: this is evaluated by measuring the impact of the PRE toolkit on everyday tasks. The long-term impact of this toolkit on users' behaviours was not evaluated during the workshop due to the nature of this preliminary evaluation. This is also proposed to be done in the case study.

5.6 Conclusions

A design method, i.e., the Perspective-oriented Requirements Excellence toolkit, was developed and evaluated during this research project to address the identified gaps in current literature and practice. This PRE toolkit supports companies in preparing and planning the process of identifying design requirements, particularly when companies are developing for unfamiliar markets. More detailed conclusions of the PRE toolkit are provided in Chapter 6.

Chapter 6. Conclusions

This thesis presents a research project, which aimed 1) to understand the process of identifying and managing design requirements for emerging markets with the purpose of examining the challenges and gaps in developed-market companies' current practice and, 2) to support companies in identifying design requirements for emerging markets with an efficient approach. Two empirical studies were conducted to address the first research aim and a design method was developed and evaluated to address the second research aim.

This chapter presents the main conclusions drawn from this research project, including the literature review, the empirical studies and the proposed support method. The chapter is structured as follows:

- Section 6.1 summarises this research project and highlights the key findings in relation to the research questions.
- Section 6.2 presents both the theoretical and practical contributions and implications of this research project.
- Section 6.3 discusses the limitations of this research project.
- Section 6.4 proposes potential topics for future studies.

6.1 Key findings

This research project was guided by four research questions and a number of objectives. Table 6-1 presents where in this research the objectives are addressed.

Table 6-1 Objectives and where they are addressed in this research

Research question	Objectives	Where in this research?
(1) How is the current practice of identifying and managing design requirements for emerging markets performed in developed-market companies?	1.1. To analyse phases in the process of identifying and managing design requirements for emerging markets. 1.2 To analyse perspectives considered in the process of identifying and managing design requirements for emerging markets. 1.3 To analyse co-evolution of design requirements and the product development process in the context of emerging markets.	1.1. Addressed in Study One 1.2. Addressed in Study One 1.3. Addressed in Study Two
(2) What challenges do developed-market companies face when they are identifying and managing design requirements for emerging markets and why do they face these challenges?	2.1. To identify challenges for developed-market companies during the identification and management of design requirements for emerging markets. 2.2. To analyse and explain these challenges with both internal and external factors.	2.1. Addressed in Study One 2.2. Addressed in Study One and indirectly in Study Two
(3) How to support an effective process of identifying complete design requirements for emerging markets?	3.1. To develop a method that enhances the completeness of the identified requirements. 3.2. To develop a method that improves the efficiency of requirement identification and the effectiveness of selecting sources and methods during this process. 3.3. To develop a method that supports the identification, analysis and dealing with the potential challenges in unfamiliar contexts.	3.1. - 3.3. Development of the PRE toolkit
(4) How does the proposed method support the process of identifying design requirements for emerging markets?	4.1. To evaluate how the proposed method supports in improving the completeness of design requirements. 4.2. To evaluate how the proposed method supports in improving the efficiency of requirement identification and the effectiveness of selecting sources and methods during this process. 4.3. To evaluate how the proposed method supports in identifying, analysing and dealing with the challenges in unfamiliar contexts.	4.1.-4.3. Preliminary evaluation of the PRE toolkit. Further validation is needed.

The key findings of this project provide answers to these research questions, which are summarised as follows.

Research Question (1): How is the current practice of identifying and managing design requirements for emerging markets performed in developed-market companies?

The two empirical studies conducted during this research project demonstrate that developed-market companies in general have limited knowledge about emerging markets and often do not have a thorough understanding of the specific differences between developed and emerging markets. In addition, in many cases, only limited effort has been made and limited resources have been allocated to investigate emerging markets.

The findings determine that companies do not often consciously consider multiple perspectives when identifying and managing design requirements. The regulatory and competition perspectives are sometimes overlooked or underestimated but these perspectives are particularly critical in the context of emerging markets. In addition, companies often select the sources and corresponding methods for gathering information in an ad-hoc manner. The contextual factors that should influence their choice of sources are not often thoroughly evaluated. A more thoughtful decision of selecting the appropriate sources is needed, especially when developing for emerging markets.

The findings also reveal that developed-market companies have not implemented sufficient adaptions in their products and processes of identifying and managing design requirements for emerging markets. There is a need to support these adaptions with a focus on understanding the competition and regulation in the markets and dealing with the unfamiliarity with these markets. The developed-market companies should also consider to structure their process of identifying and managing design requirements in a way that is more flexible to external changes, so they are more prepared for the dynamic and complex emerging-market context.

Research Question (2): What challenges do developed-market companies face when they are identifying and managing design requirements for emerging markets and why do they face these challenges?

The empirical studies demonstrate that for a developed-market company, identifying design requirements is more challenging for emerging markets than for home markets. The context of emerging markets has a stronger impact on those activities that require more interaction with the external context, e.g., communicating with and gathering information from the local stakeholders. More specifically, it is more challenging to identify and manage design requirements for emerging markets when considering the user, organisation and business, competition, regional infrastructure, regulatory, other external stakeholder perspectives. These challenges include a lack of knowledge about local users' specific needs, a lack of access to local stakeholders, difficulties in understanding a variety of regulations in different markets, difficulties in dealing with the volatile regulatory environments, and difficulties in establishing a trustworthy relationship with stakeholders with different cultural backgrounds.

These specific challenges in identifying and managing design requirements for emerging markets can be due to three reasons. First, the inherent differences between developed and emerging markets. For example, emerging markets are characterised by severe competition and underdeveloped regulatory environments. These characteristics increase the uncertainty in design requirements, which makes it more challenging to identify design requirements. Second, many developed-market companies are unfamiliar about emerging markets and might implicitly bring assumptions about familiar markets into the product development projects that focus on emerging markets. Third, the gaps in the developed-market companies' current practice, e.g., overlooking some perspectives, and selecting sources without a thoughtful decision, can be more problematic for emerging markets. Freezing design requirements early in the product development process, as observed in many developed-market companies, can be

inadequate in the context of emerging markets. For example, late changes to design requirements are more likely to take place when companies are developing for unfamiliar and volatile markets; these late changes challenge the convention of identifying design requirements during early stages of the product development process.

Research Question (3): How to support an effective process of identifying design requirements for emerging markets?

Based upon the literature review and the findings from the two empirical studies, the Perspective-oriented Requirements Excellence (PRE) toolkit was developed to support companies in preparing and planning the process of identifying and managing design requirements. This PRE toolkit aims to enhance the completeness of the identified design requirements; to improve the efficiency of the requirement identification process and the effectiveness of selecting sources and methods; and to prepare for the potential challenges that companies will face in the requirement identification process for unfamiliar contexts. The toolkit can be used for any project development projects but has the most value when used in the situations of developing for unfamiliar markets, e.g., when a developed-market company developing for emerging markets, because in such situations, companies are more likely to overlook some important perspectives and have more restricted resources.

The PRE toolkit consists of a set of tools and processes, which supports the organisation of a PRE workshop in the beginning of a product development project. This workshop is facilitated following a three-phase process: Phase 0 clarifies the objectives and prepares input for discussion. Phase 1 categorises the initial design requirements and identifies additional design requirements and gaps. Phase 2 defines specific tasks for requirement identification and formulates a feasible plan. The expected outcome of the PRE workshop includes a structured

list of existing requirements, additional requirements and gaps identified during the workshop as well as an action plan to guide the requirement identification.

The PRE toolkit contributes to practice by introducing: 1) a structured framework to organise design requirements, which supports the identification of gaps in the existing requirement set and the communication of design requirements between different stakeholders, 2) a systematic approach to plan the process for identifying design requirements, which improves the efficiency of utilising expertise and allocating resources.

Research Question (4): How does the proposed method support the process of identifying design requirements for emerging markets?

The PRE toolkit was evaluated at a workshop with 13 industrial participants. This evaluation demonstrates that the toolkit is useful and applicable. The predefined perspectives can support the method users in gaining a better understanding about the multiple perspectives in requirement identification and recognising the perspectives that were often overlooked. The evaluation also notes that the PRE toolkit is able to support in improving the completeness of design requirements and identifying the potential challenges companies may face in unfamiliar markets by thinking through each perspective. A few suggestions were collected during the evaluation for further improvements, e.g., providing a more visualised instruction in details, templates to support the framing of design requirements and gaps, and a guidance of how to integrate this method with existing methods.

A full evaluation of the PRE toolkit is proposed with: 1) a design experiment to compare the design requirements identified with and without applying the PRE toolkit in greater details and, 2) a case study to validate the toolkit's long-term effect on the efficiency of the requirement identification process and the impact on everyday tasks.

6.2 Contributions and implications

This project has been conducted as interdisciplinary research. The research was built upon established understandings about design requirements and emerging markets from requirement engineering, engineering design, management, etc. It contributes to the requirement engineering and the engineering design domains by advancing the general understanding of the identification and management of design requirements with a focus on the multiple perspectives and the co-evolution of design requirements and product development processes; and by extending the understanding generated in developed markets to emerging markets. It also contributes to innovation management with implications that support managers in planning and allocating resources for identifying and managing design requirements in the product development projects that target at emerging markets.

For academia, this research project demonstrates a need for increasing the attention paid to the underdeveloped, resources-restricted and volatile contexts, e.g., emerging markets. The knowledge gained by studying emerging markets can contribute to not only improving companies' performance in these markets, but also supporting companies in dealing with the new challenges they face in developed markets that are caused by the economic crisis, increased resource scarcity, etc. For example, reverse innovation and other similar studies investigate the cases of products first being developed for emerging markets and then spread to developed markets.

More specifically, this project determines a confusion between perspectives and sources in current studies on design requirements. These two terms are not often clearly differentiated. This project discusses these two terms and clarifies the differences and relationship between them. This differentiation supports researchers in studying how design requirements are identified from each source and the contribution of different sources. This project also assesses

seven perspectives and the multi-perspective approaches in requirement identification in the context of emerging markets. The findings indicate that particular attention should be paid to the user, regulatory and competition perspectives when researcher studying requirement identification for emerging markets. The results also suggest considering the interaction between different perspectives and the influence of the cultural contexts on these perspectives.

In addition, this project complements previous understanding of the co-evolution of design requirements and product development processes with a comparison between developed-market and emerging-market companies. The findings underline a few factors for the late identification and changes of design requirements in emerging-market companies: the processes of identifying and managing design requirements, the person or team that is responsible for design requirements, the selection of sources for gathering information, and the overall structure of product development processes.

Moreover, this project notes the differences in product development for emerging markets between large companies and SMEs. Compared with large companies, SMEs may face more challenges of the restricted resources and expertise. Methods and processes should be adapted to SMEs' special needs.

For industry, this research project demonstrates the main gaps in developed-market companies' current practice of identifying and managing design requirements for emerging markets and the major challenges that these companies face during the process. The project suggests developed-market companies listing the key perspectives and assessing the distinctions of these perspectives between their home markets and the target markets, when they are identifying and managing design requirements for emerging markets. Companies should also make thoughtful decisions when selecting sources for gathering information, so they can make the most use of

the restricted resources in emerging markets. It is also noted that companies need to react flexibly to the external changes in the dynamic and complex context of emerging markets.

Additionally, this project proposes that the process of identifying and managing design requirements should be well planned. This project provides practitioners a method that supports them in preparing and planning the process of identifying design requirements in a structured manner, which improves the completeness of the identified requirements and the efficiency of the requirement identification process as well as supports the analysis of unfamiliar markets.

6.3 Limitations

In the empirical studies conducted during this research project, the developed-market context was represented by Danish industry because: Denmark is a typical developed market; the previously established network to support this research is in Denmark; and the project was initiated by the intention of improving Danish industry. However, this is also acknowledged as a limitation, which limits the knowledge gained from this project to Denmark and countries that are similar to Denmark. For other developed-market contexts that are considerably different from Denmark, the knowledge should be validated or improved.

In addition, not equal amount of data were collected for each case in the case studies. It was not possible to conduct the same amount interviews at each company or obtain the same documents from each company due to practicality and confidentiality. Particularly, in Study Two, the two Danish cases and two Chinese cases vary in size, industry and age. These limitations in the collected data restrict the use of the cases to qualitative analysis. A quantitative cross-case comparison would have limited value with the collected case data.

Moreover, the evaluation of the PRE toolkit is only a preliminary version. This evaluation does not provide the direct comparative results for before and after applying this method and its long-term effect on the method users' behaviours.

6.4 Future work

Based on the understanding gained in this research project, following areas are proposed for further research:

First, further studies with similar approaches as this research project and with the focus on the identification and management of design requirements for emerging markets, should be conducted in a larger sample scale across different industries and countries. By doing so, the knowledge can be validated, generalised and improved in a broader context.

Second, the proposed design method (the PRE toolkit) needs to be systematically evaluated. A full evaluation is suggested to be conducted with a design experiment and a case study in collaboration with developed-market manufacturing companies that are running product development projects that target at emerging markets.

Third, this research project focuses on the process of identifying and managing design requirements. The implementation of design requirements and the final success of the projects in the context of emerging markets are excluded from the scope of this project. However, it is valuable for future studies to measure and analyse how the identification and management of design requirements affect the success of the designed product in emerging markets.

Forth, the multi-perspective approaches in requirement identification from an engineering design point of view should be studied in greater details. Particular attention needs to be paid on the interaction between perspectives, the less studied perspectives (e.g., the regulatory and

competition perspective), and the influence of the cultural contexts on perspectives. Moreover, the adaption of these approaches for SMEs should be considered.

Fifth, this project demonstrates that design requirements can be identified and changed at later stages of the product development process, especially in emerging-market companies. Further studies should be conducted to support companies in determining when to permit changes to design requirements or freeze design requirements in their product development processes.

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Appendix A – Six papers written during this project

Paper I: The Sources and Methods of Engineering Design Requirement

Authors: Xuemeng Li, Zhinan Zhang and Saeema Ahmed-Kristensen

Reference: Li, X., Zhang, Z., and Ahmed-Kristensen, S., 2014. The Sources and Methods of Engineering Design Requirement. *In: International Conference on Concurrent Engineering.* Beijing, China, 112–121.

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).

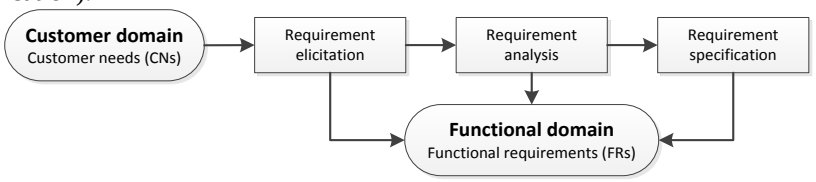

Figure 1. Customer requirement management process [5]

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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].

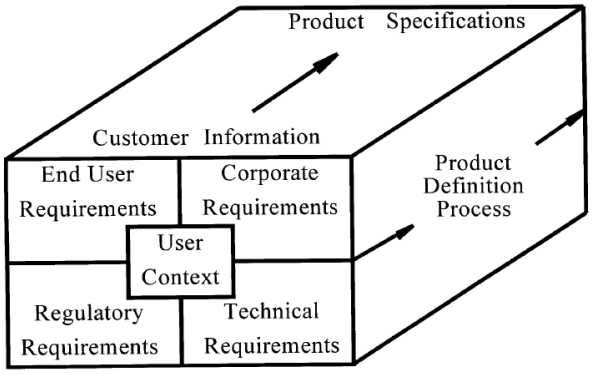

Figure 2. Requirements cube showing the various types of requirements and how the information fits into the product definition process [13]

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.

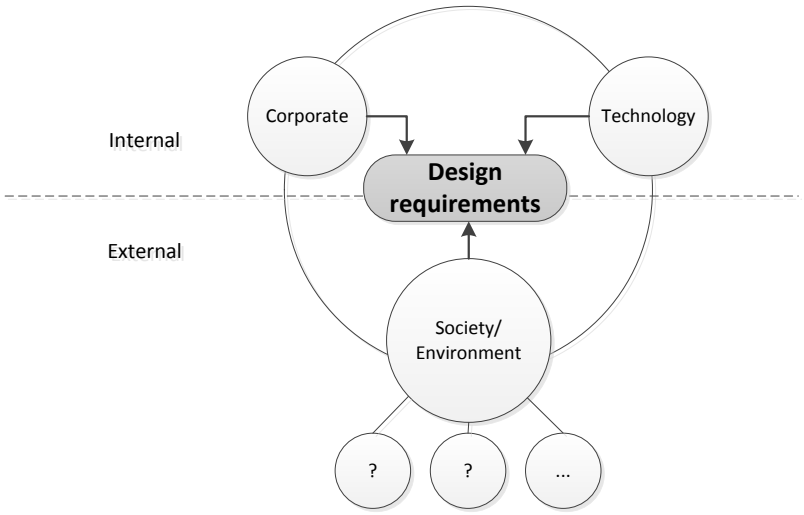

Figure 3. What influence design requirements?

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.

Acknowledgement

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Paper II: A Closed-Loop based Framework for Design Requirement Management

Authors: Zhinan Zhang, Xuemeng Li and Zelin Liu

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A closed-loop based framework for design requirement management

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Abstract. Requirement management plays a crucial role in determining a successful engineering design project. The focus of current requirement research is on the development of requirement elicitation, analysis and formalization methods and tools. Moreover, the existing requirement research often pays attention to the fuzzy front end of product design process. In fact, there exists more needs for requirement knowledge at each stage of a product lifecycle and requirement also has its own lifecycle. However, the research in the field of engineering design lack of a framework to support requirement management from product lifecycle, and requirement and requirement management lifecycle views. This paper highlights the importance of requirement lifecycle management and aims at closing the requirement information loop in product lifecycle. Then, it addresses the requirement management in engineering design field with focusing on the dynamics nature and incomplete nature of requirements. Finally, a closed-loop based framework is proposed for requirement management in engineering design.

Keywords. Requirement management, requirement lifecycle, closed-loop, engineering design

Introduction

Requirement management (RM) plays a key role in determining a successful product development [1], which is a wide research field involving marketing research, business studies, psychological studies, human factors, social factors, software engineering and artifact design [2]. Analysis the literature shows that requirement research is paid sufficient attention in the field of software engineering and information systems [3, 4]. Although, the importance of requirement management in engineering design has been widely acknowledged in design society [5-9], as pointed by Darlington and Culley [10], engineering design requirement is a relatively poorly researched area in design studies. Searching requirement research in prestigious design journals, such as *Design Studies (6), Research in Engineering Design (3), Journal of Engineering Design (10), Artificial Intelligence for Engineering Design Analysis and Manufacturing(3), Computer-Aided Design(5), Journal of Mechanical design (0), Journal of Computing and Information*

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Science Engineering(4), Concurrent Engineering: Practice and Application (13) , and *Advanced Engineering Informatics* (4), verified that only 48 papers have been published since the year of 2000 (Note that the date for searching is March, 2014, and the search engine is *ISI Web of Knowledge*). The research area of design requirements in the aforementioned design journals has developed some approaches and tools for requirement elicitation, requirement analysis, requirement management and for understanding the characteristics of requirement. However, from the requirement lifecycle and requirement management lifecycle view of points, to our knowledge, there still a lack of a closed-loop based approaches or tools for requirement management in relation to engineering design. This paper devotes effort to develop a closed-loop based framework for a better design requirement management.

1. Literature review

Due to its significance, considerable studies have been carried out on requirement management in engineering design community (e.g., [5, 7-9]). Due to limited space, only several typical related research works are briefly reviewed as follows. More complete reviews on requirement in the area of engineering design or product design can be found in the review papers presented by Darlington and Culley [10], and by Jiao and Chen [2].

Brace and Cheutet [11] defined a framework to develop a systematic approach. Based on the approach, they presented a model driven approach for deriving requirement. Zenun and Geilson [12] proposed a framework for completeness in requirement engineering and applied the framework in aircraft maintenance scenario. Robertson and Robertson [13] gave a plenty of advice on techniques for eliciting requirement. Wang and Zeng [14] proposed a generic process for eliciting product requirement by asking questions based on linguistic analysis. A software prototype is also developed to support the proposed process. Cascini et al. [15] explored how to situate needs and requirements in Gero's FBS [16, 17] framework. Xu et al. [18] developed an analytical Kano model to quantitative analyze and classify customer needs. Darlington and Culley [19] used an empirical study to investigate and model the influencing factors to design requirement. Liu et al. [20] proposed a scenario-based approach for the management of design requirement. Baxter et al. [21] developed a framework for the integration of design knowledge reuse and requirements management. This framework enables the application of requirements management as a dynamic process. Gershenson and Stauffer [22] developed a taxonomy for the classification of corporate requirements. Corporate requirements come from internal sources such as marketing, finance, manufacturing, and service that reflect the internal needs of corporate on product development. Rounds and Cooper [23] presented and applied taxonomies of environmental issues to the development of product design requirement.

By integration of the requirement classification works by Ullman [9] and Salonen et al. [24], requirement can be classified into: 1) functional performance requirement; 2) human factor requirement; 3) physical requirement; 4) reliability and feasibility related requirement; 5) lifecycle concern requirement; 6) resource concern requirement; 7) manufacturing and assembly requirement; 8) installation and use related requirement; 9) service related requirement; and 10) economical and technical related requirement.

In fact, the above ten classes of requirements can be reclassified into three categories based on a product lifecycle view: 1) BOL (Begin of Life, including planning, design, and production) related requirement; 2) MOL (Middle of Life, including use, service and maintenance) related requirement; and 3) EOL (End of Life, including reuse, material reclamation and disposal) related requirement. In an analogy with the lifecycle of a product or a piece of knowledge, a piece of requirement also has its lifecycle. Therefore, it needs a lifecycle oriented framework the understanding and management of design requirement.

2. Understanding design requirement

A better understanding of design requirement is a precondition for the development of a feasible requirement management framework. From a research perspective, the focus of the most current design requirement research is on the design object related requirement. However, in the existing works in this field, there is still a lack of design requirement research with considering both design object and design process aspects. Moreover, there also rarely exists a requirement lifecycle oriented management framework. In order to contribute to the research in design requirement management, it is of first important to explore what design is, what design requirement is and the connection of design requirement with design and design knowledge themselves.

2.1. Understanding design

What is design? Many prestigious scholars in design community have discussed its definition (e.g. [6-7, 16]). As pointed by pioneer studies, "*to design is to pull together something new or to arrange existing things in a new way to satisfy a recognized need of society"* [7]. Hence, the word design can be either a noun or a verb. The verb form of design is *designing* (i.e., design process), which refers "to conceive or to form a plan for". The purpose of designing is to transform design requirement into a solution for production, BOL and EOL. The noun definition of design is also *design* itself (i.e., design object), which often refers to "the form, parts, or details of something according to a plan". Both design and designing can be ontologically illustrated by Figure 1, as that presented by Gero et al. [17] and Ullman [9].

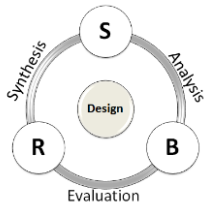

Figure 1. Design and design process

As shown in Figure 1, design object is about what the requirement (R), solution or structure (S), and behavior (B) should be; design process is about how designers fulfill the design activities of synthesis, analysis and evaluation for the transformation of requirement into a desired solution. Design process can be viewed as a series of decision nodes (see Figure 2). The decisions made on each node are based on its existing design knowledge and the gained new design knowledge; the design

knowledge is classified into design object knowledge and design process knowledge by Hubka and Eder [25]. Design requirement is also a kind of design knowledge. In this regard, design requirement should also consist two parts, i.e., design object related requirement and design process related requirement.

Figure 2. Elements of a decision node

Today's engineering design especially the design of complex long service life product (e.g., air crafts, continuous casting machines, ships etc.), should both take the design stage and the after design stage into account, see Figure 3. In this circumstance, the design does arrange existing things or pull together something new in a new way to satisfy a recognized need of society and the whole product lifecycle, which requires more information flow or knowledge flow between different user groups and projects [26]. Therefore, today's design requirement management is more complex than that have been explored in existing works.

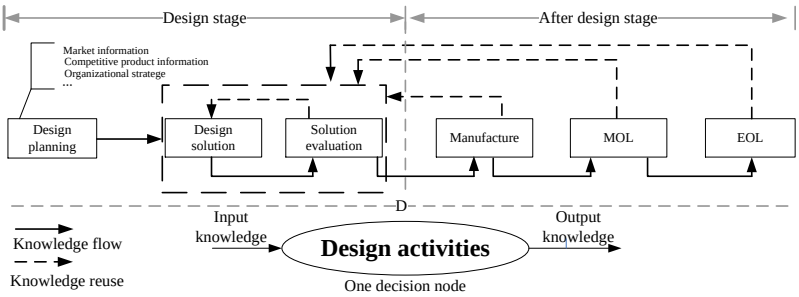

Figure 3. Product lifecycle and closing the information loop

2.2. Understanding design requirements

In the engineering design field, the characteristics of design requirement are highly related to the nature of design or design knowledge itself. Based on the above understanding of design, it should be confirmed that design requirements can classified into (see Figure 4): 1) design object related requirement, and 2) design process related requirement. The classification of design requirement is similar to that of design knowledge by Hubka and Eder [25]. Figure 5 is an ontological framework for the representation of both design object and design process and also the design knowledge required for each design activity.

- Design object related requirement

It has been widely recognized that customer value, product quality, cost and etc., are all factors that can be improved by effective requirement management. In fact, these factors are all design object related requirement. In the front end of product development, it needs effort to better understand customer requirements. It is the start point of a business successful product, which named as "do the right thing", see the

right part of Figure 5. Detailed description of object related requirement can be found in engineering design texts (e.g., [5, 7, 8]). As mentioned by Dieter and Schmidt [7], in much of new product design, 40 percent are existing parts reused without modification, about 40 percent are existing parts used with minor modification, and only 20 percent of the parts are new. It can be concluded that most of information and knowledge are reused from previous design. For example, up to 70% of information is reused from previous solution in the case of variant design [27]. Therefore, in order to support the reuse of design knowledge in an efficient and effective manner, design object related requirements should be presented as a component of design object knowledge. It is another guarantee of a successful product, which improved the probability of "do the thing right", see the left part of Figure 5.

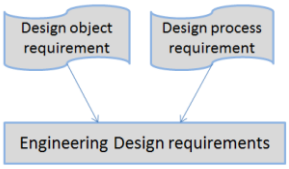

Figure 4. Design requirements

- Design process related requirement

As shown in Figure 2, designer is the key element of a decision node. Designers fulfill design activities to complete design tasks. A design activity can be characterized as a goal-oriented, constrained, decision-making, exploration, and learning activity that operates within a context that depends on the designer's perception of the context [16]. As shown in Figure 2, in order to complete a design activity, a designer has the process related requirement for input information, know-how knowledge and also context knowledge. Effective process requirement management can improve the efficient and effective of design work. Therefore, the management of process related requirement should be paid sufficient attention.

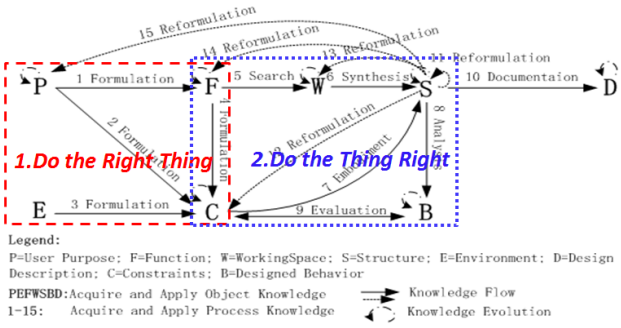

Figure 5. Design requirement (after Zhang et al. 2013)

There may be too much characteristics of design requirements; the focus of this paper is on the following two natures of design requirements.

- Incomplete nature of design requirements

Design knowledge is incomplete [7, 28]. In analog with the nature of design knowledge, design requirement is also incomplete. The requirement development process is also an evolution process of requirement knowledge, i.e., the state of

requirement knowledge will be changed from an initial high degree of incompleteness into a final considerably complete state. It should be note that, there will be no absolutely complete requirement knowledge. It is similar to that as a satisfied solution stated by Herbert Simon.

As shown in Figure 5, each concept (i.e. P, E, F, and C) in the figure can be viewed as a requirement knowledge set for product planning. At initial design stage, the set of requirement knowledge is incomplete and new requirement knowledge should be acquired to improve its degree of completeness. For example, a complete requirement knowledge set about a customer need and environment can be represented as $P= (P_G, P_A, P_O)$ and $E= (E_S, E_N, E_L, E_O)$, respectively. P_G stands for the goal, P_A is used for describing the actions sequentially taken by a customer to achieve his goal, and P_O explains the desired artifact described by a customer. E_S represents the constraints from a social aspect (e.g. laws, regulations and culture). E_N describes the constraints from a nature aspect (e.g. humidity and temperature). E_L refers to the constraints from product lifecycle operations (e.g. transportation and maintenance). E_O is used for describing the environmental entity, which is indispensable for an artifact to work properly (e.g. gasoline is necessary for the operating of gasoline engines, charging pipes are necessary for e-cars). For example, in the beginning of a design, designers only have the requirements set of $P'= (P_G, ?, ?), E'=(?,?,?,?)$ to achieve his complete requirements knowledge sets P and E, the designers have to acquire the needed new requirement knowledge sets $P^*= (?, P_A, P_O)$ and $E^*= (E_S, E_N, E_L, E_O)$ to construct a complete requirement knowledge set.

- Dynamics nature of design requirements

According to the incomplete nature of design requirement knowledge, we know that the state of requirement knowledge is dynamic. The dynamics of requirement knowledge refers to the right requirement at the right time for the right participant. The dynamics nature means 1) the evolution of design requirement knowledge from an incomplete state into a complete one, 2) changing the form of design requirement knowledge from one into another (i.e. from informal to formal, from tacit into explicit), and 3) transferring design requirement knowledge from one decision node to another.

The dynamic nature of design requirement knowledge describes the state of requirement knowledge within a specific scenario. As have been explored by Dieter and Schmidt [7], a good design should consider 1) achievement of performance requirement, 2) life-cycle issues, and 3) social and regulatory issues. All the three considerations may be a scenario which drives the evolution of design requirement knowledge from an initial incomplete state to a desired state. The environment refers to the inner or outer factors which influence a design. It should be remember that requirement knowledge is a dynamic resource, which is constantly changing. Therefore, a novel requirement management framework is necessary for guiding designers to understand the change of requirement knowledge and reuse design knowledge the design process.

3. Framework development

The proposed framework aiming at managing design requirement (includes both design object and design process requirements) taken the nature of design requirement into consideration. Due to the social, technical and cognitive characteristic of design, the attentions to social and cognitive issues are also of prominent important to requirement management, but it is out of the scope of this paper. The focus of RM is on the technical characteristics of design, i.e., the development of technical framework of RM

3.1. The closed-loop requirement management concept

According to the affordance-based relational design theory [29], customer, actor and product should provide affordable requirement information between each other. Therefore, a closed-loop [30] requirement management will allow the actors (i.e. designer, manager, production, service, maintenance, recycler engineers, etc.) who play roles during the lifecycle of a product development to elicit, analysis, transfer, manage and utilize requirement information at any stage of its lifecycle (i.e., design, production, MOL and EOL) without limitation to time and place. Figure 6 shows the closed-loop requirement management (RM) concept. The concept requires a RM system to support closing the information loop in product lifecycle and in the actor networks (customer, product, designer).

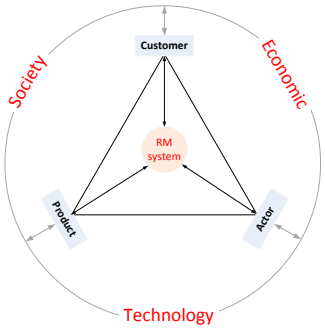

Figure 6. The closed-loop requirement management concept

As shown in Figure 6, the main elements of the closed-loop RM concept are:

- RM system to support the capture, modeling, retrieval, reuse and update of requirement information
- Knowledge flows (includes data and information) to support decision making of each actors (includes customers)
- Scenarios for the understanding of requirement to different actors.

According to the above concept of closed-loop RM, the main functions of the concept are:

- Closing the information loop in product lifecycle, aiming at gaining a better performance of transfer, sharing, application and reusing of requirements

- Closing the requirement lifecycle, aiming at improve the degree of completeness of requirement knowledge and the performance of RM.

3.2. Closed-loop requirement management framework

Figure 7 illustrates a diagram of the RM framework. The basic units of this framework are the requirement elicitation (RE), requirement analysis (RA), and requirement transfer (RT), requirement application (AAP) and requirement management system (RMS). The extended FBS framework (see Figure 1 and 5) can be employed to discuss the above units.

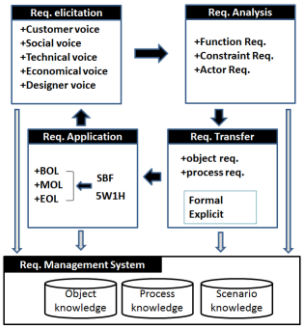

Figure 7. The closed-loop RM framework

- Requirement elicitation

The process of RE can be represented in a clearly defined structure as:

[Data Source]→[R Capture Methods]→[R Data]

The function of RE is to capture raw data from several data sources, e.g., customer voice, social voice, technical voice, economical voice, designer voice and product data, etc. these data sources can be categorized into: customer, society, corporate and product, and supporting facilities related requirement data.

The methods and tools (e.g., interview, observation, brainstorm, questionnaire, benchmarking etc.) for the capture of requirement data have been given sufficient attention in literature. It will not be discussed here. The focus of RE is on the management the output of RE process and construct scenario for the shared understanding of requirement data.

- Requirement analysis

The process of RA can be represented in a clearly defined structure as:

[R Data]→[R Methods]→[R Information]

Kano model [18] and QFD method [31] are widely used for the translation of requirement data into requirement information. The outputs of RA are function requirement, constraint requirement and actors' knowledge requirements.

- Requirement transfer

The process of RA can be represented in a clearly defined structure as:

[R Information]→[R Transfer Methods]→[Formal or Structure R]

The function of RT is to provide actors with an easier way to retrieval and understand the content of requirements. A scenario-based approach [20] can be employed to represent requirement in a formal way and thus to assist RT.

- Requirement application

The process of RAP can be represented in a clearly defined structure as:

[R Information]→[R Interpret Methods]→[R Knowledge]

The function of RAP is to provide actors with requirement knowledge to drive effective decision makings. The SBF and 5W1H (i.e., who at where and when, why and how to do what) framework can be employ to assist requirement management for application.

- Requirement management system

A RM system will provide affordable functions to manage the elicitation, analysis, transfer and application processes and the information or knowledge created in these processes. All the requirement related activities in a corporate should be record in the RM system.

4. Conclusions and future work

The objectives of this study are to highlight the importance of requirement lifecycle management and closing the requirement information loop in a product lifecycle. We address the requirement management in engineering design field with focusing on the dynamics nature and incomplete nature of requirements. The two natures explores that there is a need of a lifecycle oriented approach for requirement management, i.e., requirement and requirement management lifecycle, and embedded requirement into product lifecycle. In analogy with design knowledge, two types of requirement (design object related requirement, and design process related requirement) are recognized. The concept of closed-loop requirement management is then proposed with emphasizing consumer, product, actor and context as key elements. Furthermore, a closed-loop based framework was proposed to provide affordable functions for actors to manage requirement lifecycle information.

Further work needs to be done for a better understanding of design requirement, and the requirement information loops should also be identified in industry using deep case studies. The benefit and weakness of the proposed framework should be assessed and improved.

Acknowledgement

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Paper III: Understand the Design Requirement in Companies

Authors: Xuemeng Li and Saeema Ahmed-Kristensen

Reference: Li, X. and Ahmed-Kristensen, S., 2015. Understand the design requirement in companies. *In: International Conference on Engineering Design.* Milan, Italy, 63–74.

1 INTRODUCTION

Often product development processes, in the market-pull cases, start with identifying the needs or problems that the product is expected to satisfy or solve. The initial needs and problems should be formulated into abstract, unambiguous, traceable and validatable design requirements (Brace and Cheutet, 2012). Design requirements coordinate the diverse desires in the end product and provide the basis of synthesizing a solution (Darlington and Culley, 2004). Various studies have been conducted in the engineering design field both descriptively to comprehend the design requirement practice, and prescriptively to improve practice through developing theories and methods etc. (Darlington and Culley, 2002). Several procedures for developing design requirements have been proposed in literatures e.g. (Dieter and Schmidt, 2007; Pahl, et Al., 2007; Ulrich and Eppinger, 2011).

Poorly identified design requirements can lead to inappropriate products (Hall, et al., 2002). Understanding the nature of design requirements and the sources, from where they can or should be generated, is critical to before developing methods and processes to support this process. Requirement Engineering research, originated from the software development field, highlights the traceability of design requirements e.g. (Grove, et al., 2005), which also implies the significance of recognizing design requirement sources. However, a clear view of the sources for eliciting design requirements is still lacking, especially in the engineering design field. Therefore, this paper intends to investigate potential design requirement sources and the contribution and challenges of each source. The research question investigates a way: how do design requirement sources contribute to the final design requirement set?

The paper is structured as follows: Section 2 presents the relevant literatures. The research methods are given in Section 3. Section 4 and 5 displays the results from case studies and a survey study. Section 6 discusses the findings and Section 7 concludes the paper.

2 DESIGN REQUIREMENT TYPE AND SOURCE

Design requirements are categorised in various ways. A common approach (especially in the software engineering field) is to differentiate them into functional requirements and non-functional requirements (Sommerville, 2011). Chen & Zeng (2006) grouped design requirements into eight levels: natural laws; social laws and regulations; technical limitation; cost, time and human resource; basic functions; extended functions; exception control level; and human-machine interface. Gershenson and Stauffer (1995, 1999) proposed a taxonomy containing four design requirement types indicating the origins of those problems, needs, and constrains:

- *End user requirement*: users' expectations of the product's capabilities, aesthetics and usability;
- *Corporate requirement*: business issues and product lifecycle issues;
- *Regulatory requirement*: safety/health, environmental/ecological, disposal and/or political issues;
- *Technical requirement*: engineering principles, material properties and physical law etc.

This taxonomy was selected as the basic for this study due to its relevance to design requirement sources. Four sources were implied by the taxonomy, namely the end user, the product, the society and the science (Gershenson and Stauffer, 1999). It simplified, summarised, and represented the complicated design requirement sources with the four ultimate sources. However, the correspondence between the four design requirement types and sources can be dynamic and context-dependent. For instance, users as a source may contribute to both end user requirements, e.g. a user friendly interface, and technical requirements, e.g. a certain specific material; conversely, an end user requirement may be generated directly from several sources e.g. the user source or by analysing competitors' products. Hence, mapping out the potential design requirement sources and their connections to design requirement types can contribute a better understanding of design requirement practice, and optimized methods application to different context, and hence improve the completeness and accuracy of the requirement identification.

Several research studies use the term 'stakeholders' to refer to human sources for generating design requirements, e.g. customers, marketers, and designers (Brace and Cheutet, 2012). Sudin et al. (2010) proposed a way to categorise design requirement sources into two groups: 1) human sources, namely clients, end user, market analysis report, colleagues, the designers' expected solution, and the designer's own requirement; and 2) artefact sources, namely semi-developed specification, proposed solution, existing product, previous project, design guideline, user guidelines. This categorization recognises the non-human sources that are excluded in stakeholders. This recognition extends the information capture

boundary beyond a single project's scope. For instance, the project team can learn from the existing products both from their own company and competitors (who are normally be excluded as stakeholders). Similarly, Wootton et al. (1997) separated the sources into individuals (e.g. customer, user or supplier), written materials (e.g. book, trade journal, or technical manual), and objects (e.g. competitors' products), and suggested to differentiate the sources into internal and external sources.
The authors' previous research (Li, Zhang, & Ahmed-Kristensen, 2014) identified seven sources based upon literature study: corporate, technology, user, market competition, regional infrastructure, organizational infrastructure, and regulation. They distinguish the internal and external sources and highlight their market dependence, which can support companies to recognise and prepare for changes when developing for a new market.
Thus, this paper aims to better understand the design requirement type and source, and to explore the interconnections between them through empirical studies, which indicates the path how each source contribute to the final design requirement sets The two concepts are clarified as:

- *Design requirement type* categorise requirements, indicating who or what is calling for the requirements.
- *Design requirement source* describes the requirement origin, from where the relevant information is captured.

3 RESEARCH METHODS

The research included both primary data from three case studies and secondary data from a survey study with 89 answers. The case studies were designed to gain an in-depth understanding of design requirement practice in the case companies through interviews and documentation analysis. Only part of the survey results relevant for this research is presented here. The following part of this section describes how the primary data was collected and analysed, whereas the detailed information about the survey can be found in (Li and Ahmed-Kristensen, 2015) and is summarised here. The survey contained 28 questions and was sent to Danish companies. 131 answers from 17 large companies, 19 medium companies, 66 small companies, and 29 micro companies were collected. 89 answers provided an insight into the generation of design requirements in a western context, and 64 provided insights into both western context and emerging markets. The primary data were collected in three companies, one large company and two SMEs, referred hereafter as Company A, B and C. They were chosen for this study as they are all Danish companies which develop physical products and were interested in product development for emerging markets. The comparison provide an explorative understanding of the practice in Danish SMEs. In total, five semi-structured interviews were conducted with individuals with the knowledge and experience of design requirement in the companies. Each interview was around 90 to 120 munities and they were all audio-recorded.
Company A is a 13 years old large size company with over 500 employees. They develop medical devices for professional users. They do business all over the world while currently the biggest share comes from the United States and their second biggest market is China. Three interviews were done in this company with one product manager, one project manager, and one technologist (who has professional knowledge in the field). In addition, design requirement documents and system specifications for one specific project were included to support the analysis.
Company B was founded in 2012 and has eight people including full-time, part-time employees and internships. They produce coating equipment for academic research use. Their customers are mostly in Europe but they are expanding to China and other emerging markets. The director (co-founder) from the company was interviewed.
Company C is a micro size company (and can be described as a start-up) with three employees and three freelancers, and was started in 2012 and has. They design health care products for adults who are not able to take care of themselves, and sell to both healthcare systems and private users. Their first product was under development and planned to be ready for sale in 2015, which was mainly tested in Danish market. The company intends to develop for emerging market soon. The interview was conducted with their director (co-founder). In addition, their design requirement document was analysed.
Each interviewee was asked to describe design requirement processes, sources, methods and challenges in general in their companies. They were required to order the importance of each source and estimate the contribution from each source to the final requirement set. For each case, the design requirement sources identified through the interviews and documents analysis were mapped together with their

contribution to the four types of design requirements proposed by Gershenson and Stauffer (1995). The mapping was done according to interviewees' descriptions of the sources and their contribution. The map for company A was validated by the technologist.

Table 1 Data overview

Company	Company age	Number of employees	Document	Interviewee	Years at the company
A	13	> 500	1 design requirement 1 system specification	Product manager	2
				Project manager	11
				Technologist	12
B	2	8	N/A	Director	2
C	2	6	1 design requirement	Director	2

4 DESIGN REQUIREMENT IDENTIFICATION: FROM WHERE TO WHAT?

The analysis focused upon comprehending and demonstrating the design requirement types and sources, and the links in-between. This section presents the results from three case studies. For each case, the sources involved, methods applied, documents written and links to design requirement types are illustrated in one figure and explained in text. The various considerations from the interviewees are raised in the discussion.

4.1 Company A

Company A applied a standard and formal stage-gate product development process together with concepts from Agile Development. A product manager, a project manager and a technologist worked together to define requirements across projects. They formed a team referred to as the product owner in Agile. In this team, the technologist carried the main work of collecting requirements, especially user requirements. Figure 1 was drawn to demonstrate the design requirement sources, methods, types and documents in Company A integrating data from three interviews and two documents.

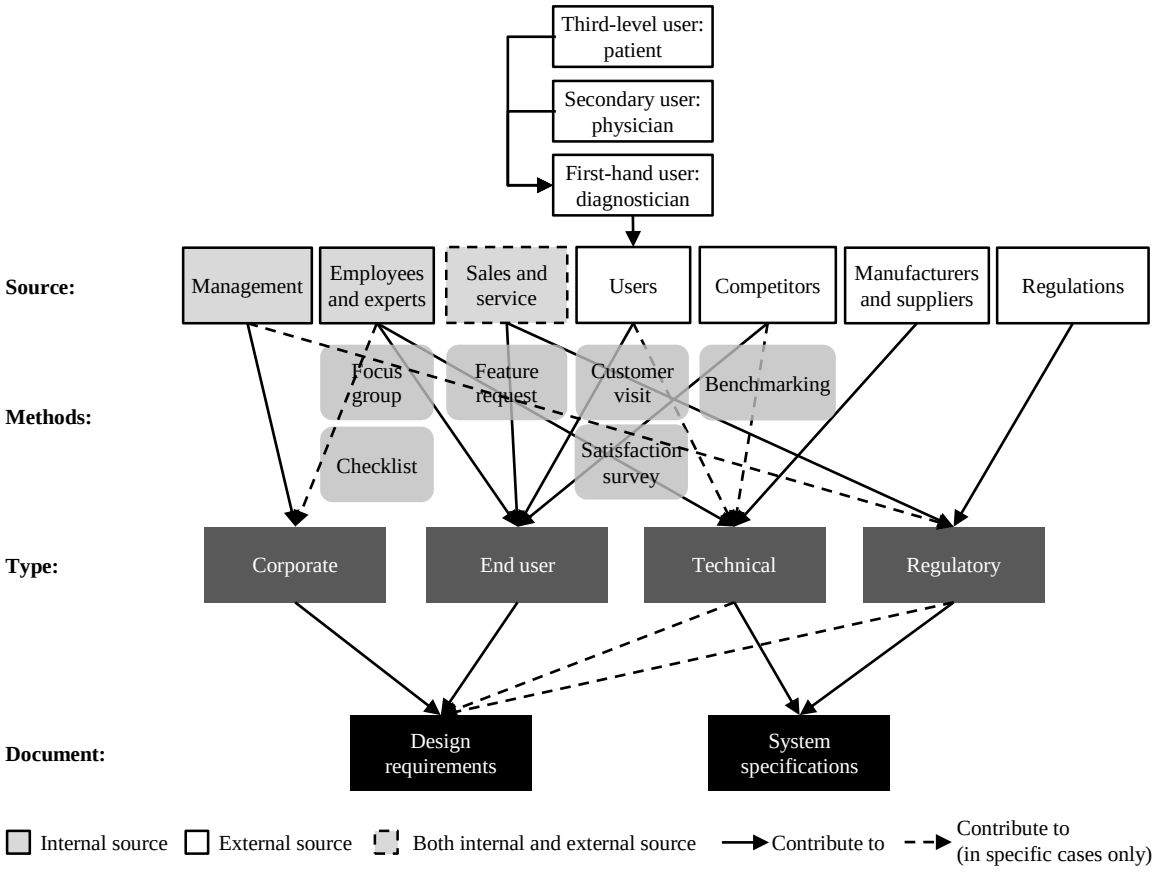

Figure 1 Design requirement practice in Company A

Seven sources were involved in the company's product development projects, including one internal source:

- Management: requirements from this source were typically aligned with company strategies and policies. For instance, the management team required a distinctive design from the existing products for strategic reasons. It had an indirect contribution to regulatory requirements by deciding which market the product would be sold to. This source was normally involved from the beginning of the projects. All three interviewees agreed that this source had a small contribution to the final number of requirements but it was very influential especially for an internal driven project.

Two mixed sources:

- Employees and experts: this source included the in-house employees as well as the external experts who were in a close relationship with the company. It was described as the most vital source for design requirements. The product manager said roughly 50% of design requirements were from this source and the technologist stated that it together with competitor source could contribute to about 90% to 95% of design requirements. In addition to the in-house idea generation, the company organised focus groups to gather experienced people. They were mostly from the company although sometimes external experts were included. Furthermore, a checklist was used to guide the design requirement identification. This source contributed to the end user requirements and technical requirements by bringing their experience and understanding of users and the technology into the design, and could indirectly influence company's strategies.
- Sales and service: the source covered both internal company departments and external partners. Their knowledge contributed to design requirement through a feature request system. In addition, when doing business in an unfamiliar market, the external sales partners supported the company to identify and understand the local regulations.

And four external sources:

- Users: this source was crucial but with a small contribution in terms of the number of requirements. It was not just a source for capturing information but also used to validate identified requirements. The technologist grouped their users into three levels. The first-hand user (diagnostician) operated the products directly; the secondary user (physician) used the information from the audiologist; and third-level users (patient) received treatment according to the information. Neither secondary nor third-level users used the products directly but were influenced by the products. Generally, a technologist visited the first-hand user and collected information about other users through the first-hand users. Satisfaction survey were used to gather users' opinion. In rare cases, professional users also requested specific technical requirements.
- Competitors: as mentioned, competitors together with employees and experts were the two main sources for design requirements in Company A. Competitors could not be involved directly in the project as stakeholders, instead their products were monitored and analysed. The requirements captured from this source were often validated by users. Technical requirements can in some case be generated from competitors, for example the new technology was applied in their products.
- Manufacturers and suppliers: this source mainly contributed to engineering considerations e.g. design for manufacturing. Both its importance and contribution were at a low level compared with other sources. This result was unexpected as literatures showed that manufacturing was the main cause for engineering change (Kanike and Ahmed, 2007). It indicated that manufacturing was not recognised as important as it would be in the design process.
- Regulations: this source included regulations, rules and industry standards etc., which was particularly critical for medical products and had to be strictly followed. But in term of quantity, its contribution was small.

In company A, the collected information would be first written into the design requirements then specified into the system specification. The project manager believed that the end user requirement were the core and formed about 75% of the design requirements. Regulatory and technical requirements were only briefly mentioned in the design requirements but clarified in system specifications, unless special issues were raised by other sources. The technologist viewed the users as the fundamental source for innovations. He gave an example that an innovative idea was initiated internally by the management team which turned out to be an unsuccessful product to the market.

Two key challenges in design requirement identification were underlined in the interviews: 1) to be innovative and to take big steps instead of cutting off small corners; 2) to achieve an agreement among various stakeholders.

4.2 Company B

Company B sold around 10 units per year and had 5-10 projects going on at the same time. It had two types of product development: customer-driven projects and internal-driven projects. For the former, design requirements were set at the very beginning within one or two months (for a one-year-project), while for the latter, the design requirement identification could be done in one week. The company did not apply formal development processes but consulted concepts from Agile Development. Two directors were in charge of the design requirement identification and their roles were not clearly distinguished.

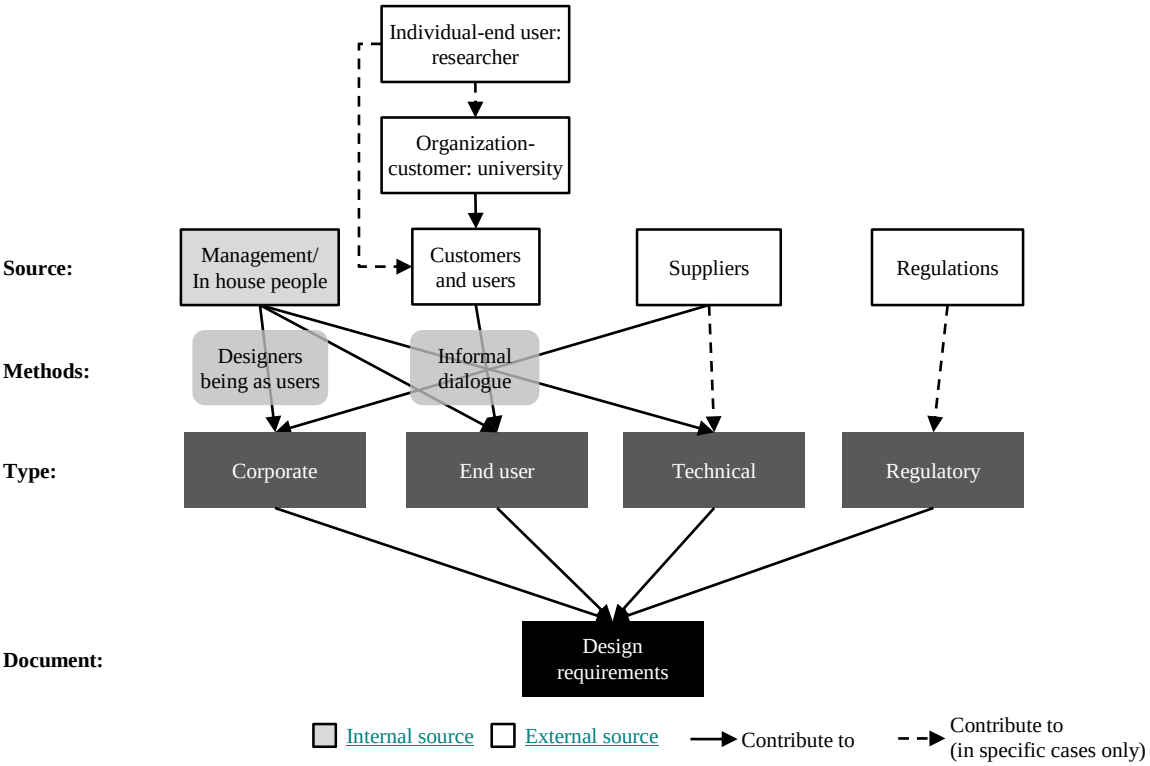

Figure 2 Design requirement practice in Company B

As displayed in Figure 2, the design requirement practice map in Company B involved fewer factors than that in Company A. Four sources were pointed out, with one internal source:

- Management and in house people: the management and in house people were not separated as two different sources because of their mixed roles in the small company. This source contributed to end user requirements by thinking around the table what the customer would want (known as designers being users approach) where the requirements were left board and open for customers to narrow down. They also contributed to corporate requirements by proposing company strategies. For instance, a distinctive colour scheme was required in order to make the products identical and eye-catching. In addition, their engineering knowledge was a source for technical requirements.

And three external ones:

- Customers and users: the customers for the company were the organisations (universities) that bought the equipments and the users were the individuals (researchers) who run them. Customers had the biggest contribution to more than 60% of the design requirements. It was especially true when the projects were customer-driven, where the customers initiated the requirements. The information was collected through informal dialogues, e.g. emails and meetings. Occasionally, they had also chances to communicate with individual users and gain direct feedback.
- Suppliers: in some projects, suppliers supported knowledge for finding out appropriate technical solutions, which was typically related to cost efficiency.
- Regulations: regulations had a limited contribution to design requirements in this case. The company tried to minimise in certifications due to cost concerns. In addition, if the customer agreed to take the risks, some regulations would not be addressed.

The company run in a niche market, where very little direct competition was currently taking place. They occasionally were inspired by the very hi-tech competitors. However, no specific requirements were from this source due to the limited access to expensive competitive products.
A key challenge emerging from the interview was to define a suitable cost strategy for supporting design requirements collection. As the customer driven approach, development started once an order was placed. Hence, an over quoted price might shut down the door in the beginning, whereas a low cost estimation would reduce the profit of the company.

4.3 Company C

Company C had not yet a product on market the development of the product was still under progress. Their process was informal and under improvement. The design requirements identification was carried out primarily by the director and sometimes involved student helpers. About half of the director's working time had been spent on collecting requirement data since the project started.

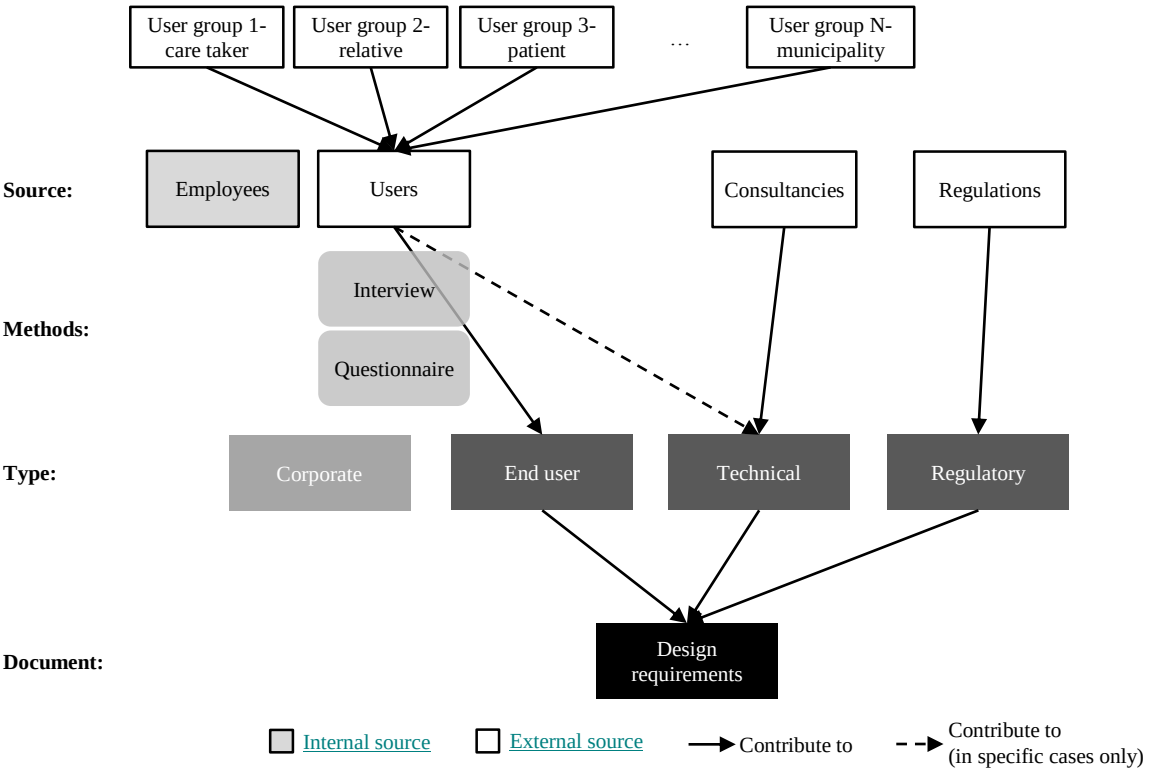

Figure 3 Design requirement practice in Company C

Three main design requirement sources were indicated from the interview. Employees as a source was added to the map (Figure 3) as it was assumed that their knowledge at least would have indirect influence on the requirements. However, this was not recognized by the interviewee, and the contribution of this source was not clear. Hence, the three external sources are described here:

- Users: this was the essential source for design requirements in this company. A few groups of users were defined according to their interactions with the product e.g. care takers and the patients. Huge amount of efforts were devoted to collect information from the various users. Questionnaires and interviews were conducted during the process. This gained the core insights for end user requirements and their questions about technology also contributed to the technical requirements.
- Consultancies: the company worked with two consultancies, which dealt with engineering and manufacturing issues. The comments they made on the design requirement document had a considerable contribution for the technical requirements (was indicated through document analysis). However, this contribution was not recognised by the interviewee.
- Regulation: some regulations were mentioned to be followed. Nevertheless, they were not of high priority in development but more for preparation of expanding to other markets.

This case displayed a strong user-driven project. A clear focus was on contacting and knowing all kinds of users and potential users. Data indicated very limited corporate requirements.

As a start-up, their approaches were explored through a learning process. As commented by the director: *'I didn't have an exact method when I started analysing the data. I used it in the process in order to get the right knowledge and information'*. Consequently, one key challenge for them was to access to the right people and find the right way.

5 DESIGN REQUIREMENT SOURCES: CONTRIBUTION AND DIFFICULTY

This section presents the result from the survey study that implies a general understanding of the difficulty level of each design requirement source and its contribution to the final requirement set. In the survey, respondents were asked to rate the seven design requirement sources, which were defined from literatures (Li, Zhang, & Ahmed-Kristensen, 2014) following two questions:

- How much do the following (sources) contribute to developing design requirements in your product development projects?
- When developing products for the Danish market, how difficult is it to identify design requirements from the following considerations (sources)?

The average score from 89 answers were calculated and illustrated. Figure 4 mapped out the seven sources according to their average scores for two dimensions: difficulty and contribution. Three sources: user, regulation and technology, were highlighted as having a big contribution and also high level of difficulty to act. Similar result was gained in the interviews for the user source and one reason was indicated as the complexity of the user groups. However, technology did not get much attention and regulations were not regarded as a challenge in the interviews. The market competition source in general contributed less than the other sources but was rated as the most difficult one. One explanation was the challenges to access to competitors' products and information, which was implied by the interviews as well. For instance, Company B could not analyse competitive products due to the high cost of their products. The regional infrastructure was rated as the least difficult with also the least contribution. This was also consistent with the case studies, where the infrastructure did not gain much attention. Company A integrated infrastructure considerations with their sales and service; Company B left infrastructure issues to customers; and Company C did not separate it from the users. Hence, it can be argued whether it is more reasonable take infrastructure as a separated source or integrate it with other sources, e.g. user.

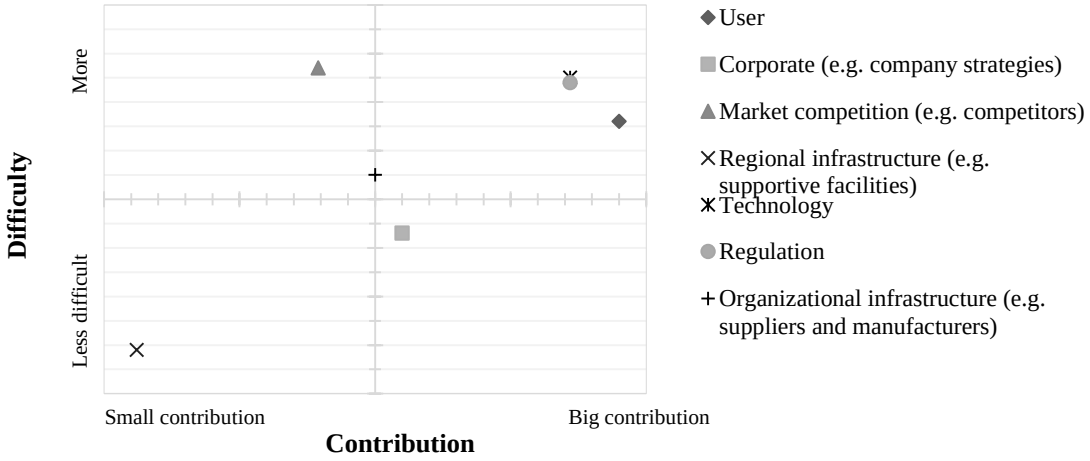

Figure 4 The difficulty and contribution of design requirement sources

6 DISCUSSION

The presented results indicate a few patterns of how companies identify design requirements and bring the confusing subjects into discussion. First of all, the research supports the view that design requirements require comprehensive information from multi-sources, e.g. (Wootton et al., 1997; Li et al., 2014). Indeed, when categorising design requirements into the four types, namely end user, corporate, technical and regulatory (Gershenson and Stauffer, 1995), each type of design requirements can have input from several sources whilst each source can contribute to more than one type of design requirements. The links between source and type are context dependent.

Second, the case studies show the confusion of understanding the design requirement type and source in companies, where the requirements for users and from users are always mixed up. Hence,

distinguishing the end user requirements and the user, as a requirement source including customer is necessary. The former designates a requirement set that can be attributed to the product users, while the latter, as an information source, provides insights into requirements. End user requirements are not necessarily solely from the user source. Among existing studies, end user requirements, also referred to as customer requirements, are commonly accepted as critical and crucial to the success of product development (Chen et al., 2003; Jiao and Chen, 2006; Morkos, et al., 2014). Its significance was verified both in the survey study and with the cases. In addition, the research shows that companies sometimes focus on end user requirements without recognising the other types. Quite a few studies on the end user requirement focus upon eliciting information from the user sources. Methods such as interview, focus group and survey have been frequently cited when approaching to users (Wood and Otto, 2000; Dieter and Schmidt, 2007). Nevertheless, the inputs to end user requirement from other sources are often omitted or neglected. In the research presented, the contribution to end user requirements from in house people and competitors is clearly revealed. In particular cases, those sources can contribute more than the user source to the end user requirements according to the product type and the project's nature. This raises a need for acknowledging the requirement collection methods from different sources, e.g. benchmarking (Zairi and Leonard, 1996) and functional decomposition (Clarkson et al., 1999) for understanding requirements from competitors.

Thirdly, the research illustrates the complexity of user sources for design requirements. In all three cases, the user source was described with subgroups. The extension can be vertical through a few levels of users and gather user information through one or more levels, or horizontal with several types of users and interaction required with each type. The extension shaped the way that company access users and the time and effort they spent on it. User identification is necessary for both access the right user group and to gain supplement user requirements from other sources.

Therefore, the research raises two issues: the understanding of the product nature and project type, and the awareness of available resources. Design requirement identification is a context dependent process, knowing your own situation is the precondition to start. The product and project prioritise design requirement types and indicate their likely contributions. Awareness of the existence of different types of design requirements is meaningful, instead of only concentrating on user requirements. For instance, regulatory requirement may only contribute to a very limited part to the final requirements but it can be crucial dependent on the industry sector, e.g. medical devices. Moreover, mapping out the available resources both internal and external can support companies to find the links between design requirement sources and types. For example, large companies might have a rich internal source for experience and knowledge while small companies can take advantages of more external sources, such as partners and consultancies. Finally, effective methods need to be developed and applied appropriately to elicit requirement from different sources.

7 LIMITATION

One drawback of the study was the case selection. The three case companies were varied in size and business scale, which was clearly not enough to represent the whole picture of Danish manufacturing industry. It was in particular challenge of gathering data from small companies due to their tight agenda and strained resources. However, the study was intended to explore some patterns of design requirement practice in companies. The results should be validated and generalized with a larger sample. In addition, data from 89 companies collected in the survey supported the studies and confirmed part of the findings.

8 CONCLUSION

This research consisted of primary case studies in three Danish manufacturing companies (with five interviews and three documents.) and secondary data from a survey with 89 valid answers from the industry. The research clarified the definition of design requirement type and design requirement sources. In addition, it investigated the sources both from literatures and empirical studies. The requirement elicitation methods for each source employed in the companies were presented. The possible interconnections from sources to four types of requirements were explored in the three case presented. The research findings enriched the understanding of where and how design requirements can be identified. This knowledge can be used to support companies to focus their efforts on the right sources according to the specific context. From the obtained data, insights were gained, which indicated several possible design requirement sources and a few patterns of how company make use of the sources. More

cases should be involved in future studies to supplement the potential missing links and to generalise the result. The development of a design requirement source-type model together with supportive toolboxes is suggested as the next step for further research.

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Paper IV: Identifying Design Requirements for Emerging Markets

Authors: Xuemeng Li, Saeema Ahmed-Kristensen and Jaap Daalhuizen

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IDENTIFYING DESIGN REQUIREMENTS FOR EMERGING MARKETS: A STUDY ON DANISH INDUSTRY

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ABSTRACT

The manufacturing industry's interest in emerging markets has been increasing dramatically during the recent decades as their economy is growing. Western companies are making efforts to develop products for emerging markets but are also facing various challenges in the process of doing so. One major challenge is the identification of reliable and valuable design requirements. This study aims at investigating the influence of the emerging market context on the practice of identifying design requirements. A survey among Danish industry was conducted with 130 responses collected. 92 answers provided an insight into design requirement identification in a western context, whereas 62 provided an insight into both emerging and western contexts. The results indicate the importance of design requirement identification when developing for emerging markets. Requirement elicitation and analysis are the most challenging phases in a design requirement identification process for both western and emerging markets. For Danish companies, identifying design requirements for emerging markets is more difficult than that for western markets, particularly when considering user needs, governmental regulations and organizational infrastructures.

KEYWORDS

Product development, design requirements, requirement identification, emerging markets, Danish industry

1. INTRODUCTION

In the past decades, western companies have increasingly turned their focus on emerging markets. This shift has had a considerable impact on the product development process as the emerging market context often demands changes in the way of working in a company. Emerging markets have different social, cultural, political and economic contexts when compared to western markets, which are known as developed markets or advanced markets [1]. These differences make it difficult for western companies to identify reliable and valuable requirements when developing for emerging markets, and challenge the direct applicability of the conventional practices that western companies use in their home markets.

Several existing studies have addressed product development for emerging markets from various perspectives. For example, product development for the base of the pyramid (BoP) [2], frugal innovation [3] and Jugaad innovation [4] support companies to develop suitable products with restraint resources; and reverse innovation [5] focuses on bringing the knowledge developed in emerging markets back to western markets. In those studies, seizing the local market opportunities and understanding the local needs and distinctive requirements are highlighted. This awareness of the significance and challenge of understanding market needs and requirements indicates the importance of requirement identification when developing for emerging markets.

From a product development perspective, discovering and identifying requirements are often the initial and critical steps of a product development process.

Design requirements coordinate diverse needs that originate from various sources, and form the basis for synthesizing a solution [6]. Deficiencies in the defined requirements can lead to the waste of resources and even to project failure [7]. Reliable and valuable requirements function as a tool to keep product development on track in terms of being able to guide and control that product development leads to the right products and effort is allocated to the right directions. They also function as an explicit reference for all stakeholders in a product development project in order to be able to negotiate, guide and check what a team should be developing all along the product development process.

Most traditional methods and tools for identifying design requirements have been developed and tested in a western context. Facts show that how to handle the differences in identifying design requirements between emerging markets and western markets is still problematic for many companies. It is necessary to study the design requirement identification for the new context of emerging markets. Hence, this study aims at investigating how the context of emerging markets influences the practice of product development, particularly on design requirement identification in western companies. In order to do so, a survey study was conducted in the Danish industry.

This paper is structured as follows: section 2 reviews the relevant literature. Section 3 describes the research approach. Section 4 presents the results and analysis. Section 5 discusses the findings. Section 6 concludes the paper and proposes for future studies.

2. LITERATURE REVIEW

This section presents the reviewed literature from two aspects: Section 2.1 introduces emerging markets from a product development perspective. A large portion of the investigations and discussions on emerging markets are in such fields as management, business, marketing and economics. Few studies have been found that address the issue from an engineering design perspective. Section 2.2 presents relevant literature on design requirement identification. Relevant studies from the engineering design field, as well as from requirement engineering in software engineering and system engineering are included. Finally, section 2.3 summarizes the gaps in the literature and specifies the research questions for this study.

2.1. Characterising emerging markets

According to Hoskisson et al. [8], Emerging markets are 'low-income, rapid-growth countries using economic liberalization as their primary engine of growth'. They are distinguished from both developed markets and other developing countries with the characteristics of rapid economic growth, and achieved substantial industrialization and modernization [9]. For instance, the BRICS countries (Brazil, Russia, India, China and South Africa) are the most often recognized and mentioned emerging markets. Based on the literature, five characteristics of emerging markets that influence product development are identified.

Growing potential and opportunities

The fast economic growth distinguishes emerging markets from any other markets and enables them to stand out and attract increasing attention from the world's industry [8, 10, 11]. The gross domestic product of emerging markets is estimated to permanently surpass that of all advanced markets by 2035 [12].

Distinctive and heterogeneous markets

In spite of the impressive growth, the income level in general in emerging markets is still much lower than that in developed countries [10, 13], which limits customers' purchasing power and shapes their behaviours.

In addition, users and customers in emerging markets may have complete different needs and interpretations of products compared to western customers, due to their cultural, social and economic background. The differences also exist within an emerging country, e.g. from eastern China to western China, which makes the market fragmented [13].

Underdeveloped regulatory environment

The regulatory environment of emerging markets, which companies are exposed to, is considered as unstable and underdeveloped. It influences the market regulation, product regulation, governance transparency, and eventually have an impact on a company's ability to earn profits [1].

Severe competition

Western companies in emerging markets are competing with both a huge number of local and international competitors [9, 10]. Moreover, the relatively poorer IP rights protection and other consequences of the underdeveloped regulatory

environment can make the competition even more chaotic.

Inadequate infrastructures and resources

The physical infrastructures in emerging markets are often weak and underdeveloped [13] and the resources are more restraint compared to that in developed countries. For instance, the technology is often less mature and less invested in emerging markets [11, 13].

2.2. Design requirement identification

Acquiring information and transforming it to well-defined requirements require many resources and much effort. It is a time-consuming and error-prone process [14]. Identifying requirements typically happens along a number of structured phases. The commonly mentioned phases in a requirement identification process are:

Requirement elicitation: to systemically extract the requirements from customers and other sources [14, 15].

Requirement analysis: to analyse the requirements for conflicts, overlaps, omissions, and inconsistencies [16, 17].

Requirement specification: to specify explicit and formal requirements for development and evaluation use [18].

Requirement validation: to validate whether requirements are consistent with stakeholders' intention [19].

Requirement maintenance: to update, maintain and support the evolution of requirements [20].

Requirements build a bridge from the individual stakeholder's needs (the user domain) to the issues that have to be considered throughout the design process (the product domain). For instance, Pugh [21] listed 32 issues that needed to be considered when developing a product specification. Ahmed [22] identified four classes of issues that designers must consider whist carrying out the design process: the lifecycle of the product, the environment of the product and interfaces, the functional requirements, and the characteristics of the product.

In requirement engineering, the notion of viewpoint is introduced as 'a way of collecting and organizing a set of requirements from a group of stakeholders who have something in common' [23]. Each issue which is considered in the product development process can be identified from multiple viewpoints. Figure 1 illustrates an example of the relationship between the viewpoints and issues in design requirement identification.

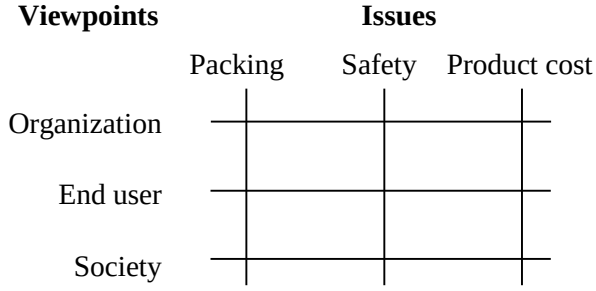

Figure 1 The relationship between viewpoints and issues in design requirement identification (adapted from [23])

In this paper, the concept of viewpoint is extended beyond the human stakeholders by including the non-human sources for design requirements, e.g. project reports and existing products. In the process of identifying design requirements, not only the technical issues of the product itself should be considered but also the socio-cultural context where the product will be immersed should be included [2]. This is particularly true when developing for emerging markets due to the gaps in the external environment. Li et al. [24] summarized seven viewpoints that should be covered in the process of design requirement identification when developing for emerging markets:

User: all relevant units that buy or use the products, e.g. end users and customers (see e.g. [25, 26, 27]).

Corporation: the company's own competencies, processes, guidelines, policies and strategies (see e.g. [25, 26, 28]).

Competition: the competition in the market (see e.g. [29, 30]).

Regional infrastructure: the infrastructures that are needed to support products to work, e.g. physical facilities (see e.g. [31, 32]).

Technology: scientific and engineering laws and principles (see e.g. [29, 33]).

Regulation: governmental regulations, and international and regional standards (see e.g. [26, 30, 31]).

Organizational infrastructure: the stakeholders involved in the product development that are external to the company, e.g. suppliers and distributors (see e.g. [25]).

2.3. Research questions

Two gaps in the literature are identified. First is the lack of research studies on examining the conventional product development and requirement identification theories and methods under the context of the rise of emerging markets. Secondly, a large number of the existing studies focus on customer requirements such as the elicitation or transformation of the customer requirements (e.g. quality function employment [34]), but a comprehensive overview of other viewpoints in requirements (e.g. corporation and regulation) is still missing.

Hence, concerning both the literature reviewed and the challenges in practice, two research questions are formulated to guide the study:

- *How is the practice of developing for emerging markets in western companies different from that for western markets in terms of identifying design requirements?*

- *How can western companies improve their practice of identifying design requirements for emerging markets?*

3. RESEARCH METHODS

In order to answer the research questions, a survey study was conducted. Denmark was chosen to represent the western context in this study due to 1) the information accessibility since the authors are based in Denmark; 2) Danish companies are also facing the challenges of identifying design requirements for emerging markets as other western companies. This section describes how the survey was conducted and the collected sample.

3.1. Survey instruments

The survey was designed to investigate the product development practice in Danish companies when developing for emerging markets and Danish industrial practitioners' opinions on emerging markets. The seven predefined viewpoints as described in section 2, namely user, corporation, competition, regional infrastructure, technology, regulation and organizational infrastructure, were used as a reference in the survey. The survey was tested and revised in a workshop with over 20 industrial participants in Denmark. The survey consisted of four parts:

1. Background information about the company:
- Company name, size, and industry sector
- Typical project length and budget
- Business status in emerging markets

2. Background information about the participant:
- Position, background, experience

3. Design requirement identification in general and for Danish market:
- Time spent on identifying requirements in general
- The contribution of each defined viewpoint to the final set of design requirements
- The difficulty level of identifying design requirements from each defined viewpoint for Danish market
- The difficulty level of each phase in a design requirement process for Danish market

4. The understanding of emerging markets and design requirement identification for emerging markets:
- The influence of emerging markets' characteristics on product development
- Key barriers when developing for emerging markets
- The difficulty level of identifying design requirements from each defined viewpoint for emerging markets
- The difficulty level of each phase in a design requirement process for emerging markets
- General opinions on product development for emerging markets

3.2. Sampling process

An initial list with 7723 Danish companies was extracted from a professional online business database called *Bisnode*. Those companies all:
- operated in Denmark;
- developed or manufactured products, or provided product design services to other companies;
- and were making profit.

A link to the survey was sent to the companies on the list by an email research invitation. Two screening questions were added in the email to select relevant companies that:
- have experience with emerging markets;
- or have potential interest in selling to emerging markets.

3.3. Sample description

A total of 131 respondents answered the survey. One response was deleted due to clearly invalid answers. The remaining 130 answers represented 125 different companies. Not all respondents completed the survey.

All 130 respondents finished part 1 and part 2, which presented the basic background information and the company's business status in emerging markets. 75 (57.69%) of these 130 respondents were working in companies that were doing business in emerging markets. 92 respondents filled in part 1, part 2, and part 3, and 56 (60.87%) of them were doing business in emerging markets. Their answers provided an insight into the identification of design requirements in a western context that was represented by the Danish market. Among these 92 respondents, 65 completed all four parts, of which 45 (69.23%) were doing business in emerging markets. Their answers provided an insight into both emerging and western contexts. Table 1 presents the counts of respondents and the represented company sizes.

Table 1 Sample overview

Size (number of employees)	Total answers	Insights for Danish market	Insights for emerging markets
Large (>249)	17	13	10
Medium (50-249)	19	12	11
Small (10-49)	66	46	29
Micro (>10)	28	21	15
Total	130	92	65

The survey response rate was lower than 5%. Possible explanations for the low response rate were 1) not all the companies on the initial list passed the two screening questions, 2) the email addresses generated from the database and used to contact companies were often general email addresses (e.g. information or customer service) and not always up to date.

Among the 130 respondents, 89 were the business owners or from the top management team, 21 were managers, while 10 were from other positions, e.g. engineers and sales. 68 respondents have a background of engineering, 47 have a business background, and 47 have a management background (multiple choices allowed).

4. RESULTS

This section presents the analyzed results from the survey study, and the results are discussed in section 5.

4.1. Differentiating for emerging markets

66 respondents in the survey study described the business status of their companies in emerging markets. 11 (16.7%) companies were developing new products for emerging markets. 19 (28.8%) companies were adapting existing products for emerging markets (with some changes in the design). 36 (54.5%) of the companies were selling existing products (without any changes in the design) to emerging markets.

Another reports gained similar results when investigating the western companies' business statuses in several emerging markets [35], which corroborates the results of this study, see Table 2. It provided an extended view from the Danish industry to a broader range of companies all over the world, and specified data for each emerging market. In addition, these results verified the representativeness of the sample.

Table 2 How are the products sold by companies in emerging markets compared to products sold in home markets (adapted from [35])

Emerging market	Very different	Somewhat different	Very similar
Indonesia	12%	41%	47%
India	16%	32%	52%
Russia	11%	43%	46%
China	14%	36%	50%

65 respondents commented on the necessity of differentiating products for emerging markets. 29 (44.6%) respondents agreed that there was a need to differentiate products sold to emerging markets from that sold to Danish market. 20 (30.8%) stood neutral and 16 (24.6%) disagreed.

About half of the surveyed companies were already either adapting existing products or developing new products for emerging markets and close to half of the respondents thought it was necessary to differentiate products for emerging markets. The necessity of differentiating and redeveloping products for emerging markets requires understanding of the different local needs and requirements, and the adjustment of the supportive processes, methods and tools for the new context [36].

This concern was also reflected in the key challenges faced by companies when developing for emerging markets. In the survey, respondents were asked to choose the three most difficult challenges from a list

made upon literature review and a workshop. Table 3 listed the challenges and counts of answers.

The top challenges on the list implied the insufficient understanding about the requirements and needs in the local market and the socio-cultural context. Specially, they reflected the difficulty in identifying design requirement from the viewpoints of regulation and user. It, on the other hand, confirmed the need and significance of studying design requirement identification for emerging markets.

Table 3 Key challenges faced by Danish companies when developing for emerging markets

Challenges	Answers	Percent n=65
Difficult to reach and understand the local regulation and to get local approvals	28	43%
Different business culture of deeply embedded networks and personalised exchange	27	42%
Insufficient understanding of market needs	24	37%
Unstable political and regulatory environment	22	34%
The shortage of financial support	21	32%
Difficult to develop affordable products with sufficient features for local consumers	16	25%
Poor intellectual property right protection	15	23%
Special constraints under the using context, e.g. a lack of supportive infrastructure and space	12	18%
Difficult to overcome the impediments to distribute	11	17%
High level of product diversion within or between countries	8	12%
Possibility of watering down a premium brand	4	6%
Language, distance, and time zones	2	3%

4.2. Comparing design requirement identification for Danish market and emerging markets

65 respondents expressed their opinion on whether it is more challenging to identify design requirements for emerging markets than for that Danish market (or western markets). 41 (63.1%) supported that it was more challenging for emerging markets; 16 (24.6%) were neutral; and only 8 (12.3%) were against it.

In order to further understand how the design requirement identification for emerging markets are different from that for western markets, the authors compared the design requirement identification practice for the two contexts from two aspects: 1) the phases in a design requirement identification process, 2) the viewpoints of design requirements.

Requirement identification phases

Respondents were asked to rank the five design requirement phases (elicitation, analysis, specification, validation and maintenance) with respect to how challenging they were in the process. The ranking was done separately for Danish market and emerging markets.

The ranking of each phase was coded with the value that equal to its rank. For instance, if requirement elicitation was ranked as the second most difficult, it would be coded as 2 in the analysis. A non-parametric Friedman test of the differences among the ranking of each phase was conducted respectively for Danish market and emerging markets. Friedman test is used to detect the differences between groups when the dependent variable is ordinal. For Danish market (n=92), the test rendered a Chi-square (χ^2) value of 72.57, which was significant (p=.000), while for emerging markets (n=65), the Chi-square (χ^2) value was 24.78, which was also significant (p=.000). The mean ranks and the values in the 25th, 50th (median) and 75th percentile of each phase is showed in Table 4. Here lower means indicated higher difficulty levels of the phase.

The results showed that for both western and emerging contexts, requirement elicitation and analysis were the two most difficult phases in a design requirement identification process. Particularly, in emerging markets, requirement elicitation was ranked as the most difficult phase.

Table 4 Descriptive statistics of the ranking of five phases in a design requirement identification process

Phase	Mean rank	Percentiles		
		25th	50th (Median)	75th
Danish market(n=92)				
Elicitation	2.50	1	2	4
Analysis	2.25	1	2	3
Specification	2.98	2	3	4
Validation	3.22	3	3	4
Maintenance	4.05	3	5	5
Emerging markets (n=65)				
Elicitation	2.38	1	2	4
Analysis	2.62	2	2	3
Specification	3.51	2.5	4	5
Validation	3.09	2	3	4
Maintenance	3.40	2	4	5

Post hoc comparisons using the Wilcoxon signed-rank test were conducted to check the where the differences actually occur.

The results showed that the difficulty level of requirement elicitation was not significant different from requirement analysis in both Danish market and emerging markets contexts. In Danish market, both requirement elicitation and analysis were found significantly more difficult than the rest three phases: requirement specification, validation and maintenance. The Z values and p values are presented in Table 5.

Table 5 Post hoc test of the difficulty differences between phases in Danish market (only the results for requirement elicitation and analysis were showed)

Phase	Compared phase	Z	p
Elicitation	Analysis	-1.01[a]	.314
	Specification	-2.14[b]	.032*
	Validation	-3.14[b]	.002**
	Maintenance	-5.54[b]	.000***
Analysis	Specification	-3.30[b]	.001**
	Validation	-4.43[b]	.000***
	Maintenance	-6.63[b]	.000***

a. Based on positive ranks.

b. Based on negative ranks.

* p < .05, **p < .01, ***p < .001

In emerging markets, requirement elicitation was significantly more difficult than specification, validation and maintenance, while requirement analysis was significant more difficult than specification and maintenance. The Z values and p values are presented in Table 6.

Table 6 Post hoc test of the difficulty differences between phases in emerging markets (only results for requirement elicitation and analysis were showed)

Phase	Compared with	Z	p
Elicitation	Analysis	-.86[a]	.389
	Specification	-3.55[a]	.000***
	Validation	-2.43[a]	.015*
	Maintenance	-3.19[a]	.001**
Analysis	Specification	-3.20[a]	.001**
	Validation	-1.92[a]	.055
	Maintenance	-3.00[a]	.003**

a. Based on negative ranks.

* p < .05, **p < .01, ***p < .001

Viewpoints in design requirements

To explore how design requirement identification is different from western markets to emerging markets from various perspectives, respondents were asked to rate how difficult it was to identify design requirements considering each viewpoint when developing for Danish market and for emerging markets respectively. The difficulty level of each viewpoint was rated by the respondents on a 5 point Likert scale from 1 (not at all difficult) to 5 (extremely difficult). The means (M) and standard deviations (SD) of the ratings were presented in Table 7.

Table 7 Descriptive statistics of the difficulty level of identifying design requirements considering each viewpoint

Viewpoint	Danish market (n=90)		Emerging markets(n=64)	
	M	SD	M	SD
User	2.29	.95	2.86	1.08
Corporation	2.08	.92	2.42	.92
Competition	2.39	.99	2.83	.97
Regional infrastructure	1.81	1.03	2.28	.86
Technology	2.38	.96	2.37	.93
Regulation	2.37	1.03	2.98	1.08
Organizational infrastructure	2.17	.90	2.76	.85
Average of all viewpoints	2.21	.67	2.64	.64

Friedman tests showed that the differences among the seven viewpoints were significant in both Danish market [χ^2 (6) =38.96, p=.000] and emerging markets [χ^2 (6) =45.15, p=.000]. The medians are reported in Table 8.

Table 8 Value of difficulty level for each viewpoint in the 25th, 50th (median) and 75th percentile when developing for Danish market and for emerging markets

Viewpoint	Danish market (n=90)			Emerging markets(n=64)		
	25th	50th	75th	25th	50th	75th
User	1	2	3	2	3	4
Corporation	1	2	3	2	3	3
Competition	2	2	3	2	3	3
Regional infrastructure	1	1	3	2	2	3
Technology	2	3	3	2	2	3
Regulation	2	2	3	2	3	4
Organizational infrastructure	1	2	3	2	3	3

The top three difficult viewpoints in Danish market were competition, technology and regulation, followed by user, organizational infrastructure, corporation, and regional infrastructure. And the gap between regulation and user was significant tested by a Wilcoxon signed-rank test, Z = -6.19, p=.000. And in emerging markets, the top four difficult ones in were regulation, user, competition and organizational infrastructure. The gap was not significant between competition and organizational infrastructure [Z = -.81, p=.416], but was significant between organizational infrastructure and corporation [Z = -2.57, p=.010].

A paired sample t-test was conducted to compare the differences between the two contexts. Table 9 displays the compared means (equal to values in Danish market minus values in emerging markets) and p values. The bigger absolute values of the compared means indicated larger differences between the contexts of developing for Danish market and for emerging markets.

The average mean of all viewpoint, in terms of how difficulty it was to identify design requirements from for emerging markets, was significantly higher than the average mean for Danish market. Six viewpoints (user, corporation, competition, regional infrastructure, regulation, and organizational infrastructure) were rated significantly more challenging when developing for emerging markets than for Danish market. No significant difference was found in technical viewpoint between the two contexts. The difficulty level dramatically increased from developing for Danish market to developing for emerging markets for three viewpoints: organizational infrastructure, regulation and user.

Table 9 Comparing the viewpoints in design requirement identification between developing for Danish market and for emerging markets (n=61)

Viewpoint	Compared means	SD	p (2-tailed)
User	-.53	1.18	.001**
Corporation	-.37	1.18	.016*
Competition	-.32	1.14	.030*
Regional infrastructure	-.389	1.12	.009**
Technology	.02	1.08	.907
Regulation	-.60	1.21	.000***
Organisational infrastructure	-.65	1.14	.000***
Average of all viewpoints	-.41	.77	.000***

* p < .05, **p < .01, ***p < .001

5. DISCUSSION

The study implies the importance of making efforts on design requirement identification when targeting the new context of emerging markets. Two reasons revealed by the results are discussed here.

First is the need of differentiating products for emerging markets. The results show the fact that roughly half of the western companies are either adapting existing products or developing new products for emerging market, and almost half of the respondents were positive about the differentiation. Moreover, research studies support that products sold to emerging markets should be redesigned or adapted for the local context. A couple of studies have found that the conditions especially the local market needs in emerging markets are very different from a western market [37], e.g. the lower income level and local frugal competitors' products affect users' behaviours. The existing products developed for western customers do not necessarily satisfy the customers in emerging markets. And it costs less for western companies to learn emerging markets and adapt their products for them than to change the markets or to educate the customers to accept the offered products [37-40]. This need of differentiating products for emerging markets calls for new processes and

methods to identify design requirements that are suitable for the new context [36].

Second, the challenges western companies are facing in emerging markets are connected with design requirement identification. The top three key challenges defined in this study can be interpreted as a lack of knowledge about the local regulations, business cultures and market needs. Particularly, regulations and market needs contribute to considerable amount of design requirements [41]. Facing those challenges indicates that western companies may have problems of identifying reliable and valuable design requirements or even be using inappropriate design requirements.

In addition, the study points out potential directions of where the efforts should be made on identifying design requirements when developing for emerging markets.

Firstly, requirement elicitation and analysis are found as the most challenging phases in a design requirement identification process. Particularly, requirement elicitation is challenging when developing for emerging markets. These two phases involve interaction with a number of external factors, which requires that a company to have not only professional knowledge to interpret and understand the market but also suitable approaches and adequate resources to gather sufficient information. This is particularly demanding for western companies in emerging markets because of 1) the complexity of accessing to information; 2) the lingual, social and cultural gaps that block the information communication and understanding.

Secondly, the study assesses seven viewpoints in design requirement identification and compares them between the western and emerging contexts. The results suggest that 1) the new context of emerging markets increases the difficulty level of identifying design requirements; 2) some viewpoints are influenced more by the shifting of the context than others. The seven viewpoints are hence be grouped into three categories based on their market-dependence:

Highly market-dependent viewpoint: a viewpoint in design requirement identification that highly depends on the target market. The requirements proposed from the viewpoints vary to a great extent from market to market. In this case, the highly market-dependent viewpoints are organizational infrastructure, regulation and user. Both regulations and users are context-dependent entities. Governmental regulations and regional standards are normally formulated by the local authorities and often different from place to place. Users are affected by the social and physical surroundings, and they perceive and use the products based on their own background and experience. Furthermore, when companies enter a new market, they often find new local partners, suppliers, manufacturers, or distributors. Those new organisational infrastructures on one hand contribute with their experience and understanding of the market, but on the other hand it increases the complexity of information gathering.

Slightly market-dependent viewpoint: a viewpoint in design requirement identification that depends on the target market but to a small extent. The requirements from those viewpoints can be different from market to market. In this case, the slightly market-dependent viewpoints are regional infrastructure, corporation, and competition. The regional infrastructures such as the power supply and internet access, are crucial in many cases to enable the use of a product, and they are particularly critical in the undeveloped areas. Corporates can modify their strategies or propose new strategies in the new markets which can be reflected on the product design. The competitors in the new market both local and international can have different features from those in a company's established market and hence results in changes in the design in order to compete with them.

Market independent viewpoint: a viewpoint in design requirement identification that does not depend on the target market. The requirements from those viewpoints remains the same or only be influenced limitedly by the target market. In this case, the market-independent viewpoint is technology. In most of the Danish companies, technology is considered as an internal competency. They often develop technology back home and utilise in other markets, hence it is limitedly influenced by new markets.

For specific cases, the market-dependence of each viewpoint can be different. For example, companies that develop products for a very niche market are competing with almost the same competitors all over the world. Changing the market does not changes much of the competition for them compared with other industries. Defining the market-dependence of each viewpoint can increase companies' awareness of the consequential changes when entering emerging markets.

Two viewpoints in design requirement, namely user and regulation are emphasized in this study due to 1) the highly increased relative difficulty level from western market to emerging markets; 2) the reflection to the highlighted key challenges. In addition, previous study indicate that user viewpoint contributes the most to the final design requirement set in terms of the number of requirements, followed by regulation and technology [41]. Hence, companies are suggested to focus their attention and effort to these two aspects when identifying design requirements for emerging markets.

The study also implies the challenges of identifying design requirements from regulations may be overlooked. Limited methods have been developed to support the design requirement identification from the regulatory viewpoint, which is probably due to the impression that regulations are normally well-documented, easy-accessed and context-dependent [42]. However, in the survey, respondents regarded the regulatory viewpoint as problematic to design requirements in both western and emerging contexts, particularly in the emerging context. Thus, it is necessary to revaluate the regulation's role in design requirement identification and develop necessary supports.

6. CONCLUSION AND FUTURE RESEARCH

This study investigates the design requirement identification practice in western companies under the context of developing for emerging markets. Relevant literature about product development for emerging markets from different fields, e.g. business, management, and design were reviewed. Empirical data were collected from a survey study conducted in Danish industry.

The study examines the differences between identifying design requirements for western market and emerging markets from two aspects: the process of design requirement identification and the viewpoints in requirement identification. The results highlighted the challenges that the industry is facing and the necessity of improving the theoretical understanding and supporting on design requirement identification for emerging markets. For the industry, the study indicates that western companies should focus their effort on identifying design requirements when developing for emerging markets, especially considering user needs and regulations.

The study is limited by its sample size and the representativeness of the Danish industry. The results would be generalizable if the study is extended to a larger sample and to other western countries.

Three potential topics are proposed for future studies. First is to deeply understand the reasons behind those challenges when companies developing for emerging markets and to understand companies' decisions in emerging markets, e.g. why sell existing products or adapt products. Second is to compare the differences and commonalities of product development for emerging markets between western companies and the local companies in emerging markets, and the possible learning from each other. Thirdly, by combining the first two points, supportive design methods or tools are needed to guide companies' practice in emerging markets. The majority of existing discussions on product development for emerging markets e.g. frugal innovation, are in such fields as innovation management and business. At the same time, design studies should follow up the trend and provide sufficient supports to facilitate the unique design tasks emerged under this specific context.

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Paper V: Identifying and Changing Design Requirements during the Product Development Process

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Identifying and Changing Design Requirements during the Product Development Process

Keywords: design requirements, product development, survey, case study, emerging markets

Abstract (max 200 words)

Design requirements in the context of emerging markets have become critical because the influence of emerging markets on product development has increased. This study investigates when design requirements are identified and also when changes to those requirements are permitted during product development processes. This study compares manufacturing companies' practices in western and emerging markets and discusses three contextual factors (i.e., users, competition and regulations) and their effects on design requirements. A survey of Danish (n=80) and Chinese (n=165) companies provides the primary data. Four case studies (two from Denmark and two from China) support the interpretation and discussion of the survey results. The results demonstrated that Danish companies focus their efforts on design requirements during the early stages of the product development process, and Chinese companies allow design requirements to be changed later in the product development process. Noticeable differences in the effects of competition and regulations on the two different contexts were noted, which impact how design requirements are identified and changed. This study extends conventional knowledge about design requirements that was developed in western contexts to emerging markets and provides information for companies in both contexts that addresses design requirements during the product development process.

1 Introduction

Identifying design requirements is a critical component of the product development process and a central issue for design research (Chakrabarti 1994). Traditional product development models often suggest that design requirements should be identified during the early stages of the product development process. In practice, design requirements may need to be changed because of a number of factors such as new legal requirements, unexpected competitor situations and customer preferences (Almefelt et al. 2006). Therefore, identifying design requirements is an iterative process, and design requirements co-evolve with the product development process (Sudin and Ahmed-Kristensen 2011; Darlington and Culley 2002).

The influence of emerging markets (e.g., Brazil, China and India) on product development is growing. Therefore, it is increasingly valuable to gain an advanced understanding of how design requirements are identified in the context of emerging markets. The impressive size and growth rate of emerging markets (Hoskisson et al. 2000; Gu, Hung, and Tse 2008; Hitt et al. 2000) attract a large number of western manufacturing companies. In addition, increasingly more companies that originate in emerging markets perform well in product development. For example, China has been broadly perceived as a new centre of gravity for global R&D activities (Chen and Vang 2008; Li and Yue 2005).

Emerging markets have different social, cultural, political and economic contexts than western markets (Dubiel and Ernst 2012). These differences result in different needs and requirements for products. For example, one study indicated that Russia's cultural features (e.g., high power distance, femininity, high uncertainty avoidance) affected the preferred designs in the Russian market (Salmi and Sharafutdinova 2008). These scholars demonstrated that socio-cultural factors (e.g., national cultural politics, mass culture, the importance of mainstream fashion, and a distinct expression of masculinity and femininity in dress and other public behaviour) affected customer requirements.

In addition, these differences between emerging markets and western markets influence product development processes. For companies that originate in emerging markets, the early process design activities such as need definition and conceptual design are, in certain cases (e.g., Kenyan companies), not standardised, and design decisions are not documented (Donaldson 2006). User involvement occurs more often during the later stages of the product development process in companies that originated in emerging markets when compared to western companies (Li and Ahmed-Kristensen 2014).

Despite certain exceptions, prior studies regarding how product development processes are influenced by the emerging market context are scarce, and most design research is conducted in the context of developed countries and relatively affluent markets (Viswanathan and Sridharan 2012; Jagtap and Larsson 2013; S. Jagtap, Larsson, and Kandachar 2013; Jagtap et al. 2014). Currently, there is only a limited understanding of product development processes in the context of emerging markets. Specifically, it is not well understood how emerging markets affect the identification and management of design requirements. Do design requirements co-evolve with the product development process in the same manner for emerging markets as in western markets? What are the influential factors? These questions remain unanswered.

Therefore, this study seeks to gain a better understanding of the processes used to identify design requirements by comparing the product development practices of manufacturing companies in western and emerging markets. This study focuses on the co-evolution of design requirements and the product development process. The analysis is based on data collected from a survey and multiple case studies. This study has two primary goals: first, to advance the knowledge of design practices in emerging markets and examine the suitability of traditional design knowledge in this new context; and second, to better understand the evolution of design requirements, (e.g., by analysing when the design requirements are identified and changed during the product development process). Two primary research questions are formed to guide the study:

Research question 1: What are the differences in the processes that companies use to identify and change design requirements between western and emerging markets?

Research question 2: What factors affect these differences?

2 Literature Review

This section reviews relevant research studies and includes a description of the processes that companies use to identify and change design requirements (Section 2.1). In addition, this section provides a summary of the characteristics of emerging markets (Section 2.2) and compares product development between western and emerging markets (Section 2.3).

2.1 Identifying and Changing Design Requirements

Design requirements describe the qualitative and quantitative definition[s] of the functions and constraints that should be fulfilled by a product (VDI 1987). Identifying design requirements is a central component of the design process (Jevnaker 2005; Haug 2015; Rizal 2005); poorly defined design requirements can lead to inappropriate products and even project failures (Hall, Beecham, and Rainer 2002).

Design requirement identification requires comprehensive information from multiple sources. Sudin, Ahmed-Kristensen, and Andreasen (2010) categorised design requirement sources into two groups: human sources (e.g., clients, end users, and colleagues) and artefact sources (e.g., semi-developed specifications, proposed solutions, existing products, prior projects, and guidelines). Stakeholders (e.g., customers, marketers, and designers) (Brace and Cheutet 2012) often represent the human sources that generate requirements. Similarly, Cooper, Wootton, and Bruce (1998) separated the sources into individuals (e.g., customers, users or suppliers), written materials (e.g., books, trade journals, or technical manuals), and objects (e.g., competitors' products) and suggested that firms differentiate between internal and external sources. Sources, particularly external sources such as customers, are context dependent and consequently vary for different markets. For example, a Chinese user may have different requirements for a product than a Danish user, and special regulatory requirements could exist for the Chinese market that a product would have to fulfil prior to entering the market.

It is often suggested that design requirements should be identified early in the product development process (Cross 2008) because of their influence on the entire process, and the costs for design changes increase dramatically if they are not implemented early in the process (Abts and Schaudt 2015). Ulrich & Eppinger (2011) propose a generic product development model that includes six stages: planning (pre-stage), concept development, system-level design, detail design, testing and refinement, and production ramp-up. In this model, customer needs should be identified at the beginning of the concept development phase. Then, the product specifications are established during a two-stage process. The target specifications are determined immediately after identifying the customers' needs. The final specifications are established after the product concept has been determined. Similarly, Pahl et al. (2007) offers a comprehensive model of the design process that includes the following design stages: planning and task clarification, conceptual design, embodiment design, and detail design. For this model, the design requirements should be determined during the planning and task clarification stages.

However, in practice, clear and unambiguous design requirements are rarely identified during the early stages of the product development process (Haug 2015). Researchers have recognised that the process for identifying design requirements is iterative and design requirements co-

evolve with the product development process (Sudin and Ahmed-Kristensen 2011; Darlington and Culley 2002) because clearly understanding the problems and developing solutions are two aspects that also co-evolve (Dorst and Cross 2001). Suwa, Gero, and Purcell (2000) studied the architectural design process using protocol analysis. These scholars provided empirical evidence of the co-evolution of the problem-space and the solution-space. Maher and Tang (2003) proposed four types of requirement changes: adding new problem requirements, refining problem requirements, searching for new problem requirements and re-examining problem requirements. Ahmed and Kanike (2007) determined that specification changes were likely to occur during the development and prototype phase and more than likely to occur during the design phase, before changes are documented.

Studies have been conducted to analyse the reasons for requirement changes and their co-evolution with the product development process. Both internal and external factors initiate requirement changes (Morkos, Shankar, and Summers 2012). Almefelt et al. (2006) revealed the underlying factors for changes in requirements that included knowledge gained through development work (e.g., through testing), conflicting requirements, technical difficulties in meeting a high specification, opportunities for function-sharing and synergies, unexpected demands to reduce costs, new legal requirements, and unexpected competitor situations and customer preferences that result in changed market requirements. Sudin and Ahmed-Kristensen (2011) proposed a mechanism to determine when a requirement change is needed, and the mechanism includes internal factors of change (i.e., requirement analysis and solution evaluations) and external factors of change (i.e., technology changes, market demands changes and customer requests changes). Vajna et al. (2005) stated that requirements could be affected by changes in technology, trends, perceptions, and regulations.

However, many of these studies were conducted with a focus on only one or a few projects or companies and are mostly related to product development for western markets. Therefore, little is known about how firms identify and change requirements differently between the western and emerging market contexts, and an analysis of this issue is needed.

2.2 Characteristics of Emerging Markets

There is a broad consensus that emerging markets differ from conventional western markets in a number of dimensions (Sheth 2011). Many of emerging markets' distinctive characteristics significantly affect product development processes and design requirements. Four characteristics are summarised along with their relevance to product development in the following section.

2.2.1 Low average per capita income and inadequate infrastructure

Despite their rapid growth, emerging markets have a per capita income that is lower than average (Kuepper 2016; Heakal 2015). Their infrastructure is generally inadequate (Sheth 2011), which requires specific focus on the price-performance relationship and resource-constrained limitations as they relate to design requirements. This issue has prompted a number of design studies that address low-income populations (e.g., studies on design for the bottom of the pyramid).

2.2.2 Distinctive socio-cultural contexts

Emerging markets that are located in the Middle East, Latin America, East and Southeast Asia and Africa, have entirely different histories, cultures and social customs and differ greatly from western markets (e.g., West and Northern Europe and North America). It is critical that companies understand these cultural differences and adapt their strategies and products (Dubiel and Ernst 2012). Numerous stakeholders in design (e.g., users and customers) are immersed in the context and are also affected by the local culture.

2.2.3 Underdeveloped legal and regulatory environments

The regulatory environments of emerging markets are unstable and underdeveloped, and enforcement of existing rules is insufficient. The external institutions in emerging markets, which may be associated with, for example, highly bureaucratic and corrupt legal-political governance (Bruton et al. 2010; Khanna and Palepu 1997), make the innovation process particularly challenging (Chen et al. 2013).

2.2.4 Severe competition

In emerging markets, a company competes with a large number of both local and international competitors (Gu, Hung, and Tse 2008). In emerging markets, 60% of the consumption is of unbranded products and services (Sheth 2011). In addition, competition is chaotic due to relatively poor intellectual property rights protections and other consequences of underdeveloped regulatory environments. Severe competition may incite companies to closely monitor competitors' activities and include any new information in their design requirements.

These characteristics indicate possible reasons for differences in product development processes and the identification of design requirements between companies in emerging and western markets and highlight specific challenges for emerging markets.

2.3 Product Development in the Contexts of Western and Emerging Markets

Products developed for emerging markets and their requirements are affected, to a large extent, by contextual factors (e.g., customers, competition and regulations). Salmi and Sharafutdinova (2010) analysed mobile phones in Russia and determined that Russia's cultural features (e.g., high power distance, femininity, and high uncertainty avoidance) influenced the preferred design in the Russian market. Donaldson (2006) stated that Kenyan customers did not trust vendors and had a 'West is the best' bias. Kenyan product buyers and sellers focused on a short-term perspective, which reflected the prevalent desire for 'quick profit'. Er (1997) determined that competition was the vital ingredient for industrial design in the context of newly industrialised countries. Parry and Song (1994) suggested that regulations' effects on production were one of the primary constraints for Chinese state-owned enterprises that developed new products. Li, Ahmed-Kristensen, and Daalhuizen (2016) determined that identifying design requirements was more challenging for emerging markets than for western markets and considered six factors that included users, organisations and businesses, regulations, competition, regional infrastructure, and other stakeholders.

Product development is organised differently in western markets than in emerging markets and is often considered to be less advanced in emerging markets than in western markets. For example, Donaldson (2006)'s study demonstrated that Kenyan engineers and technicians from industrialised sectors lacked design expertise and did not understand the need for a rigorous design process. This scholar observed that firms concentrated on the detailed design and manufacturing phases of the product development processes in Kenya; the early design phases (i.e., need definition and conceptual design) were absent when adapting designs or importing foreign designs for local markets. Li and Ahmed-Kristensen (2014) compared the product development processes for Danish and Chinese manufacturing companies. These scholars noted that the projects were more controlled in the Danish companies than in the Chinese companies, particularly during the early stages of the product development process. In addition, the Danish companies involved product users during the early stages, in contrast to the Chinese companies. Jagtap et al. (2014) investigated design processes used for the base of the pyramid (BOP) and top of the pyramid (TOP) markets in terms of the design strategy employed by the designers, requirement handling behaviour, and information behaviour. Their study determined that the BOP designers used a problem driven strategy, and the TOP designers used a solution driven strategy; the BOP designers engaged in more planning activities to address design requirements and spent more effort evaluating the design requirements.

Despite the efforts made to address emerging markets, prior studies on design that focused on design requirements were predominately conducted in the context of developed countries and relatively affluent markets (Viswanathan and Sridharan 2012; Jagtap and Larsson 2013; Jagtap, Larsson, and Kandachar 2013; Jagtap et al. 2014). Donaldson (2006) stated that design studies that address emerging markets are largely descriptive and characterise the design process and the environment differences relative to more industrialised economies. To the best of the authors' knowledge, few studies have analysed design requirements with a specific focus on emerging markets.

3 Research Method

This section explains the research approach and describes the data collection and analysis methods.

The goal of this research is to compare manufacturing companies' processes for identifying and changing design requirements in the context of western and emerging markets. For practical reasons, the authors investigated Danish and Chinese companies to represent these two contexts. Denmark is a developed country with sufficient infrastructure and advanced innovation capacity. China is perceived as one of the most representative countries of emerging markets. China is one of the most popular emerging markets and has maintained a considerably high economic growth rate (Mutum, Roy, and Kipnis 2014). The contrast between Denmark and China is expected to provide valuable insights on practices for these two different contexts. This study focuses on design requirements for a home market (i.e., Danish companies developed products for the western context, and Chinese companies developed products for the emerging market context). Designing for foreign markets is a control variable and investigates whether the target market influenced design requirements.

The data for this study was collected using two methods and included data for both the Danish and Chinese manufacturing industries. A survey questionnaire was distributed and used as the primary data source to specify quantitative differences in the design requirement practices between the two contexts. Four case studies were performed to gather complementary data and to better understand the practices and determine any possible explanations for the survey results. Section 3.1 presents information regarding the survey, and Section 3.5 describes the case studies.

3.1 Survey

This section presents the survey instrument, the design and sampling processes, the validity check, and the sample characteristics.

3.1.1 Survey Design and Instrument

The survey used for this study was originally designed in English by the research team. The survey was evaluated by five other academic experts for clarity and unambiguity, then revised in several iterations based on this feedback. A native-speaking researcher on the research team translated the survey into Chinese using the same structure and questions to ensure comparability (Leeuw, Hox, and Dillman 2008) and to capture both commonalities and differences in and across the two cultures (Kumar 2000). Three independent native Chinese speakers (one academic expert and two industrial experts) checked the Chinese version for clarity and unambiguity.

The survey included four sections: 1) background information for the respondent and their respective company, 2) the product development processes used in the company, 3) the processes for identifying design requirements and 4) a description of the factors that influenced design requirements.

The primary issues that were investigated in the survey include the following:

The product development process: the product development processes used by the companies were investigated with reference to the generic product development model that was developed by Ulrich & Eppinger (2011). To document the product development process that was used by the company, respondents were asked if their own processes included stages that were the same or similar to those in the model. The survey included open-ended questions such as, “If your product development process involves other stages, please specify.” This type of question enabled respondents to specify activities that were not included in this model.

Design requirements, as related to the product development process: this section investigated how companies identified design requirements during the product development processes from two dimensions: 1) the stage of the product development process that design requirements were identified; and 2) how changes to design requirements were addressed and when they were permitted in the process.

Factors that influenced design requirements: three influential factors were analysed to improve the understanding of contextual differences and include the following.

- *Users*: for this study, this term refers to customers and users that buy or use the product. The user's perspective is generally considered to be the basis for product development (Wang and Tseng 2014). Users are important because they directly influence the identification of design requirements (Chen, Khoo, and Yan 2003).
- *Competition*: this term refers to competition in the market and should be assessed when companies identify design requirements because of the risk of institutionalising old and non-competitive designs (Tseng and Jiao 2007). Competition is one of the primary external reasons for requirement changes (Fricke et al. 2000).
- *Regulations*: this term refers to government regulations and international and regional standards. Almefelt et al. (2006) determined that new legal requirements are factors that lead to changes in requirements for projects. Specifically, the regulatory environment is different for western and emerging markets.

The participants' responses that were related to the three influential factors were measured by two dimensions: first, the contribution of the three influential factors to design requirements; and second, the difficulty in identifying design requirements when considering the three influential factors. Five-point Likert scales were applied for these measurements. The scale ranged from "no contribution" to "essential contribution" to measure contribution and ranged from "not at all difficult" to "extremely difficult" to measure the difficulty in identifying design requirements. The scales were coded as 1-5 in the analysis, as illustrated in Table 1.

Table 1 Code scheme of responses for the contribution and difficulty of the influential factors on design requirements.

Code	1	2	3	4	5
Responses for contribution	No contribution	Slight contribution	Moderate contribution	Significant contribution	Essential contribution
Responses for difficulty	Not at all difficult	Slightly difficult	Somewhat difficult	Very difficult	Extremely difficult

3.2 Sampling process

The survey was distributed online and used different sampling processes in China (Chinese version) and in Denmark (English version). In Denmark, the research team conducted the sampling. In China, the sampling was outsourced to a third party service agency because the contact information for Chinese companies was not available; this approach has been adopted by other researchers (e.g., Zhou et al. 2013; Chen, Cheng, and Urpelainen 2015). The sampling process used for each country is described in detail in the following section.

In Denmark, the companies were recruited from multiple sources to minimise sample homogeneity (Sawang and Unsworth 2011). The first source, Bisnode (a professional business information provider), provided a list of companies that was extracted from a database of Danish companies. From this database, companies were selected using two criteria: 1) manufacturing companies were selected by using the NACE (Nomenclature of Economic Activities) code (category C) (European Commission 2010) and 2) firms that exported to foreign countries (an option provided by the database). The list included 1726 companies, and

1570 companies provided a valid company email address. The second source was a list of Danish subsidiaries in 17 foreign countries (e.g., Argentina, Brazil, Chile, China, and Portugal) that was downloaded from the Ministry of Foreign Affairs of Denmark. From this list, the research team identified 366 additional manufacturing companies. Among these, 239 companies provided valid email addresses for specific individuals (managers and product development related positions, e.g., product managers, were prioritised), and 127 companies provided valid general company email addresses.

The survey was submitted to all 1936 companies with an email invitation that was followed by two reminders. In total, 119 responses were collected from the two sources. A total of 46 responses were obtained from the first source, with a 2.5% response rate, and 73 responses were obtained from the second source, with a 19.9% response rate. Although the response rate for the first source was low, this was expected because the email addresses that were extracted from the database were often for general information or customer service and were less likely to generate interest in supporting academic research or reach an individual who possessed the necessary knowledge to respond to the survey. The low response rate was also expected and often occurs when the self-enumeration method is applied, i.e., a respondent completes a questionnaire without the assistance of an interviewer (Statistics Canada 2010).

In China, the survey responses were collected by a paid sampling service that used a generally acknowledged online survey platform, 'Sojump', which has been used by other research studies. (see e.g., Zhou et al. 2013; Chen, Cheng, and Urpelainen 2015). This platform has a user base of more than 2.6 million voluntary users and is similar to a crowdsourcing platform, e.g., the Mechanical Turk (Kaufmann, Schulze, and Veit 2011). The study used three criteria to recruit participants from the user base. First, the participants worked in a manufacturing company (controlled by the survey platform). Second, the company was located in the Yangtze (Changjiang) River Delta in China. The Yangtze River Delta includes the Shanghai municipality, the Zhejiang province and the Jiangsu province and was selected because it is a hub of the Chinese economy (see, e.g., Marton 2000). In addition, numerous manufacturing companies operate in the Yangtze River Delta. Third, the company exported products to foreign countries (controlled by the survey platform).

A total of 23113 surveys were submitted, and 252 responses were collected, which resulted in a 1% response rate. This response rate was very low and can be explained by the following three reasons. First, the Sojump service did not screen participants for their suitability prior to submitting the survey and therefore resulted in a large percentage of unsuitable participants. Second, reminders were not sent, and third, the respondents did not receive assistance from an interviewer to complete the survey (self-enumerated) (Statistics Canada 2010).

3.3 Validity check

The process resulted in 371 total responses from both China and Denmark that were reviewed and checked for validity. All incomplete, repeated and invalid answers were removed. Incomplete answers included all responses that did not complete all the compulsory questions. Repeated answers included all responses that were submitted from the same IP address more than once. Invalid answers were noted when a participant responded that they did not

understand the survey, responded with meaningless random letters for the optional open questions or selected the same option for all the questions. A total of 125 responses were removed from the analysis, which reduced the total valid responses to 246 (66.3%) (see Table 2). An additional review was conducted by the research team; 25 (10%) of the 245 valid answers were randomly selected to confirm the company name, size and contact information (the participant was permitted to voluntarily provide their information for future contact after the survey). All 25 responses were valid; the company name represented an existing company, and the contact information (if provided) was valid and consistent (i.e., the company name and size matched the public information).

Table 2 Overview of deleted answers from China (CN) and Denmark (DK)

	CN	DK	Total
Total answers	252	119	371
Deleted answers			
Invalid answers	86	1	87
- Incomplete answers	1	36	37
- Repeated answers	0	2	2
Valid answers	165 (65.5%)	80 (68%)	245 (66.3%)

3.4 Sample Characteristics

The final sample included 165 responses from China and 80 responses from Denmark. The sample included a wide spectrum of company sizes that ranged from micro to large. Table 3 and Table 4 illustrate the distribution of companies and the total number of employees. Both the number of total employees and the number of non-production employees were recorded during the survey. Non-production employees were not directly engaged in the production process. This information increased the equivalency between China and Denmark because many Chinese manufacturing companies employ a large number of production employees, but Danish companies often outsource their manufacturing processes to other countries (Hansen and Ahmed-Kristensen 2010).

Table 3 Distribution of companies for total number of employees

	Size class (total number of employees)						
	<10	10-49	50-199	200-499	500-1000	>1000	Total
CN (n=165)							
Number of companies	1 (0.6%)	3 (1.8%)	27 (16.4%)	49 (29.7%)	44 (26.7%)	41 (24.8%)	165 (100%)
DK (n=80)							
Number of companies	6 (7.5%)	26 (32.5%)	24 (30.0%)	11 (13.8%)	3 (3.8%)	10 (12.5%)	80 (100%)

Table 4 Distribution of companies for total number of non-production employees

	Size class (total number of non-production employees)						
	<10	10-49	50-199	200-499	500-1000	>1000	Total
CN (n=165)							

Number of companies	5 (3.0%)	66 (40.0%)	50 (30.3%)	22 (13.3%)	11 (6.7%)	11 (6.7%)	165 (100%)
DK (n=80)							
Number of companies	21 (26.3%)	30 (37.5%)	18 (22.5%)	3 (3.8%)	2 (2.5%)	6 (7.5%)	80 (100%)

To compare the differences in company size for Denmark and China, one-way ANOVA tests were conducted. The results indicated that in the sample, Chinese companies were significantly larger than Danish companies both in terms of total employees (M(CN)=4.55, SD(CN)=1.123; M(DK)=3.11, SD(DK)=1.432, F(1,243)=72.874, and p=.000) and the number of non-production employees (M(CN)=3.01, SD(CN)=1.237; M(DK)=2.41, SD(DK)=1.384, F(1,244)=11.463, and p=.001).

The survey collected information regarding the positions held by the respondents in their company. Respondents held various positions, including business owners, top managers, mid-level managers, and employees. Respondents were involved in various functions of the company's engineering design activities (e.g., R&D, production, management and marketing), and their diverse backgrounds provided insights from several perspectives.

The survey included a question about the respondents' experience in product development (see Table 5). The Chinese respondents had significantly less experience in product development than the Danish respondents (as determined by one-way ANOVA tests, M(CN)=1.97, SD(CN)=.768; M(DK)=2.33, SD(DK)=.897, F(1,243)=10.304, and p=.002).

Table 5 Respondents' experience in product development

	Years of experience in product development		
	<5 years	5-10 years	>10 years
CN (n=165)			
In general	51 (30.9%)	68 (41.2%)	46 (27.9%)
For foreign markets	95 (57.6%)	45 (27.3%)	25 (15.2%)
DK (n=80)			
In general	23 (28.7%)	8 (10.0%)	49 (61.3%)
For foreign markets	30 (37.5%)	6 (7.5%)	44 (55.0%)

3.5 Case studies

In addition to the survey data, four case studies were conducted to support the survey results with a qualitative analysis. Two Danish companies and two Chinese companies were included in the case studies; all were manufacturing companies and exported products to foreign markets (see Table 6). All four companies were among the leading players in their home markets, and they all applied plan-driven product development processes that were comparable to a generic product development process (Ulrich and Eppinger 2011). The case companies varied in size and industry. Because this study focuses primarily on a qualitative analysis of the survey findings instead of a quantitative analysis of the companies, these differences were not deemed critical.

Table 6 Overview of the four cases analysed in this study

Company	Company A	Company B	Company C	Company D
Country	Danish	Danish	Chinese	Chinese
Product	Medical devices	Medical devices	Lighting LEDs	Consumer electronics
Registration date	2001	1985	2007	1994
Size (Total employees)	Approx. 500	31	Approx. 1300	Approx. 6000
Size (Non-production employees)	Approx. 150	19	Approx. 500	Approx. 4000

For each case, interviews were conducted with employees who were involved in product development (e.g., project management and design). The research team conducted a total of 11 interviews with 11 different interviewees. The interviews were audio recorded with permission and were semi-structured to ensure consistency across the cases by using the same questions and allowed interviewees to answer freely. The interviews were conducted in English for the Danish companies and in Chinese for the Chinese companies. The interview language was selected based on the interviewee's preference. The interviews were analysed in the original language. The key issues discussed in the interviews include the following:

1) the product development process utilised by the company,
2) the stage of the product development process that design requirements were identified,
3) the sources were used to identify design requirements,
4) changes to design requirements and at what stage in the process they were permitted,
5) factors that influenced design requirements, and
6) how processes differed for home and foreign markets.

In addition, documents from three companies (A, C and D), including product development process documents and requirement documents, were reviewed during the data analysis. The research team was not able to access documents from Company B due to confidentiality issues. The data overview is presented in Table 7.

Table 7 Overview of data collected from the four cases

Company	Company A	Company B	Company C	Company D
Interviewees	Managing Director Marketing Manager Quality Manager R&D Manager	Designer Product Manager	Product Manager Project Manager Technologist	Managing Director Product Manager
Documents reviewed	Process doc. Requirement doc.	N/A	Process doc. Requirement doc.	Process doc. Requirement doc.

4 Survey Results

This section presents the results from the survey. The survey results and the four case studies are assessed in greater detail in Section 5. The primary focus of this study is on the home market; therefore, all results refer to designing products for the home market unless otherwise stated.

4.1 Identifying and Changing Design Requirements

Danish companies and Chinese companies were compared to determine at which stage of the product development process the design requirements were identified. The respondents were asked to select the stage(s) during which they identified design requirements. The generic model by Ulrich and Eppinger (2011) was used as a reference.

Figure 1 illustrates the percentage of Danish and Chinese companies that identified design requirements at each stage of the product development process. Respondents were able to select multiple stages. In Denmark, a large percentage of companies identified design requirements during the first two stages: the planning stage (52.5%) and the concept development stage (45.0%). Fewer than 20.0% of the Danish firms identified design requirements during any of the remaining stages (i.e., system-level design, detail design, testing and refinement, and product ramp-up). The highest percentage (43.6%) of Chinese companies identified design requirements during the concept development stage, followed by 38.8% during the planning stage. More than 20% of Chinese firms identified design requirements during the later stages; however, this was less than for the first two stages. These results indicate that more Chinese companies identified design requirements during the later stages of the product development process.

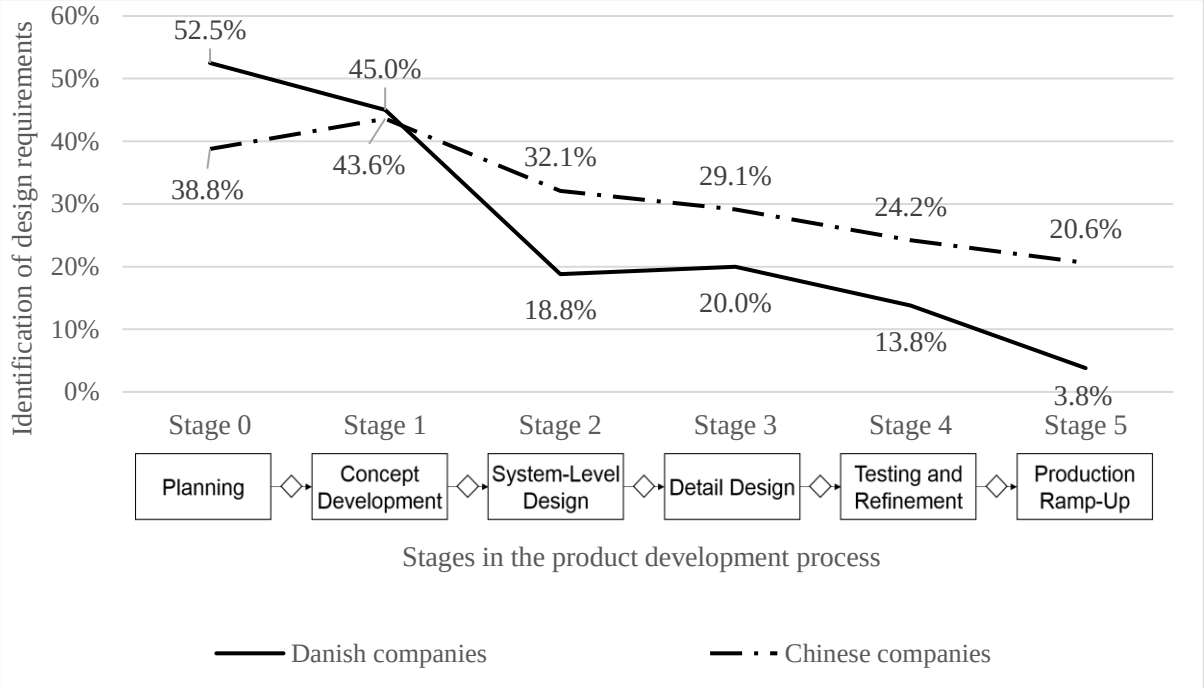

Figure 1 The stage(s) in the product development that companies identified design requirements.

The Chinese and Danish companies reported that design requirements were identified at each stage of the product development process; these results were tested by one-way ANOVA. The results are reported in Table 8 and indicate that Danish companies significantly more often identified design requirements during the planning phase, and Chinese companies significantly

more often identified design requirements during the system-level design and production ramp-up stages.

Table 8 Differences in the identification of design requirements at each stage for Denmark (DK) and China (CN)

Stage	DK (n=80)		CN (n=165)		Difference between DK and CN	
	M	SD	M	SD	F(1,243)	Sig.
Planning	.53	.503	.39	.489	4.163	.042*
Concept development	.45	.501	.44	.497	.040	.841
System-level design	.19	.393	.32	.468	4.860	.028*
Detail design	.20	.403	.29	.456	2.310	.130
Testing and refinement	.14	.347	.24	.430	3.622	.058
Production ramp-up	.04	.191	.21	.406	12.449	.001**

* p < .05, **p < .01, ***p < .001

Respondents were asked to indicate which stage(s) in the product development process that changes were made to design requirements. Figure 2 illustrates the percentages of Danish and Chinese companies that change design requirements at each stage in the product development process. The largest number of Danish companies (35.0%) changed requirements during the concept development stage. The largest number of Chinese (47.9%) changed requirements during the testing and refinement stage. It appears that Danish companies identified and addressed changes early in the product development process, but Chinese companies identified changes during the testing stage.

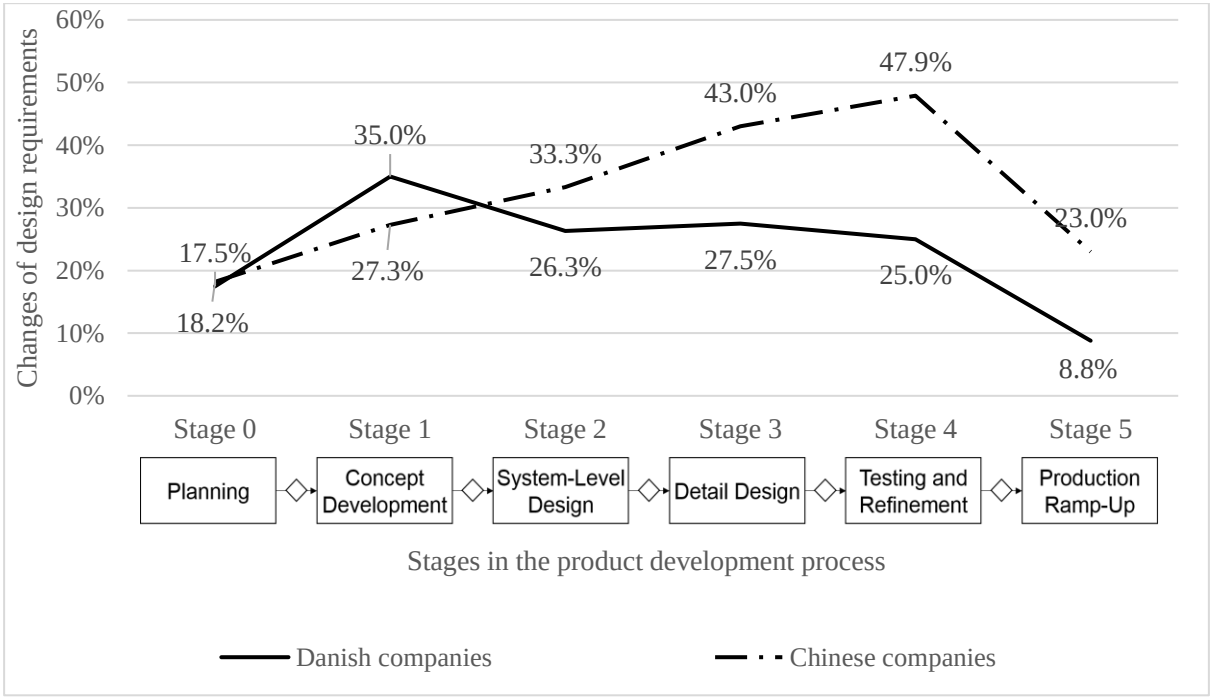

Figure 2 The stage(s) of the product development process that companies changed design requirements.

The one-way ANOVA tests indicated that significantly more Chinese companies changed design requirements during the later stages of the product development process (i.e., the detail

design stage, the testing and refinement stage or the product ramp-up stage) than Danish companies (see Table 9).

Table 9 Differences in the stages that design requirement changes were permitted for Denmark (DK) and China (CN)

Stage	DK (n=80)		CN (n=165)		Difference between DK and CN	
	M	SD	M	SD	F(1,243)	Sig.
Planning	.18	.382	.18	.387	.017	.897
Concept development	.35	.480	.27	.447	1.535	.217
System-level design	.26	.443	.33	.473	1.260	.263
Detail design	.28	.449	.43	.497	5.599	.019*
Testing and refinement	.25	.436	.48	.501	12.199	.001**
Production ramp-up	.09	.284	.23	.422	7.492	.007**

* p < .05, **p < .01, ***p < .001

A comparison was conducted between the home and foreign markets of the Danish and Chinese companies to determine if there were differences in when design requirements were identified and changed (see Table 10). As in the prior results, for both home market and foreign markets, Chinese companies identified and changed design requirements during the later stages in product development, and the Danish companies changed design requirements during the earlier stages in product development. Therefore, it is reasonable to state that differences in identifying and changing design requirements between Danish and Chinese companies were primarily due to the country of origin of the companies. The target market context (i.e., whether the product was developed for western markets or emerging markets) may have affected these differences, but does not appear to be the primary reason for these differences in this case.

Table 10 Differences in identifying and changing design requirements at each stage for China (CN) and Denmark (DK) when designing for foreign markets

Stage	DK (n=80)		CN (n=165)		Difference between DK and CN	
	M	SD	M	SD	F(1,243)	Sig.
Identifying design requirements						
Planning	.54	.502	.44	.498	1.953	.164
Concept development	.54	.502	.41	.494	3.438	.065
System-level design	.25	.436	.39	.489	4.594	.033*
Detail design	.24	.428	.33	.473	2.351	.127
Testing and refinement	.19	.393	.35	.477	6.599	.011*
Production ramp-up	.06	.244	.24	.430	12.113	.001**
Changing design requirements						
Planning	.18	.382	.22	.418	.789	.375
Concept development	.39	.490	.25	.437	4.601	.033*
System-level design	.34	.476	.39	.490	.728	.394
Detail design	.33	.471	.50	.502	7.057	.008**
Testing and refinement	.28	.449	.50	.502	11.902	.001**
Production ramp-up	.11	.318	.30	.458	10.499	.001**

* p < .05, **p < .01, ***p < .001

4.2 Influential Factors

Three influential factors (i.e., users, competition and regulations) were analysed in this study through two constructs. The first construct was contribution and was measured by how much each factor contributed to identifying the requirements during the product development process. The second construct was difficulty and referred to how difficult it was to identify requirements when considering these factors.

4.2.1 Contribution to design requirements

Table 11 presents the descriptive statistics of the three factors and the differences for the Danish and Chinese companies (one-way ANOVA test). No significant differences were observed for users and regulations for the Danish and Chinese companies. However, the competition's contribution was rated significantly different for the Danish and Chinese companies.

Table 11 Contribution of the three factors - users, competition and regulations - to design requirements for firms operating in Denmark (DK) and China (CN)

Factor	DK		CN (n=165)		Difference between CN and DK	
	M	SD	M	SD	F	Sig
Users	3.61 (n=80)	1.355	3.62	.836	.007 (1,243)	.934
Competition	2.76 (n=78)	1.197	3.69	.867	47.715 (1,241)	.000***
Regulations	3.42 (n=78)	1.419	3.39	1.057	.032 (1,241)	.858

* p < .05, **p < .01, ***p < .001

The differences of the three factors were analysed in greater detail for each context by using the Kruskal-Wallis Test. The results indicated that the differences in contribution among the three factors were significant for the Danish companies [$\chi^2(2) = 19.131$ p = 0.000] and the Chinese companies [$\chi^2(2) = 6.660$ p = 0.036]. Post hoc tests (Mann-Whitney Test) were conducted to analyse the differences in contribution for the three factors (results presented in Table 12).

Table 12 Comparison of the influential factors' contribution to design requirements

Comparison of the factors	DK (n=78)		CN (n=165)	
	Z	Sig (1-tailed)	Z	Sig (1-tailed)
Users vs. competition	-4.317	.000***	-.694	.244
Users vs. regulations	-.789	.215	-1.860	.032*
Competition vs. regulations	-3.075	.001**	-2.442	.008**

* p < .05, **p < .01, ***p < .001

As illustrated in Figure 3, among Danish companies, competition contributed significantly less to design requirements than users and regulations; the analysis did not determine any significant difference between users and regulations. For Chinese companies, both users and competition contributed more to design requirements than regulations, and the analysis did not determine any significant differences between users and competition. These results indicate that Chinese

companies focus more on competition and users, and Danish companies focus on users and regulations when considering design requirements.

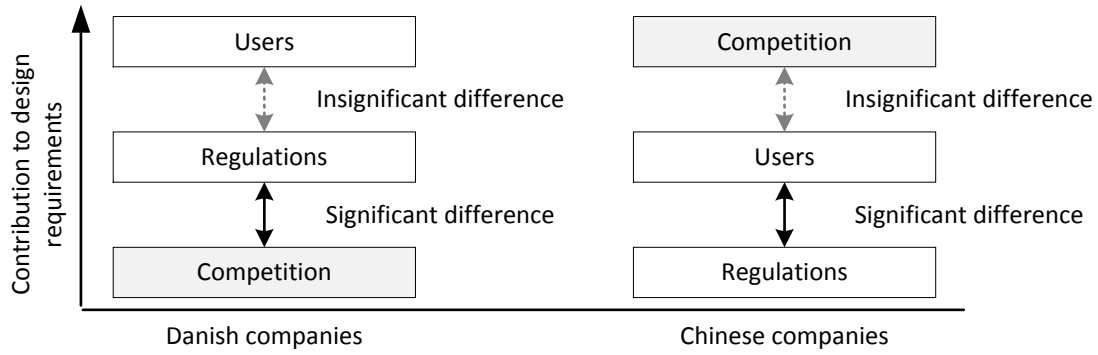

Figure 3 The contribution of users, competition and regulation to design requirements

4.2.2 Difficulty in identifying design requirements

To measure the difficulty associated with the three factors, respondents were asked to identify the level of difficulty for identifying design requirements when considering the factors. Table 11 presents the descriptive statistics of the three factors and the differences for companies that operated in Denmark and China (one-way ANOVA test). For all three factors, the rating was significantly higher in China than in Denmark. These results could have occurred for two reasons: 1) Design requirements were more challenging for Chinese companies than for Danish companies, or 2) Chinese respondents, in general, responded with higher ratings. Therefore, the relative rates between the three factors within each context were more valuable in this case.

Table 13 The difficulty in identifying design requirements when considering users, competition and regulation for Denmark (DK) and China (CN)

Factor	DK		CN (n=165)		Difference between CN and DK	
	M	SD	M	SD	F	Sig
Users	2.01 (n=80)	.968	2.81	.968	38.032 (1,243)	.000***
Competition	2.35 (n=78)	.965	2.94	1.016	18.636 (1,241)	.000***
Regulations	2.31 (n=78)	1.061	2.76	.989	10.463 (1,241)	.001**

* p < .05, **p < .01, ***p < .001

The Danish companies reported the most difficulty in identifying design requirements when considering competition, followed by regulations and users. For the Chinese companies, the most problematic factor for design requirements was competition, but users were reported to be more difficult than regulations. However, the Kruskal-Wallis Test did not result in any significant differences in difficulty between the three factors for Danish companies [$\chi^2(2) = 4.215$ p = 0.122] or for Chinese companies [$\chi^2(2) = 2.437$ p = 0.296].

5 Discussion

In this section, the survey results and the supplementary data from the four case studies are discussed. The differences in identifying and changing design requirements for Danish and

Chinese companies are first interpreted, then explained in Section 5.1 and discussed in greater detail in relation to the three influential factors in Section 5.2.

5.1 Identifying and Changing Design Requirements

The survey results indicated that for both Danish and Chinese companies, design requirements were identified during the entire product development process. However, for Danish companies, most of the requirements were identified during the early stages of the product development process, (i.e., the planning stage and the concept development stage); this trend was less evident in the Chinese companies. Jagtap et al. (2014) study that analysed the design process for BOP and TOP addressed similar issues related to the emerging markets context. Their results indicated the BOP designers were more engaged in clarifying design objectives, and the BOP designers were more information intensive. These differences suggested that the market-context (e.g., BOP and TOP) could influence the design processes. One of the primary explanations the researchers provided for this difference was that the BOP designers were less familiar with the design tasks because none of the participants were from the BOP strata. In contrast, this study investigates design requirements in manufacturing companies operating in western countries and emerging markets, and provides a broader perspective by analysing different companies and extends the focus from designers to external factors (e.g., users, competition, and regulations).

The Danish practice is similar to methods described in numerous product development models (e.g., Ulrich and Eppinger 2011). The study results indicate that design requirements and product development processes co-evolve. Changes to design requirements were noted for the Danish firms, but most of these changes occurred during the concept development stage and decreased along the process. The experiences reported by the Danish companies are similar to other studies that were conducted in a western context. For example, Chakrabarti, Morgenstern, and Knaab (2004) observed in a design experiment that requirements were identified primarily during the task clarification phase and increasingly less during the subsequent phases. Ahmed and Kanike (2007) analysed over 1500 reports and determined that changes to design requirements were more likely to occur during the development and prototype phase and more than likely to occur during the design phase, before changes were documented. This consistency is expected because most product development models were constructed based on the developed western context.

For Chinese companies, the majority of requirements are identified during the early stages of the product development process. However, significantly more requirements are identified later in the product development process for Chinese companies than for Danish companies. In addition, most Chinese companies permitted changes to design requirements at later stages of the product development process, which appears to contradict western practices and models. Changes in design requirements that occur late in the product development process were noted in both Chinese cases. For Company C (Chinese), around 10% of the projects accepted late changes in the requirements (Managing Director, Company C). For Company D (Chinese), requirements were changed for 20% of the projects (Product Manager, Company D). These changes were permitted during any stage of the product development process, and

modifications were permitted even after the product had been delivered to the market. Three explanations for these differences are provided.

The first explanation relates to the organisation and the processes for identifying requirements in Chinese companies. For the two Chinese case companies (Company C and D), the information collection and requirement specification processes were separated and conducted by different teams. Information related to the requirements was first collected by an independent team (often from the marketing department) and then delivered to product managers. Then, the product manager compiled the information into design requirements for a specific project. Conversely, the information collection and requirement specification processes were conducted by the same person for both Danish cases (Company A and B). The Chinese product managers who manage the design requirements may have a limited understanding of the collected data, if all requirement information is collected by the marketing department. In addition, when requirements are formulated by a variety of experts (e.g., marketing), designers have more difficulty in fully understanding the precise meaning or implications of the information (Haug 2015). However, a short physical distance between the employees (e.g., marketing professionals, product managers, designers and engineers) can enhance communication in Chinese companies.

For the Chinese companies, the data collected by the marketing department were used for specifying design requirements for multiple projects, and the planning phase is simplified for each project and often excluded from the project process. This explains why significantly fewer Chinese companies identified design requirements during the planning stages. The results indicate that platform products (Ulrich and Eppinger 2011), where new products were based on established platforms, may be popular among Chinese manufacturing companies. The types of new products (e.g., market pull, technology push and platform products) affect design requirements and how they are developed (Darlington and Culley 2004).

Second, the sources that provide requirement information affect the requirement identification process. The case studies indicated that end users were typically used as a crucial source of requirements for Danish companies. For Company A (Danish), the four primary sources that were used to identify design requirements included customer visits, focus groups with professional experts, using competitors' products as a benchmark and management decisions. For Company B (Danish), the most important sources for design requirements were customers (either through direct contact or feedback through sales or distributors), internal R&D teams and regulations. In contrast, Chinese companies more often generated design requirements by benchmarking competitors' products and learning from best practices. Company C (Chinese) primarily benchmarked their design requirements against competitors' products, particularly from advanced competitors in Northern America. Company D (Chinese) combined benchmarking and sales data (e.g., sales records) and additional data from user studies to develop design requirements. In general, Chinese companies place less importance on field studies, which allows them to spend less time identifying requirements early in the process. However, companies may make changes in requirements late in the process when they are highly dependent on benchmarking and sales data, particularly in a highly competitive market such as China. For instance, requirements may be changed late in the process because a

competitor launched a new product. One problem is that marketing data may be too general to provide designers with accurate information regarding a specific user's situation and experience; this may result in a design that fails to adequately target end users' needs (Haug 2015; McGinley and Dong 2011). Furthermore, it was noted that for Company C (Chinese), the development team informally interacted with users during the development process, and customers were invited to the testing and refinement stage to validate the end product. The involvement of users in the testing and refinement phase in Chinese companies (Li and Ahmed-Kristensen 2014) can result in changes to requirements late in the process.

Third, in general, Chinese manufacturing companies spend more time on the later stages than the early stages of the product development process. This was noted during the analysis of the product development processes for the four case companies. The product development processes for each case company are illustrated in Figure 4 according to company documents and interviewees' descriptions. For the Chinese cases, the testing and refinement stage and production ramp-up stage actually occurred during several stages of the process (more detailed steps than for Danish companies). The designed product is tested and refined in several formal rounds (e.g., as engineering samples or in pilot production). The product development processes of the Chinese companies differed from many product development models (e.g., the stage gate system (Cooper 2008)), for which the early stages are planned in greater detail. This indicates that Chinese companies strongly focus on correcting errors, which results in changes late in the process of product development. However, product improvement is often the motivation for changes during the earlier stages (Sudin and Ahmed-Kristensen 2011; Ahmed and Kanike 2007). Although costs increase when changes are made late in the process, late changes are also more feasible because Chinese companies own their manufacturing facilities and utilise relatively cheaper human resources.

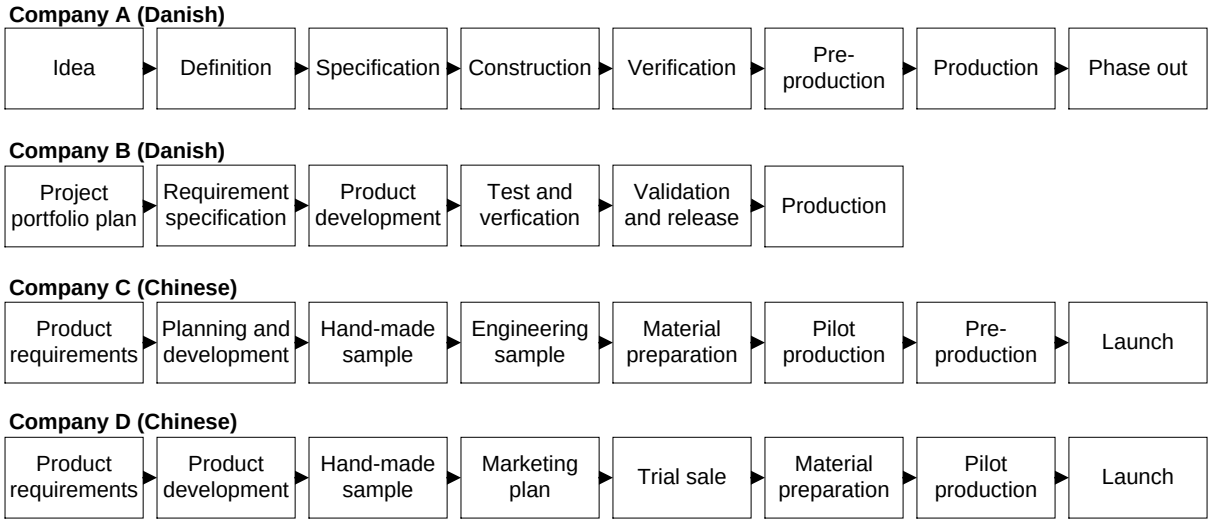

Figure 4 Product development processes in case companies

5.2 Influential Factors

In the survey, three factors (users, competition and regulations) were investigated for each context, i.e., western and emerging markets. The results indicated differences in these three

factors for the two contexts. This section discusses the effects of these differences on the identification and change of design requirements during the product development process.

The difficulty in identifying requirements when considering the different factors was not significantly different. However, significant differences were noted for the contribution of each factor to design requirements. Specifically, competition contributed the least for Danish companies but contributed the most for Chinese companies. It appears that Chinese companies focused more on competition when they identified design requirements.

This strong focus on competition among Chinese companies may be a result of inherent features of the Chinese market. The large number of competitors in the Chinese market, and particularly local unbranded competitors, result in incredibly severe market competition (Sheth 2011). Furthermore, the majority of emerging markets have a low per capita income (Kuepper 2016; Heakal 2015) and are considered low-end or middle-end markets. In this study, both Danish cases (Companies A and B) targeted the high-end market; their products were specialised for a small group of users. The products of both Chinese cases (Companies C and D) targeted the middle and low-end markets. Middle and low-end markets are generally larger, particularly in China. This makes it easier for Chinese companies to meet customer needs. Conversely, the lack of significant barriers stimulates the development and production of a large number of competitive products and substitutes, which drives companies to prioritise competition during the product development process. Companies that compete in a competitive market with mass products should carefully observe customers reactions and make improvements to products accordingly (Fricke et al. 2000).

As a consequence, competition pressures Chinese companies to respond quickly. The response time is of great importance, and speed becomes important during the product development process. Therefore, the process for identifying design requirements should be effective and conducted as quickly as possible. Unlike the western context that is engaged in quality-based competition, companies in Asian emerging countries generally employ a price-based competition strategy (Er 1997). Rather than focusing on product differentiation and adding considerable value to products, Chinese companies generally launch products that are similar to existing products with only minor modifications, which requires less time and effort spent on identifying requirements, particularly during the early stages of the product development process.

In addition, for the Chinese companies, regulations contributed significantly less to design requirements than users and competition; the companies were less challenged by the effects of regulations during the requirement identification process. This result indicates that Chinese companies may be less concerned about regulations and may have less problems with regulations when addressing design requirements.

Compared to western markets, emerging markets are, in general, less regulated. Less regulation allows companies to operate with more freedom and less control. Conversely, this type of environment may make competition more chaotic. Less effective intellectual property right protections and imitators in the markets may discourage companies from engaging in fundamental innovation, which strengthens the focus on competition among Chinese companies.

In a well-regulated market, a well-formulated product development process is often required, particularly for certain industries such as medical devices. For example, both Danish case companies that were analysed in this study had implemented a stage-gate product development model for more than 10 years, which requires more standardised methods of identifying design requirements. In contrast, companies operating in emerging markets often believe that a formal product development process is not necessary (Donaldson 2006). The Chinese manufacturing industry, in general, is less knowledgeable and has less experience with product development models. For example, the two Chinese companies had structured their engineering product development processes within the last five years. Company C stated that they implemented the Integrated Product Development (IPD) model with support from an external consultant. However, internal employees did not well understand the model. This indicates that the product development process (including identifying and changing design requirements) in Chinese companies is generally less standardised, which provides another explanation for the differences between the Danish and Chinese companies.

6 Implications and Conclusion

This study compared the processes used by western and emerging markets to identify and change design requirements by contrasting the practices of Danish and Chinese companies. This study analysed when the requirement identification took place during the product development process and at what stage changes to requirements were permitted. Three influential factors that included users, competitions and regulations were investigated for each context; in addition, their influence on design requirements was analysed. This study reviewed primary quantitative data that were collected through a survey that resulted in 80 Danish responses and 165 Chinese responses. In addition, this study reviewed secondary qualitative data from two Danish case companies and two Chinese case companies.

The results demonstrate distinct differences between the Danish and Chinese companies. The Danish companies had a stronger focus on identifying design requirements during the early stages of the product development process. The Chinese companies permitted more changes to design requirements during the later stages of the product development process. Competition and regulations affected the differences between the western and emerging markets.

From an academic perspective, this study provides an understanding of design requirements and extends the understanding from the conventional context of western markets to emerging markets. The study indicates that current stage-gate product development models are limited with respect to identifying design requirements. It is unclear, with those models, how to present how when design requirements are identified and changed throughout the product development process, particularly for Chinese firms. This study noted differences in the co-evolution between design requirements and product development processes for companies operating in western countries and emerging markets. Specifically, this study indicated that competition and regulations directly influenced design requirements for the two contexts.

This study has practical implications for practitioners of both western and emerging markets. The results revealed that Chinese companies and Danish companies focus their efforts on identifying design requirements during different stages of their product development processes.

The analysis implies that Chinese companies respond quickly to changes but may lack thorough and systematic user studies. This Chinese practice may be an effective method to react to intense competition for middle and low-end markets and/or in a less-regulated market. It is suggested that companies adapt their product development processes and approaches to the specific context.

Future studies should investigate this issue in greater detail by analysing multiple countries in both western and emerging markets. By doing so, the findings can be tested and generalised to a larger sample. In addition, this study demonstrated that the context of the origin (i.e., from western countries or emerging markets) of the manufacturing companies was the primary reason for the differences in when the different companies identified and changed design requirements. However, the target market (i.e., whether the product was developed for western markets for emerging markets) may also affect this practice. This should be explicitly investigated in a future study.

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Paper VI: Understanding the Challenges of Identifying Design Requirements for Emerging Markets

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Understanding the challenges of identifying design requirements for emerging markets

Abstract

Western manufacturing companies are increasingly paying more attention to emerging markets. A number of western companies have recognized their current strategy to sell existing products to emerging markets as inadequate, highlighting the need to understand local requirements in emerging markets and adapt the approaches for that context. However, few studies have focused on design requirements in the context of emerging markets, especially how design requirements are identified from multiple perspectives. Therefore, this study investigates the process of and challenges in identifying design requirements for emerging markets. The authors of this study collected 64 responses from a survey distributed to Danish companies and also conducted nine interviews at four Danish companies. The results reveal that, for western companies, identifying design requirements for emerging markets is more difficult than doing so in home markets. Specifically, the results indicate that the activities requiring more interaction with the external context, e.g., communicating with local stakeholders and gathering information from the local context, are more acutely affected by the context of emerging markets. In particular, it is more challenging to identify design requirements from a user perspective, a regulatory perspective and the perspective of other stakeholders. This study provides a structured approach for comparing the process of identifying design requirements between emerging markets and western markets and proposes a few suggestions for companies operating in this area.

Keywords: design requirements, challenges, emerging markets, product development

1 Introduction

Emerging markets comprise a group of fast-growing and newly industrializing countries. Brazil, Russia, India and China are the most well-known and more mature examples. Consumption in these markets is increasing rapidly, whereas a parallel stagnation in western markets seems prevalent (Wilson & Purushothaman, 2003). Emerging markets thus present huge potential for western companies (Ernst, Kahle, Dubiel, Prabhu, & Subramaniam, 2015).

Currently, a large number of the products sold by western companies to emerging markets are very similar to those sold in their home markets or are older versions at a lower price (Deloitte Touche Tohmatsu, 2006). However, this strategy has been argued to be inadequate for winning in emerging markets (Deloitte Touche Tohmatsu, 2006). It is important for successful product development to cater to market needs and satisfy unique customer requirements (Griffin, 2013). Therefore,

companies need to gain a deeper understanding of design requirements for emerging markets and implement these design requirements in the product development projects.

Identifying accurate and complete design requirements is a time-consuming and error-prone process (Jiao & Chen, 2006). Companies can face various challenges throughout this process. For example, users often have difficulty understanding their own requirements, or they may frame a statement personally and ambiguously, which makes eliciting user requirements difficult (Coughlan & Macredie, 2002; Sutton, 2000).

The challenges faced by western companies in identifying design requirements for emerging market can be different and tougher compared to doing so for their home markets. This can be attributed to distinctions in social, cultural, political and economic contexts between emerging and western markets. Often, adapting processes and methods for emerging markets is necessary. For example, Jagtap et al., (2014) demonstrated that designers made more effort planning to address requirements instead of solutions when developing for the bottom of pyramid, with which they are unfamiliar. Developing a better understanding about design requirements for emerging markets can support companies in these challenges. However, prior studies on design have primarily been carried out in the context of western countries and relatively affluent markets (Jagtap et al., 2014; Jagtap, Larsson, & Kandachar, 2013; Jagtap & Larsson, 2013; Viswanathan & Sridharan, 2012). To the best of the authors' knowledge, few studies have analyzed design requirements with a specific focus on emerging markets.

Therefore, this study seeks to understand the process of identifying design requirements for emerging markets and identify the challenges that western companies face in this process. This understanding is based on analysis of the different phases of the process of identifying design requirements and the various perspectives considered during this process.

The remainder of this paper is structured as follows. Section 2 reviews current literature relevant to this study and identifies lacunae. The specific aim and research questions of this study are clarified in Section 3. Section 4 describes the research methods applied in this study. Section 5 presents the results from a survey; these results are discussed in Section 6. Section 7 concludes the paper.

2 Literature review

2.1 The process of identifying design requirements

A design requirement is a characteristic that a designer is expected to fulfill through the final design (Chakrabarti, Morgenstern, & Knaab, 2004), whether a functional requirement or a non-functional requirement (also known as a constraint) (Sommerville, 2011). Identifying design requirements is essential to the design process and a central issue for design research (Chakrabarti, 1994).

Researchers have proposed various processes for identifying design requirements. Doing so successfully leads to a document specifying requirements for satisfying stakeholder interests (Sommerville, 2011). Often the process starts with identifying initial needs and requirements, which may be overlapping, vague or conflicting, etc. These needs and requirements must be analyzed and translated to formal requirements that specify precise and measurable details (Ulrich & Eppinger, 2011). In many cases, it is also necessary to validate the requirements in order to ensure that they are correct, complete, and consistent, so that a real-world solution can be built and tested to prove that requirements can be met (Bahill & Henderson, 2005). Five common phases of the requirement identification process are listed in Table 1.

Table 1 Main phases in the requirement identification process

Phase	Goal	References
Requirement elicitation	To systemically extract the requirements and information from multiple sources.	(Jiao & Chen, 2006; Carla Pacheco & Garcia, 2009)
Requirement analysis	To analyze the requirements for conflicts, overlaps, omissions and inconsistencies.	(Sommerville & Pete Sawyer, 1997; Wood & Otto, 2000)
Requirement specification	To specify explicit and formal requirements for development and evaluation.	(Ulrich & Eppinger, 2011)
Requirement validation	To validate whether requirements are consistent with stakeholders' intentions.	(Bahill & Henderson, 2005; Loucopoulos & Karakostas, 1995)
Requirement maintenance	To update, maintain and support the evolution of requirements.	(Kotonya & Sommerville, 1998; Sutcliffe, 2014)

It is often recommended to identify accurate and complete requirements early in a product development process (Cross, 2008). For example, in Ulrich & Eppinger (2011)'s generic product development model, customer needs are identified and requirements are specified in the second phase, i.e., the concept development phase. However, in practice, clear and unambiguous design requirements cannot always be identified at the beginning of the product development process. Instead, the co-evolution between design requirements and the product development process has been increasingly recognized by researchers (Darlington & Culley, 2002; Sudin & Ahmed-Kristensen, 2011). Requirement identification is intimately connected with solution generation and detailing (Chakrabarti et al., 2004) as the problem space co-evolves with the solution space (Dorst & Cross, 2001). Such changes to design requirements can be caused by a number of factors, such as knowledge gained through the development work (e.g., through testing), conflicting requirements, technical difficulties in meeting a high specification, opportunities for function-sharing and synergies, unexpected demands for cost savings, new legal requirements and

unexpected competitor situations and customer preferences (Almefelt, Berglund, Nilsson, & Malmqvist, 2006).

Identifying design requirements is a time-consuming process prone to errors (Jiao & Chen, 2006), and companies face various challenges in this process. Many of these challenges are associated with customers and users, including communicating with customers (Pa & Zin, 2011), identifying users' implicit needs, quantitatively measuring customer satisfaction (Liu, Zhang, Tu, & Jiang, 2008) and eliciting requirements from potential users (Hull, Jackson, & Dick, 2011). In addition, other challenges have been identified and investigated, such as interpreting precise stakeholder information (Nilsson & Fagerström, 2006), aligning business objectives of stakeholders (Solaimani, Guldemond, & Bouwman, 2013) and getting the relevant stakeholders on board (Shuhud, Richter, & Ahmad, 2013).

2.2 Identifying design requirements from multiple perspectives

Stakeholders might have different perspectives about design requirements. Incorporating multiple perspectives can lead to requirements that are more likely to satisfy the needs of a diverse set of stakeholders (Sommerville, Sawyer, & Viller, 1998).

The viewpoint-oriented requirement engineering methods, which were originally developed for software engineering, suggest explicitly identifying and separating different perspectives (Finkelsetin, Kramer, Nuseibeh, Finkelstein, & Goedicke, 1992; Greenspan & Feblowitz, 1992; Kotonya & Sommeiville, 1996). According to do Prado Leite & Freeman (1991), a viewpoint is defined as physical or mental positions used by individuals when examining or observing a universe of discourse. For example, the viewpoint-oriented requirement definition (VORD) model, developed by Kotonya & Sommerville, (1996), proposed three iterative steps: viewpoint identification and structuring, viewpoint documentation and viewpoint requirement analysis and specification.

Other studies propose similar multi-perspective thinking in the process of identifying design requirements. For example, Sharp et al. (1999) proposed an approach for identifying stakeholders and uncovering a network of stakeholders in the elicitation, analysis and management of design requirements. Gershenson and Stauffer (1999) proposed a taxonomy categorizing requirements into four groups: end-user requirements, corporate requirements, regulatory requirements, technical requirements; this study suggested that requirements could be identified from an end-user perspective, a corporate perspective, a regulatory perspective and a technical perspective. Chen and Zeng (2006) suggested design requirements should satisfy all stakeholders, including designers, manufacturing workers, salespeople, deliverers, users, maintenance workers and recycling workers. Li et al. (2014) suggested seven perspectives when identifying design requirements for emerging markets, namely, the user, corporation, competition, regional infrastructure, technology, regulation and organizational infrastructure.

To be consistent, the term 'perspective' is used through this study. A perspective is defined as a combination of the idea of a group of 'actors' in the development and usage process of the product that shares similarities and a 'view' that those actors maintain (adapted from (Easterbrook, Finkelstein, Kramer, & Nuseibeh, 1994)). The actor can be either human, e.g., user and supplier, or non-human, e.g., regulation.

Despite a common understanding of the need for multiple perspectives in design requirements, studies on design requirements have focused on customers and users. One reason for this emphasis is that requirements from customers and users often initiate and have direct influence on product development projects (Pedgley, 2009). For example, Jacobs and Ip (2005) investigated how the preferences of users were prioritized, analyzed and incorporated into game design. Wang and Tseng (2014) applied Bayes factor-based sequential analysis to identify emerging customer needs. Haug (2015) studied the emergence patterns for client requirements and potential communicative problems with clients. Franceschini et al. (2015) prioritized customer requirements with a technique based on the generalized Yager's algorithm. Only a limited number of studies have focused on the requirements from other perspectives, e.g., regulations, and no overview exists of how different perspectives influence design requirements from an engineering design point of view.

2.3 The characteristics of emerging markets

Emerging markets notably differ from western markets in various dimensions that can affect the design process, including requirement identification. Five of the characteristics of emerging markets commonly mentioned in the literature are summarized as follows.

2.3.1 Fast growing economy but low average per capita income

Fast economic growth distinguishes emerging markets from other markets (Gu, Hung, & Tse, 2008; Hitt, Dacin, Levitas, Arregle, & Borza, 2000; Hoskisson, Eden, Lau, & Wright, 2000) and results in an increase in local purchasing power but also leads to fluctuating and volatile markets (Enderwick, 2007). The fast-changing context in emerging markets challenges companies' assumptions about designing, developing and manufacturing products for emerging markets (Gudlavalleti, Gupta, & Narayanan, 2013). Despite the rapid growth, emerging markets have a per capita income that is still lower than average (Heakal, 2015; Kuepper, 2016), which encourages studies on designing for low-income populations, e.g., for the bottom of the pyramid.

2.3.2 Distinctive sociocultural contexts

The histories, cultures and social customs of emerging markets located in the Middle East, Latin America, East and Southeast Asia and Africa differ among themselves and from western markets, e.g., in Western and Northern Europe and North America. It is critical for manufacturers to understand these cultural differences in adapting their development strategy and products (Dubiel & Ernst, 2012).

2.3.3 Underdeveloped legal and regulatory environment

The regulatory environments of emerging markets that companies enter are unstable and underdeveloped. The enforcement of existing rules is inadequate (UNDP, 2008) and influences market regulations, product regulations, governance transparency and, eventually, a company's ability to earn profits in those markets (Dubiel & Ernst, 2012).

2.3.4 Severe competition

Western companies in emerging markets are competing with both a large number of local competitors and other international competitors (Gu et al., 2008). In emerging markets in particular, 60% of consumption is for unbranded products and services (Sheth, 2011). In addition, the relatively poorer protection of intellectual property rights and other consequences of the underdeveloped regulatory environment make the competition even more chaotic. Hence, western manufacturers must revaluate both their strategies and products.

2.3.5 Inadequate infrastructures and resources

Infrastructure in emerging markets is in general inadequate and underdeveloped (Sheth, 2011), and the resources are more restrained compared with those of developed markets. There is also a shortage of supporting resources, such as technology, education and finance, which constrains the ability of manufacturers to adapt their products and business opportunities for improving this area.

2.4 Studies on product development for emerging markets

Product development for emerging markets can be separated into two groups. The studies on the first group are based on the traditional view that innovation flows from advanced markets to emerging markets (von Zedtwitz, Corsi, Søberg, & Frega, 2015), e.g., frugal innovation. Frugal innovation, according to Radjou and Prabhu (2015), is the ability to create significantly more business and social value and to minimize the use of diminishing resources such as energy, capital and time. It emphasizes concern for turbulent global markets and competitive landscape, e.g., the scarcity of natural resources, competition in and from emerging markets, etc. (Radjou, Prabhu, & Ahuja, 2012), which results in new patterns in product development. Frugal innovation and other concepts in this group, such as low-end disruptive innovation (Christensen, 1997), cost innovation (Williams & van Triest, 2009; Williamson, 2010), bottom of pyramid (BoP) (Prahalad, 2004) and resource-constrained innovation (Ray & Ray, 2010), suggests offering suitable products that fulfill the basic needs of customers at a low price (Zeschky, Widenmayer, & Gassmann, 2011).

Another group of studies has noticed a contrary direction of the innovation flows, e.g., reverse innovation. In reverse innovation, a product is first developed in an emerging country before being adapted to developed countries (Govindarajan & Ramamurti, 2011). In this case, Govindarajan and Trimble (2012) determined five needs gaps: the performance gap, the infrastructure gap, the sustainability gap, the regulatory gap and the preferences gap.

In addition, a few studies have explicitly analyzed the design process for emerging markets in comparison to that for western markets. For example, Donaldson (2006) determined that the early phases of a design process (e.g., needs definition and conceptual design) in Kenyan companies were not standardized and design decisions were not documented. He demonstrated that Kenyan engineers and technicians from industrialized sectors lacked design expertise and did not see the need for a rigorous design process. Jagtap et al. (2014) compared the design processes between base of pyramid (BOP) designers and top of pyramid (TOP) designers. The study indicated that the BOP designers were engaged more in the clarification of design objectives and that the BOP sessions were more information intensive. These differences suggested that the market context (e.g., BOP and TOP) could affect the design processes. As the researchers explained, none of the participants came from the BOP strata, which led to a higher level of unfamiliarity with the design tasks in the BOP sessions. Jagtap et al. (2014)'s study focused on the differences in the designers' own experience and background. That study either excluded or did not directly address external factors, e.g., competitive situation and regulatory environments. The real tasks of designing for emerging markets can be much more complex; therefore, further research in the industry environment is necessary.

Research on innovation in the context of emerging markets has captured increasing attention in recent years (Subramaniam, Ernst, & Dubiel, 2015). Despite efforts to investigate emerging markets, prior studies on design, especially those that focused on design requirements, were predominately conducted in the context of developed countries and relatively affluent markets (Jagtap et al., 2014, 2013; Jagtap & Larsson, 2013; Viswanathan & Sridharan, 2012). To the best of the authors' knowledge, few studies have explicitly analyzed the identification of design requirements with a focus on emerging markets.

3 Aims and significance

This study aims to understand the process of identifying design requirements for emerging markets and identify the challenges that western companies are facing in this process based on a comparison of how western companies identify requirements for western and emerging markets. The study addresses two specific gaps identified in the literature review, which are as follows: 1) a lack of understanding about the process of identifying requirements for emerging markets and 2) an incomplete understanding of multiple perspectives in design requirements from an engineering design perspective.

Two research questions guide the study.

Research question 1: How are the challenges faced by western companies when identifying design requirements for emerging markets different from those for home markets?

Research question 2: How can the challenges faced by western companies when identifying design requirements for emerging markets be supported?

4 Method

This study consists of a survey with 64 valid answers from Denmark and nine interviews conducted with four Danish companies. The survey explored general patterns in the processes of identifying design requirements in western companies, while the interviews supported the interpretation and discussion of survey findings. This section introduces how the two research methods, i.e., survey and interview, were applied in this study and describes the sample collected by each method.

In this study, the western context is represented by Denmark, a developed country with sufficient infrastructure and advanced innovation capacity. This selection is acknowledged as a limitation. Further studies across multiple countries should be conducted to apply the knowledge gained from this study to other countries that are different from Denmark. The seven perspectives investigated in this study are adopted from Li et al., (2014) due to their relevance to emerging markets. These perspectives are clarified as follows:

1) *User*: Customer needs and users' expectations about the product's capabilities, experience, aesthetics and usability, etc.
2) *Organization and business*: Concerns that affect the product design, such as strategic plans, business situations, financial status and marketing.
3) *Competition*: The competition situation and competitive landscape in the target market, including competition with both local competitors and international players.
4) *Regional infrastructure*: The condition of the services and facilities in the region that are necessary for the product to function, e.g., roads, electrical grids, water supply and telecommunications.
5) *Technology*: The technical aspects that a product must fulfill, e.g., technical functions, technical performance and engineering requirements.
6) *Regulation*: The governmental regulations, certifications and international and regional standards on issues such as safety/health, environment/ ecology, disposal and polity.
7) *Other external stakeholders*: Expectations concerning the product from external stakeholders involved in the product life cycle, excluding users but including suppliers, manufacturers, distributors and business partners.

4.1 Survey

4.1.1 Survey design

A survey was conducted to investigate the process of identifying design requirements for emerging markets in western companies. The survey was designed by the research team and was tested and revised in a workshop with over 20 industrial participants in Denmark. The survey consisted of three sections:

1. Background information:

- Company name, size and industry sector.

- Typical project length and budget.
- Business status in emerging markets.
- Participant's position, background and experience.
- Time spent on identifying requirements in general.

2. Design requirement identification for home market and for emerging markets:

- The difficulty level of each phase in the process of requirement identification (i.e., elicitation, analysis, specification, validation and maintenance), asked for both home markets and emerging markets.
- The difficulty level of identifying design requirements when considering each of the seven predefined perspectives (i.e., user, organization and business, competition, regional infrastructure, technology, regulation and other external stakeholders), asked for both home markets and emerging markets.

3. The understanding of emerging markets

- The characteristics of emerging markets
- Key challenges when designing for emerging markets

4.1.2 Sampling process

The survey was distributed among representatives of Danish industry. The sampling was performed in two steps. First, an initial list was extracted from a professional online business database called *Bisnode* with 7723 Danish companies using the following three criteria:

- The company operates in Denmark (an option provided by the platform),
- The company develops or manufactured products, or provided product design services, to other companies (filtered by NACE classification of economic activities (Eurostat, 2016)), and
- The company is making a profit (an option provided by the platform).

A link to the survey was sent to the selected companies by an email. Two screening questions were added in the email to further narrow the target companies, because these two criteria could not be filtered with the database:

- The company has experience in selling to emerging markets, or
- The company has an interest in selling to emerging markets.

A total of 131 respondents answered the survey, which provided a response rate lower than 5%. Two practical reasons explained the low response rate: 1) only approximately 10% of the companies on the initial list passed the two screening questions, according to the export ratio in Denmark (Hennigan, 2015), and 2) the email addresses generated from the database and used to contact companies were mostly general email addresses (e.g., information or customer service) and not always up to date. Moreover, a low response rate is expected and is often the case when the

self-enumeration method was applied, i.e., where the respondent completes the questionnaire without the assistance of an interviewer (Statistics Canada, 2010).

4.1.3 Sample description

Unfortunately, not all respondents finished the whole survey. All 131 respondents finished part 1, which requested basic background information and the company's business status in emerging markets. Only 64 responses completed all questions and were used in the analysis. These 64 responses varied in terms of company size and business status in emerging markets. **Error! eference source not found.**Table 2 lists the size of the represented companies.

Table 2 The size of participating companies

Size (number of employees)	Micro (>10)	Small (10-49)	Medium (50-249)	Large (>249)	Total
Count	15	29	10	10	64
Percent	23.4%	45.3%	15.6%	15.6%	100%

Of the companies, 45 (70.3%) were conducting business in emerging markets, and the rest were interested in doing so. Among these 45 responses, 21 (46.7%) were selling existing products, 14 (31.1%) were adapting products for emerging markets and 8 (17.8%) were developing new products for emerging markets. These numbers indicate Danish companies' general business status in emerging markets, which is corroborated by similar findings from another report conducted by Deloitte Touche Tohmatsu, (2006). That report provided an extended view from the Danish industry to a broader range of companies all over the world and specified data for each emerging market, as show in Table 3. The report also verifies the representativeness of the sample collected.

Table 3 How are the products sold by companies in emerging markets compared to products sold in home markets, adapted from (Deloitte Touche Tohmatsu, 2006)

Emerging market	Very different	Somewhat different	Very similar
Indonesia	12%	41%	47%
India	16%	32%	52%
Russia	11%	43%	46%
China	14%	36%	50%

The 64 respondents came from different backgrounds. The three most common areas were engineering (42 respondents), management (30 respondents) and business (28 respondents) (multiple choices were allowed). The respondents' experience in product development and emerging markets are presented in Table 4.

Table 4 Participants' experience in product development and emerging markets

Years of experience in	None	<1 year	1-3 years	3-5 years	5-10 years	>10 years

Product development	2	2	4	10	9	37
Emerging markets	8	4	13	11	14	14

4.2 Interviews

In this study, interviews were conducted to collect qualitative data for supporting the interpretation and discussion of the survey findings.

The interviews were conducted at four Danish companies that were recruited based on the following three criteria: 1) the company operates in Denmark, 2) the company is a manufacturing company that develops physical products, and 3) the company is either selling products to emerging markets or in the process of expanding to emerging markets. Table 5 presents an overview of the four companies. By the time the interview was conducted, Company D was still in the process of developing their first product.

Table 5 Statuses of the case companies

	Company A	Company B	Company C	Company D
Product	Medical devices	Medical devices /Lab equipment	Lab equipment	Medical devices
Number of employees	Approx. 500	10-50	< 10	< 10
Founded in	2001	1986	2012	2012
Products are developed for	European and US markets	European and US markets	Customized products	Nordic markets
Major target EMs	China, India, Russia, Latin America, Middle East	China, Russia, India	China	Preparing to expand to Asian markets
Products sold in EMs	Existing mature products	Existing mature products	Customized products	Plan to sell existing new products

The interview participants were selected from those involved in the process of identifying design requirements, e.g., product managers, project managers and, in some cases, the directors, to ensure they had enough knowledge to answers the questions. In total, eight interviewees participated this study and nine interviews were conducted. Table 6 provides the list of the interviewees from each company and the interview in which they participated.

Table 6 Overview of interview participants

Company	Interviewee	Years at the company	Role in the process of identifying design requirements	Interview participated
A	Product manager	4 years	Collect and validate requirements, particularly concerning business aspects	A1
	Project manager	11 years	Specify requirements	A2
	Technologist	12 years	Collect and validate requirements from users and customers	A3, A4
	Regulatory affairs manager	7 months	Regulatory requirements	A5
B	Managing director	6 years	Convert business strategy into requirements and approve requirements	B1
	Product manager	2 years	Collect, specify and validate all requirements	B2
C	Director and Cofounder	2 years	Collect, specify and validate all requirements	C1
D	Director and Cofounder	2 years	Collect, specify and validate all requirements	D1

The nine interviews were conducted in two rounds. The first round included seven interviews that aimed to understand the general practice of identifying design requirements in the company and their considerations about emerging markets. The first round interviews were conducted at all four companies. These interviews were semi-structured, which allowed the interviewee to expand on answers and hence gives room for clarification (Kvale & Brinkmann, 2009). An interview guide was prepared, and the key issues addressed in the interviews were:

- The product development process and where in the process design requirements are identified,
- The processes, sources and methods for identifying design requirements, and
- The business status in emerging markets and the challenges faced in emerging markets.

In addition, two second round interviews were conducted at Company A. Other companies did not participate the second round due to the lack of relevant people available to be interviewed. The second round interviews were unstructured (also known as open-ended), where the interviewer acts as an informant and directs the interviewee within topics, which is good for exploring an area where the investigated themes are still unknown (Kvale & Brinkmann, 2009). The second round interviews verified and clarified the data collected from the first round and provided supplementary information. Table 7 shows an overview of all the nine interviews.

Table 7 Overview of interviews conducted in this study

#	Type	Length	Recorded	1st round	2nd round
A1	Semi-structured	120 m	Yes	√	
A2	Semi-structured	75 m	Yes		
A3	Semi-structured	120 m	Yes		
A4	Unstructured	90 m	Yes		√ To gain supplementary understanding on requirement processes and sources
A5	Unstructured	50 m	Yes		√ To gain supplementary understanding on the regulatory requirements
B1	Semi-structured	150 m	Yes	√	
B2	Semi-structured	90 m	Yes	√	
C1	Semi-structured	90 m	Yes	√	
D1	Semi-structured	90 m	Yes	√	

All interviews were conducted in English. All interviews were audio-recorded with the permission from the interviewees and transcribed. Notes were taken during the interviews.

5 Survey results

In the survey, 40 respondents (62.5%) reported that it was more challenging to identify design requirements for emerging markets, 16 (25.0%) were neutral, and only 8 (12.5%) disagreed with that statement. The results demonstrate that a large number of western companies are facing more challenges in identifying design requirements for emerging markets compared to their home markets.

5.1 Phases in the requirement identification process

To understand the process of identifying design requirements for emerging markets in greater detail, this survey investigated five phases in this process: requirement elicitation, analysis, specification, validation and maintenance. These five phases were compared with respect to how challenging they were in the context of home markets (i.e., Danish market or other western markets) and emerging markets. Respondents were asked to rank the five phases according to their difficulty with respect to home and emerging markets. The ranking among these five phases were significantly different for both home markets (χ^2 (4) = 57.338, p = 000) and emerging markets (χ^2 (4) = 23.350, p = 000) (tested by the Friedman Test).

Each phase's rank was compared between home and emerging markets and was analyzed by a Wilcoxon signed-rank test. The results are presented in Table 5-1. The mean rank of requirement analysis phase was significantly higher in emerging markets than in home markets, indicating that

analysing design requirements was less difficult in emerging markets relative to other phases. In contrast, the mean value of requirement maintenance was significantly lower in emerging markets than home markets, which indicates that maintaining design requirements was viewed as much more difficult in emerging markets relative to other phases.

Table 5-1 Comparing the fives phases in the process of identifying and managing design requirements (n = 63)

Phase	Home market			Emerging markets			Differences between the two contexts	
	M	Mdn	SD	M	Mdn	SD	z	p (2-tailed)
Elicitation	2.49	2	1.435	2.30	2	1.433	-.403	.687
Analysis	2.14	2	1.189	2.62	2.5	1.250	-2.577	.010*
Specification	2.14	3	1.216	3.57	4	1.228	-1.417	.157
Validation	3.16	3	1.208	3.10	3	1.329	-.489	.625
Maintenance	4.06	5	1.243	3.41	4	1.455	-2.641	.008**

* p < .05, **p < .01, ***p < .001

5.2 Identifying design requirements from multiple perspectives

To understand the seven perspectives (i.e., user, organization and business, competition, regional infrastructure, technology, regulation and other external stakeholders) in identifying design requirements in emerging markets, Survey I measured the difficulty of defining design requirements when considering each of these perspectives for home and emerging markets. Respondents rated the difficulty level for each perspective on a 5-point Likert scale from 1 (not at all difficult) to 5 (extremely difficult), as showed in Table 2.

Table 2 Code scheme of the difficulty level of identify design requirements considering each perspective

Code	1	2	3	4	5
Option	Not at all difficult	Slightly difficult	Somewhat difficult	Very difficult	Extremely difficult

A paired sample t-test was conducted to compare the differences between the two contexts (i.e., home market and emerging markets). Table 3 displays the descriptive statistics of each context, the compared means and the p values.

Table 3 Comparing the difficulties of identifying design requirements considering the seven perspectives for both home markets and emerging markets (n = 62)

Perspective	Home market		Emerging markets		Compare means	SD	p (2-tailed)
	M	SD	M	SD			
User	2.35	.907	2.89	1.073	-.53	1.18	.001**
Organization and business	2.06	.885	2.44	.917	-.37	1.18	.016*
Competition	2.53	.970	2.85	.956	-.32	1.14	.030*
Regional infrastructure	1.94	1.069	2.32	.845	-.39	1.12	.009**

Technology	2.44	.985	2.42	.915	.02	1.08	.907
Regulation	2.44	1.081	3.03	1.055	-.60	1.21	.000***
Other external stakeholders	2.15	.921	2.80	.822	-.65	1.14	.000***
Average of all perspectives	2.27	.668	2.68	.609	-.41	.77	.000***

* p < .05, **p < .01, ***p < .001

Six perspectives, which included users, the organization and business, competition, regional infrastructure, regulations, and other external stakeholders, were rated as significantly more challenging for emerging markets than for home markets. No significant difference was found in technology between the two contexts. Three perspectives, i.e., other external stakeholders, regulation and users, increased more than other perspectives, which corresponds with and supplements the main obstacles to product development for emerging markets. The results demonstrated the challenges of identifying design requirements from a user and regulatory perspective and suggested the need for particular attention to other stakeholders' perspectives.

6 Discussion

The survey conducted for this study determined that the process of identifying design requirements for emerging markets is more challenging than for western markets. These challenges are reflected in different phases and various perspectives considered in this process. This section analyses and discusses why and how western companies face these specific challenges when identifying design requirements for emerging markets.

6.1 Gaps in the current practice of identifying design requirements for emerging markets

Data collected from the interviews indicated that it is more challenging for a western company to identify design requirements for emerging markets than for western markets. Further analysis of the interviews reveals a few gaps in the current practice.

First, western companies in general have limited knowledge about emerging markets, e.g., knowledge about the users and regulations in these markets. The following quotes serve as examples:

- 'The challenge is that it's so difficult to predict because you don't know or you don't have this history from which you can simply extrapolate.' (Product manager, Company A)
- 'The biggest challenge for us has been of course cultural issues, understanding the market, understanding the regulations in the markets…' (Managing director, Company B)
- 'I would be a little afraid that we might run into some regulations regarding [the product] that we do not know.' (Director, Company C)

It is natural for companies to know less about foreign markets than their home markets. In particular, information about emerging markets, e.g., informal rules, social rather than legal contracts and shared use of assets, and accurate knowledge about consumers are not readily available (Arnold & Quelch, 1998). In addition, companies allocated limited effort to identify

design requirements for emerging markets. For example, companies had few local employees collecting requirements in emerging markets, and product managers or other relevant team members rarely traveled to emerging markets to collect requirements (Product manager and Technologist, Company A). Hence, a large amount of the requirement information is gathered through a third party, often a distributor, which also increases the risk of missing information and misunderstandings. In addition, companies often sell the same products (older versions) to emerging markets and are not prepared to adapt their approaches for emerging markets. However, as the technologist from Company A reported, it was not adequate just to sell cheap versions in emerging markets, as the challenges were obviously much bigger in the emerging markets than in lower segments in western markets. 'Even if we have a low segment in Europe, they all have Wi-Fi, and they all have power that works 24 hours and running water and all that. Those challenges will be different in a different country' (Technologist, Company A). This attests to the fact that the infrastructure in emerging markets is generally underdeveloped, which has an impact on design requirements. These results indicate that certain companies have started to recognize the necessity of differentiating for emerging markets, though limited efforts have been made in practice.

Second, western companies are not clear about the root of the differences between western and emerging markets. Six out of the eight interviewees generally referred to these differences as cultural differences, as seen in the following quotes:

- '[The key differences between the Danish market and emerging markets are the] cultural differences and…how things are done in the emerging markets.' (Project manager, Company A)
- '[The difficulty with emerging markets] is all the basic staff with culture and language and all that.' (Product manager, Company A)
- 'I can sense that is a level that can be tricky if you do not know the culture.' (Director, Company D)

These cultural differences cover a large range of aspects, including business and consumer culture (Iyer, Laplaca, & Sharma, 2006). In a way, it testifies to the fact that western companies do not have enough knowledge about emerging markets. Moreover, it shows that the inherent differences between emerging markets and western markets – differences in users, competition and regulations – aggravate the difficulty of identifying design requirements for emerging markets. These cultural differences challenge the routine and best practices that are taken for granted in the western context. Additionally, it indicates that companies have only a vague impression about the differences between western markets and emerging markets. It is not sufficiently clear to the companies what aspects they should investigate and how, which again testifies to the need for systematic comparison across the two contexts.

Third, the understanding of emerging markets varies among employees. Seven out of the eight interviewees reported that they faced challenges in identifying requirements for emerging markets

that they did not experience in western markets. One interviewee, the Product Manager from Company B, noted no differences between the two contexts when identifying design requirements. He argued that the company competed with same competitors worldwide and that the users they served required same products. However, this argument conflicted with another comment from someone at the same company, who said that competition with local competitors in the Chinese market was increasing.

These gaps indicate that when companies examine the situation in emerging markets, they may overlook or underestimate certain aspects, which confirms the need for a more comprehensive frame for identifying design requirements for emerging markets.

6.2 Challenges of identifying design requirements for emerging markets

This study analyzes the challenges in identifying and managing design requirements for emerging markets from two perspectives: the phases in the process and the perspectives considered during the process.

6.2.1 Phases in the process of identifying design requirements

In the survey, five phases in the process of identifying and managing design requirement were compared in home and emerging markets with respect to how challenging they are. The relative difficulty (how difficult the phase is relative to other phases) of requirement analysis was lower for emerging markets than for home markets, whereas the relative difficulty of the maintaining requirement was higher for emerging markets than for home markets, indicating that the influence of emerging markets on the process of identifying and managing design requirements varies across each phase. One explanation is that identifying requirements for emerging markets has a greater impact on those activities that require more interaction with the external context, e.g., communication with local stakeholders and gathering information from the local context. According to the technologist from Company A, information gathering was easier in home markets, as they could physically reach different stakeholders and understand culturally what they said. The technologist noted that challenges in information gathering and understanding influence the entire requirement identification process because information gathering is normally the initial step in the process and therefore dictates everything.

6.2.2 Identifying design requirements from multiple perspectives

The survey indicates that identifying design requirements is more challenging for emerging markets when considering the perspectives of the organization and business, competition, and regional infrastructure, and particularly so for users, regulations and other stakeholders. This section discusses how the challenges of identifying design requirements for emerging markets are related to these perspectives.

The user perspective

The challenges of identifying design requirements for emerging markets from the user perspective can come from three aspects. The first aspect is the identification of users. Existing studies have discussed the identification of different stakeholders in business (Pouloudi & Whitley, 1997; Reed et al., 2009) and specifically in design requirements (C. Pacheco & Garcia, 2008). Users are often the relatively obvious and direct stakeholders in a project. However, it can be very challenging for western companies to identify target users and establish communication with them in emerging markets. For instance, Company D was familiar with users in German markets, where both the public healthcare and private insurance would pay for their medical devices, but the healthcare system in China was unknown. Identifying the right people to talk to and obtaining such information was both challenging and crucial for Company D.

The second aspect is an awareness of the differences between users in emerging markets and those in western markets. Users in different cultural contexts can have diverse expectations about the same products. Company C provided such an example. Their customers in western countries, e.g., Germany and Sweden, cared mostly about scientific results when using their laboratory equipment in studies, while the Chinese customers insisted upon a commercial end goal. Similar results were supported by Salmi & Sharafutdinova (2008). They found that the Russian users have unique requirements for mobile phones. Several socio-economic factors influence the users' preferences, e.g., low average income, concentration of money in the capital region, sharp distinctions between the poor and the rich, social structures not corresponding to income distribution, high levels of street crime and underdeveloped fixed telephone lines (Salmi & Sharafutdinova, 2008).

The third aspect is the access to local users in emerging markets. The lack of information from emerging markets results in high information asymmetries between companies and users (Kramer & Belz, 2008). Moreover, due to limited resources in emerging markets, many western companies do not have the possibility of directly collecting requirements from local users in emerging markets. Instead, they often collect user requirements through distributors (noted in Company A, Company B and Company D). On the one hand, this approach saves lots of time and money for the company in terms of setting up their own sites in emerging markets. It also reduces language and cultural barriers in communication by involving local people in the process. On the other hand, it involves higher risks and more uncertainties, as the information processed by distributors can be biased based on their own interest and knowledge. This indirect communication with users is against current studies' advice to involve locale users in the design process, e.g., (Mattson & Wood, 2014).

The regulatory perspective

As shown by the survey, regulations are one of the most challenging issues for western companies when identifying design requirements for emerging markets, though researchers have not focused on them in terms of addressing design requirements. According to Gershenson and Stauffer (1999), regulatory and technical requirements received less attention in research for two reasons. First, they were often well-documented and easy to find for the design team. Second, they were more

context-dependent compared with other perspectives. Therefore, studies on these two perspectives could be either too broad or specific and hence of lesser value.

The survey indicated the significance of addressing regulatory requirements for emerging markets. In the interview, only two out of seven first-round interviewees mentioned regulations in design requirements spontaneously. However, after the interviewer specifically asked about regulations, they all agreed that the regulatory perspective in identifying design requirements is critical. The role of regulation in design requirements may have been overlooked, as regulatory requirements are of high importance for certain industries, e.g., medical devices, but can be of low concern in others. The design teams' attitude towards the perspectives is critical. Designers failure to realize the importance of capturing requirements is one possible cause of problems in design requirements (Ward, Shefelbine, & Clarkson, 2003). According to the regulatory affairs coordinator from Company A, companies have not focused much on allocating resources to regulatory affairs and are just starting to do so.

Context dependency is one reason that the regulatory perspective is more challenging for western companies to identify design requirements for emerging markets. Companies have to make an effort to investigate the situation for each country or region. The specific challenges in each country are different. For example, China requires special tests and verifications to approve products. The requirements should consider how the product is to be tested. The registration process can take up to two years before the products can be sold, which challenges the validity of requirements over a long period. In other countries, e.g., Brazil, India and Indonesia, standard international certifications are accepted, so it is easier for a company to sell existing products there (regulatory affairs coordinator, Company A). Considering the significance of regulatory requirements, the current approach in many companies, e.g., collecting regulatory requirements through distributors and online databases, may be inadequate for emerging markets (regulatory affairs coordinator, Company A).

The perspective of other external stakeholders

The perspective of other external stakeholders (e.g., suppliers and distributors (Cooper, Wootton, & Bruce, 1998)) is not negligible, particularly when considering the underdeveloped regulatory environments of emerging markets. Western companies in general may face high level of uncertainty and risk in collaborating with supply chain partners in emerging markets, where the legal institutions, including intellectual property rights and contracts, provide little governance or protection for firms' innovation outputs (Jean, Sinkovics, & Hiebaum, 2013). This gives a good example that regulatory perspectives and other external stakeholders' perspectives affect each other.

The distributors received significant attention in the interviews conducted for this study. They can have specific requirements about the product (managing director, Company B), but more often they act as the intermediary that connects the company and many other information sources in

emerging markets, e.g., users and regulations. For example, companies can collect user feedback through distributors without knowing the names of specific users in emerging markets (product manager, Company B). This indicates that the user perspective and other external stakeholders' perspectives are interrelated, as the distributing mechanism affects the user understanding.

It is of particular importance to build and maintain a trustworthy relationship with stakeholders in emerging markets in order to collect high-quality requirements. For example, in China, personal relationships and reputation are highly recommended; they affect how companies establish collaboration with business partners and hence gather requirement information from them (director, Company D).

The competition perspective

Competition is one of the major reasons for changes to design requirements (Fricke, Gebhard, Negele, & Igenbergs, 2000), though it has been rarely studied in relation to identifying design requirements. However, it might be necessary to do so in the context of emerging markets. As suggested in the literature, the competition in emerging markets for western companies can be fiercer compared to that in their home markets (Sheth, 2011). Er (1997) identified competition as the vital ingredient for design in emerging markets. Unlike the western context, which seeks quality-base competition, companies in the emerging Asian market largely employ the price-based competition strategy (Er, 1997). However, this study presented cases in which western companies attach limited attention or act passively to the local competition in emerging markets. For example, Company B realized that the competition in the Chinese market was increasing and affected their performance in the market. However, this action shifted focus to the Indian market, where the company observed an opportunity for growth, as a competition-oriented approach seems to contradict their innovation strategy.

Benchmarking competitors' products is a commonly practice in requirement identification (Technologist, Company A). Often, basic user requirements are also discovered by studying competitor products during benchmarking (Dieter & Schmidt, 2007), which shows that user perspective is connected with competition perspective.

The other three perspectives, i.e., the technology, organization and business and regional infrastructure, were not discussed in detail in this study due to three reasons: 1) the technical perspective was not significantly differentiated between the two contexts and hence was not interesting in this study, and 2) the regional infrastructure perspective and the organization and business perspective were not explicitly described in the interviews. It was found the regional perspective was often considered together with user perspective since it constrained the use of the product. The organization and business perspective, e.g., concerning about company strategies and financial status, was often addressed before identifying design requirements, e.g., at the planning phase (Ulrich & Eppinger, 2011).

7 Conclusion and suggestions

This study identifies and explains the challenges that western companies face when identifying design requirements for emerging markets. The analysis was based on a survey study conducted in Denmark with 64 responses and nine interviews conducted at four Danish companies.

This study demonstrates that it is more challenging for a western company to identify design requirements for emerging markets than for home markets. Western companies in general have limited knowledge about emerging markets. In addition, in many cases, they make only a limited effort, and only limited resources are allocated to investigate emerging markets.

The results indicate that the influence of emerging markets varies on the process of identifying and managing design requirements across each phase. The context of emerging markets has a stronger impact on those phases that require more interaction with the external context, e.g., communicating with and gathering information from the local stakeholders.

The results also reveal that the process of identifying and managing design requirements is more challenging in emerging markets than in western markets when considering a user perspective, a regulatory perspective and that of other stakeholders. These challenges include a lack of knowledge about local users' specific needs, a lack of access to local stakeholders, difficulties in understanding a variety of regulations in different markets, difficulties in dealing with the volatile regulatory environments and difficulties in establishing a trustworthy relationship with stakeholders with different cultural backgrounds. Moreover, the results imply that a competition perspective can be critical in the context of emerging markets but has received inadequate attention from companies.

These findings also indicate that perspectives are interrelated with each other. For example, regulations, like the protection of IP rights, affect how companies compete in the market. Therefore, the studies on identifying and managing design requirements should comprehensively cover multiple perspectives and consider the interaction between perspectives. Particularly, in the context of emerging markets, design requirements from a regulatory perspective, a competition perspective and that of other stakeholders should be studied in greater detail due to limited understanding in current literature of their significance in emerging markets. Furthermore, the study indicates the importance of selecting appropriate sources for gathering requirements in emerging markets and suggests the need for further investigation on the relationship between perspectives and sources in the identification and management of design requirement and practical guidance to support the selection process.

This study extends existing knowledge about design requirements developed in western countries to emerging markets. It provides evidence that identifying design requirements for emerging markets is different from doing so for western markets. It proposes understanding these differences in a systematic manner, i.e., analyzing the process itself, and maintains that the perspectives should be considered during the process. The results showed that the comparison between emerging and western markets following this manner could generate valuable insights.

The knowledge gained about the seven perspectives in design requirement can be applied to other situations beyond product development for emerging markets.

For industry, this study demonstrates the main gaps in western companies' practice of identifying and managing design requirements and major challenges that western companies face during this process. The project suggests that western companies should actively strive to thoroughly understand emerging markets. Western companies should consider adapting the processes and methods that they applied in western markets, given the considerable distinctions between western and emerging markets. This adaption should consider multiple perspectives.

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Appendix B – Survey I

Survey I

Information

Thank you for finding the time for this survey.

The survey was designed by a research group from Technical University of Denmark. The research aims at generating supportive design methods for Danish companies to develop products for emerging markets. It is part of the *Global Opportunities for Danish SMEs in Emerging Markets* project (www.godsem.dk), which is funded by *Industriens Fond* with 4 million DKK. This survey is for gaining an initial understanding about the practice and challenges when developing products for emerging markets. Hence, we are sending this survey to companies which have experience in emerging markets or have potential interests in them. Your input is greatly appreciated and will contribute to the Danish industry.

The survey will take about 10 minutes. All data will be kept confidential and respondents will be kept anonymous. If you have any questions regarding the survey, please don't hesitate to contact us:

Xuemeng Li: xuemli@dtu.dk (PhD student)

Saeema Ahmed-Kristensen: sakr@dtu.dk (Professor)

Thanks again for your time and efforts.

Survey I

About the company

* 1. What is the name of the company where you work?

* 2. What is the size of your company (number of employees)?

- ◯ Micro (< 10)
- ◯ Small (10-50)
- ◯ Medium (51-250)
- ◯ Large (> 250)

* 3. What is the industry sector of the your company?

- ☐ Material
- ☐ Consumer Goods
- ☐ Information Technology
- ☐ Automobiles & Components
- ☐ Industrials
- ☐ Health Care
- ☐ Telecommunication Services
- ☐ Energy
- ☐ Other (Please specify)

* 4a. What is the typical length of product development projects in your company?

- ◯ < 3 months
- ◯ 3 - 6 months
- ◯ 6 months - 1 year
- ◯ 1 - 2 years
- ◯ 2 - 4 years
- ◯ > 4 years

* 4b. What is the typical number of employees involved in one product development project in your company? (in full time equivalents)

- ◯ < 5
- ◯ 5 - 10
- ◯ 11 - 20
- ◯ 21 - 50
- ◯ 51 - 100
- ◯ > 100

* 4c. What is the typical budget-size of product development projects in your company? (in DKK)

* 5. Is your company doing business in*emerging markets*?

(*Emerging markets* refer to developing countries which are growing rapidly, e.g. Brazil, China, and India.)

- ◯ Yes.
- ◯ No, but has planned to.
- ◯ No, and no plans recently.

Survey I

About the company

6a. What is the best description for your company's business status in *emerging markets*?

- ◯ Sell existing new products to emerging markets (without changes).
- ◯ Sell existing mature products to emerging markets (without changes).
- ◯ Adapt existing products to emerging markets (with some changes).
- ◯ Develop new products for emerging markets and sell them in *emerging markets*.
- ◯ Develop new products for emerging markets and sell them in both *emerging markets* and *western markets*.
- ◯ Other (Please specify)

6b. Please explain the answers given to the previous question (business status in emerging markets) from your company's perspective. (e.g. intended business strategy or financial constraint)

7. How would you describe your company's product development practice for *emerging markets*?

(Please rate from:

extremely successful - products have been sold successfully in emerging markets;

to not successful - attempted but unsucceeded in either adapting or selling products to emerging markets)

- ◯ Extremely successful
- ◯ Very successful
- ◯ Moderately successful
- ◯ Slightly successful
- ◯ Not successful

8. In which *emerging markets* is your company doing business in or planning to do business in?

- [ ] Brazil
- [ ] China
- [ ] India
- [ ] Russia
- [ ] South Africa
- [ ] Other (Please specify)

Survey I

About you

* 9. What is your current position in your company?

* 10. What is your experience or educational background?

- [ ] Business
- [ ] Design
- [ ] Engineering
- [ ] Management
- [ ] Marketing
- [ ] Sales
- [ ] Other

* 11. How much experience do you have with product development?

- ◯ None
- ◯ < 1 Year
- ◯ 1 - 3 Years
- ◯ 3 - 5 Years
- ◯ 5 - 10 Years
- ◯ > 10 Years

* 12. How much experience do you have with *emerging markets*?

- ◯ None
- ◯ < 1 Year
- ◯ 1 - 3 Years
- ◯ 3 - 5 Years
- ◯ 5 - 10 Years
- ◯ > 10 Years

Survey I

About you

13. In which *emerging market or markets* do you have experience?

- [ ] Brazil
- [ ] China
- [ ] India
- [ ] Russia
- [ ] South Africa
- [ ] Other (Please specify)

Survey I

Design requirement

To answer the following questions, please think of a typical product development project for the *Danish market* you have been involved in or you know about.

* 14. Do you have a formal written list of design requirements for each of your product development project?

(Design requirement - A description that defines what the product should do (not how to do) and set up the boundaries to product solution space, also referred to as specification.)

- ◯ No, we develop without clearly defined design requirements.
- ◯ No, but we have an informal design requirement list.
- ◯ Yes, we have formally documented design requirement documents.
- ◯ Other (Please specify)

* 15a. How much time do you usually spend on identifying design requirements in a product development project? (Percentage of the total project time)

- ◯ < 5%
- ◯ 5% - 10%
- ◯ 11% - 20%
- ◯ 21% - 30%
- ◯ 31% - 40%
- ◯ > 40%

* 15b. Is the time you spend on identifying design requirements:

- ◯ before the product development process.
- ◯ during the product development process.
- ◯ both before and during product development process.
- ◯ Other (Please specify)

* 16. How much do the following contribute to developing design requirements in your product development projects?

	No contribution	Slight contrubution	Moderate contribution	Significant contribution	Essential contribution
Users and customers	○	○	○	○	○
The company's processes and policies (e.g. product portfolios and organisational processes)	○	○	○	○	○
Competitors	○	○	○	○	○
Supportive infrastructures (e.g. roads, power and telecommunications)	○	○	○	○	○
Technology	○	○	○	○	○
Regulations and standards	○	○	○	○	○
Suppliers, distributors, and external manufacturers	○	○	○	○	○

Other (Please specify)

* 17. When developing products for the *Danish market*, how difficult is it to identify design requirements for the following considerations?

	Not at all difficult	Slightly difficult	Moderately difficult	Very difficult	Extremely difficult
Users and customers	○	○	○	○	○
The company's processes and policies (e.g. product portfolios and organisational processes)	○	○	○	○	○
Competitors	○	○	○	○	○
Supportive infrastructures (e.g. roads, power and telecommunications)	○	○	○	○	○
Technology	○	○	○	○	○
Regulations and standards	○	○	○	○	○
Suppliers, distributors, and external manufacturers	○	○	○	○	○

Other (Please specify)

* 18. Please rank the following aspects with respect to how challenging they are during the development of design requirements in a product development project for the *Danish market*.

Please be aware that the choices will be reordered automatically from the lowest number to the highest once you choose a number. 1 stands for the most challenging aspect.

- **Requirement elicitation/collection:** to collect requirements from users, regulations and other sources
- **Requirement analysis:** to analyse and prioritise requirements and achieve agreement to satisfy all stakeholders
- **Requirement documentation:** to record requirements in order to make them formal through proper specification mechanism
- **Requirement validation:** to test and ensure that documentations accurately express the stakeholders' needs
- **Requirement management:** to update and support the evolution of requirements

Survey I

Emerging markets

To answer the following questions, please think about a product development project for *emerging markets* that you have been involved in or you know about.

* 19a. When developing products for *emerging markets*, how influential are the following aspects?

(If you don't understand one specific description, you may choose N/A)

	Not at all influential	Slightly influential	Moderately influential	Very influential	Extremely influential	N/A
Rapidly growing economy and changing market	○	○	○	○	○	○
Fragmented market (high level of product diversion)	○	○	○	○	○	○
Population in 'bottom of the pyramid' and the growing middle class	○	○	○	○	○	○
Different cultural, social and historical context	○	○	○	○	○	○
Unstable regulatory environment	○	○	○	○	○	○
Underdeveloped local regulations	○	○	○	○	○	○
Severe competition with unbranded competitors and state supported giant competitors	○	○	○	○	○	○
Poor-organised competition due to the regulatory environment	○	○	○	○	○	○
Underdeveloped infrastructure for supporting the products and distribution	○	○	○	○	○	○
Shortage of supporting resources, e.g. power, material, technology, education and finance	○	○	○	○	○	○

Other (Please specify)

* 19b. Please identify when developing products for *emerging markets*, which of these aspects is the most influential and please explain why.

- ◯ Rapidly growing economy and changing market
- ◯ Fragmented market (high level of product diversion)
- ◯ Population in 'bottom of the pyramid' and the growing middle class
- ◯ Different cultural, social and historical context
- ◯ Unstable regulatory environment
- ◯ Underdeveloped local regulations
- ◯ Severe competition with unbranded competitors and state supported giant competitors
- ◯ Poor-organised competition due to the regulatory environment
- ◯ Underdeveloped infrastructure for supporting the product and distribution
- ◯ Shortage of supporting resources, e.g. power, material, technology, education and finance

Please specify your reasons.

* 20. What are the barriers/challenges when developing products for *emerging markets*?

Please choose the three most challenging aspects.

- ☐ Unstable political and regulatory environment
- ☐ Difficult to reach and understand the local regulation and to get local approvals
- ☐ Poor intellectual property right protection
- ☐ Overcome the impediments to distribute can be frustrating
- ☐ Special constraint under the using context, e.g. a lack of supportive infrastructure and space
- ☐ The shortage of financial support
- ☐ High level of product diversion within or between countries
- ☐ Insufficient understanding of market needs
- ☐ Possibility of watering down a premium brand
- ☐ Different business culture of deeply embedded networks and personalised exchange
- ☐ Difficult to develop affordable products with sufficient features for local consumers
- ☐ Other (please specify)

* 21. When developing products for *emerging markets*, how difficult is it to identify design requirements considering the following ?

	Not at all difficult	Slightly difficult	Moderately difficult	Very difficult	Extremely difficult
Users and customers	○	○	○	○	○
The company's processes and policies (e.g. product portfolios and organisational processes)	○	○	○	○	○
Competitors	○	○	○	○	○
Supportive infrastructures (e.g. roads, power and telecommunications)	○	○	○	○	○
Technology	○	○	○	○	○
Regulations and standards	○	○	○	○	○
Existing suppliers, distributors, and external manufacturers	○	○	○	○	○
New suppliers, distributors, and external manufacturers established for entering emerging markets	○	○	○	○	○

Other (Please specify)

* 22. Please rank the following aspects with respect to how challenging they are during the development of design requirements in a product development project for the *emerging markets*.

Please be aware that the choices will be reordered automatically from the lowest number to the highest once you choose a number. 1 stands for the most challenging aspect.

- **Requirement elicitation/collection:** to collect requirements from users, regulations and other sources
- **Requirement analysis:** to analyse and prioritise requirements and achieve agreement to satisfy all stakeholders
- **Requirement documentation:** to record requirements in order to make them formal through proper specification mechanism
- **Requirement validation:** to test and ensure that documentations accurately express the stakeholders' needs
- **Requirement management:** to update and support the evolution of requirements

* 23. How do you view the product development for *emerging markets*?

	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
There is a need to differentiate products sold to *emerging markets* from that sold to *Danish market* (or *Western markets*).	○	○	○	○	○
It is more challenging to identify design requirements for *emerging markets* than for *Danish market* (or *Western markets*).	○	○	○	○	○

Survey I

Thank you for taking the time to complete this survey

More information about our research (a 4 MDKK project funded by Industriens Fond) can be found on: www.godsem.dk

Invitation to further collaboration

If you are interested in developing products for emerging markets and are interested in being a case study for the research, or if you wish to join the *Global Opportunities for Danish SMEs in Emerging Markets* project (no costs required with the possibility to join free workshops, networking, or be case company), please set in contact.

Current partner companies (over 80 companies including 7 networks) are available on: http://godsem.dk/members.html

Information about our next workshop in October: http://godsem.dk/events/index.html

Name	
Email	
Telephone	
Other	

Appendix C – Interview guide for Study One

Interview guide

Term explanation:

Design requirement: a description that defines what the product should do (not how to do) and set up the boundaries to product solution space [1], also referred to as the product description, technical specification, or design specification [2].

Emerging markets: low-income, rapid-growth countries using economic liberalization as their primary engine of growth [3], e.g. BRICS countries (Brazil, Russia, India, China, and South Africa).

Interview questions:

Product development and design requirement

1) Can you describe the general product development process (physical products?) in your company?
   a) Do you apply any product development process model?
   b) How many phases are included and what tasks are specified in each phase?
   c) Please draw the process step by step
2) How do you define design requirements in product development projects? What is a design requirement from your understanding?
3) Can you describe the specific process that how you identify design requirements in your company?
   a) Please draw the process for design requirements step by step
4) In which phase in your product development process, are design requirements identified?
   a) Please place the design requirement process in the product development process
5) How much time do you spend on identifying design requirements?
6) How much money do you spend on identifying design requirements?
7) How many people generally work on identifying design requirements?
8) What are their roles in the project?
9) From where do you collect design requirements? (describe the sources of design requirements)
   a) First answer openly, then draw on the paper, check the following if not mentioned (both human and non-human sources):

      - ***local partners, suppliers, external manufacturers***
      - ***users and customers***
      - ***regional infrastructures needed for the products to work in the using context***
      - ***the market competition***
      - ***regulation***
      - ***your companies own policies and strategies***
      - ***technological requirements***

10) Are there any sub-groups under each source?
11) Evaluate each source in table 1.
12) How do sources interact with each other?
    13) Draw the interactions and information flow in figure 3
14) Introduce the design requirement types and finish figure 1
15) Finish figure 2
    16) What techniques/methods do you use to identify design requirements from each source?
    17) Who is responsible for the task?

---

[1] I. Sommerville, *Software Engineering (6th edition)*, Boston, MA, USA: Addison-WesleyLongman Publishing Co., Inc., 2001.

[2] M.J. Darlington, and S.J. Culley, Current research in the engineering design requirement, *IMechE Part B: Journal of Engineering Manufacture*, **216** (2002), 375-388.

[3] A. Dubiel and H. Ernst, Success factors of new product development for emerging markets, in *The PDMA handbook of new product development*, 2012, pp. 100–114.

18) Mark out the challenges in each source
19) Which sources will be affected when developing for emerging markets? (market-dependent sources)
20) What aspects(perspectives) do you consider when identifying design requirements?
21) How do you manage the changes to design requirements?

Emerging markets

22) What are your understandings about emerging markets?
23) What are you motivations of entering emerging markets?
24) What were the considerations you have before entering emerging markets?
25) Is the reality different from your expectations? What are the differences?
26) What are the key differences between Danish market and emerging markets from your perspective?
27) What are your expectations in emerging markets?
28) What are the challenges (related to product development) you are facing when approaching emerging markets? What are the challenges in design requirement identification for emerging markets?
29) What have you learned from the experience in emerging markets?

Document permission

Ask if it is possible to have their:

- Design requirement documents/specification
- Project report
- Platform requirement/specification
- Other documents they think may be relevant

Closing

Thank interviewee for cooperation, inform the interviewee that a summary will be sent to him/her with the survey link (if requested), ask if is possible to get in contact again if there is a need for clarification of information. A further meeting will be discussed if the participant expresses a need for this or wishes to talk off the record.

Ask for:

- The time frame for observing? (meetings, process etc.)
- Other people can be interviewed?

Evaluation

An evaluation of how the interview went and any areas for suggested improvement will be sent with the summary in preparation for the future interview.

Interview form

Company:		
Location:		Date:
Start:	End:	Duration:
Researcher: Xuemeng Li		
Structure: semi-structured		Audio recorded: X□Yes □No
Interviewee name:		Years at the company:
Telephone:		Email:
Previous experience:		
Position in the team:		Years:
Comments:		

Evaluation form

Is the content of the interview relevant to your business?
How do you feel about the structure of the interview?
Do you have any other comments about the interview?

Design requirement types:

- *End user requirement*: users' expectations of the product's capabilities, aesthetics and usability;
- *Corporate requirement*: business issues and product lifecycle issues;
- *Regulatory requirement*: safety/health, environmental/ecological, disposal and/or political issues;
- *Technical requirement*: engineering principles, material properties and physical law etc.

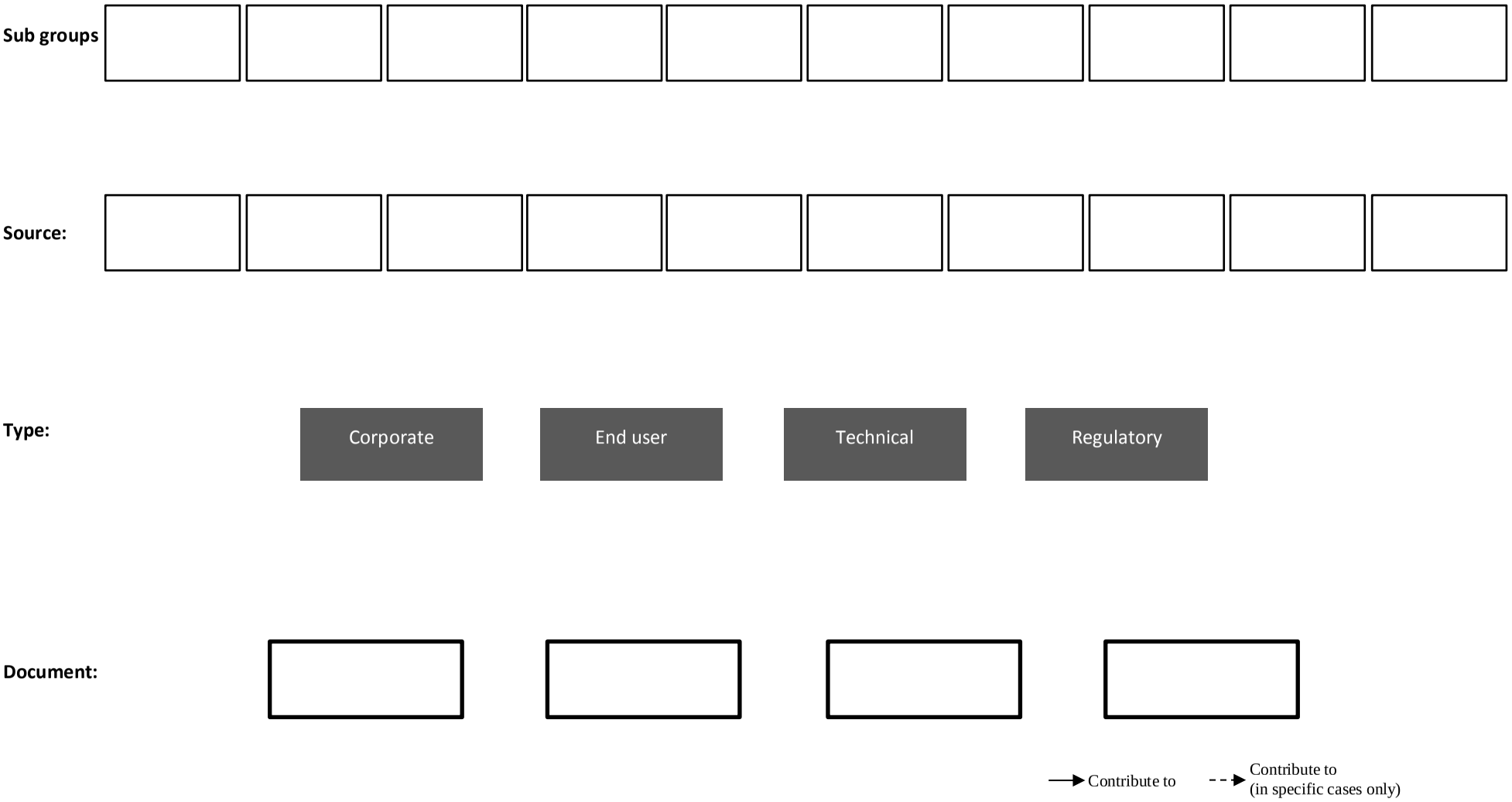


Figure 1 The sources used for gathering information in requirement identification and what types requirements they contribute to.

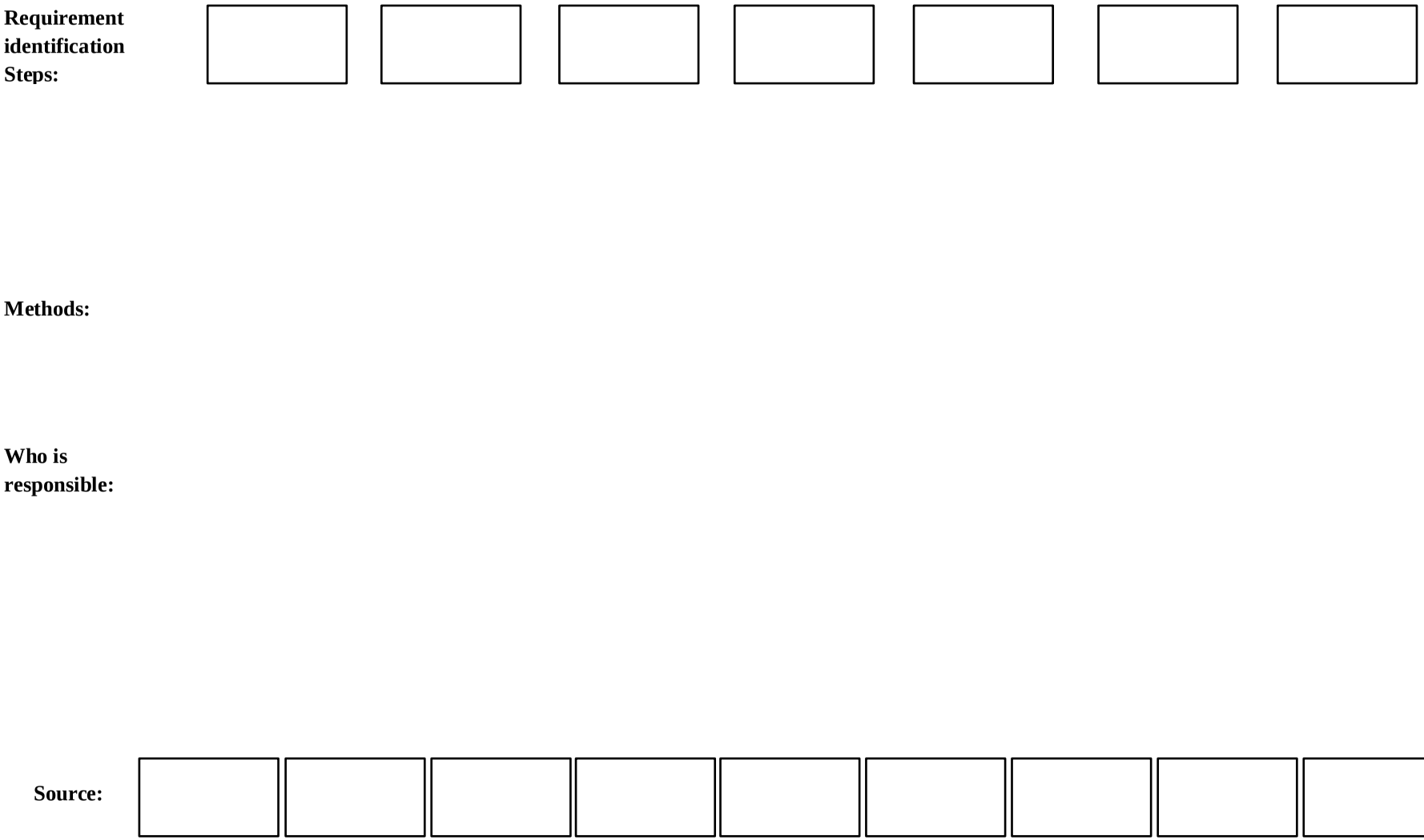


Figure 2 The process of identifying and managing design requirements and the methods, responsible and sources for each phase in this process.

Table 1 The characteristics of each sources used for gathering information in requirement identification.

Source										
Importance										
Contribution										
Category										

Importance - How important is this source to generating design requirements? (1-10)

Contribution – how much does the source contribute to design requirements generation? In terms of the number of design requirements? (%)

Category - internal to the team, internal to the organisation, or external to both.

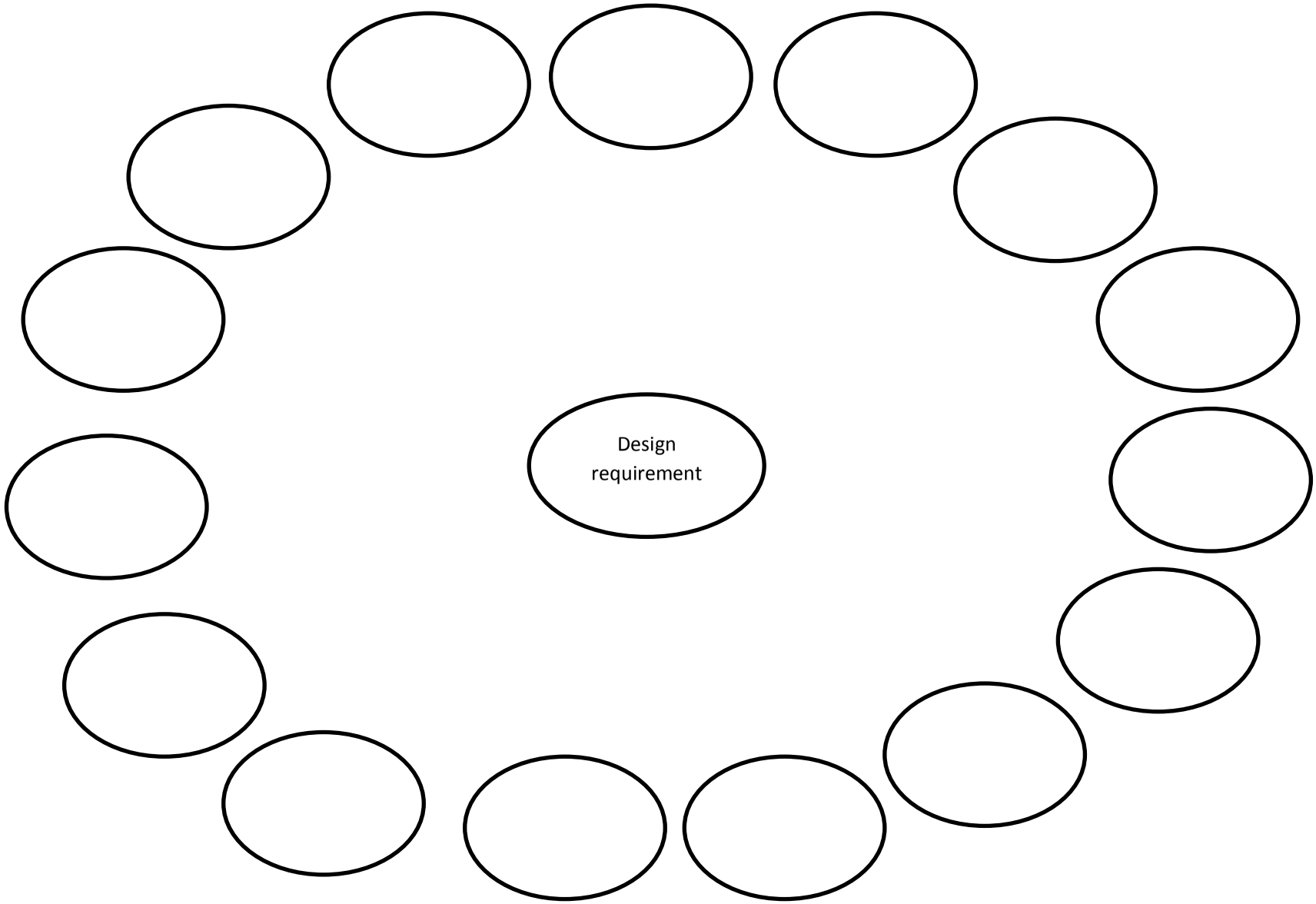


Figure 3 How does the information flow among different stakeholders and from stakeholders to design requirements?

Appendix D – Survey II

Survey II

About the survey

Thank you for finding the time for this survey.

The survey was designed by a research group from Technical University of Denmark, the Department of Management Engineering. The research aims at generating supportive design methods for Danish companies to develop products for foreign markets. This survey will collect fundamental information for us to understand the practice in order to develop new methods. Hence, we invite all Danish manufacturing companies that deliver products to foreign markets to give your input. Your participation will contribute to the improvement of our industry.

This research is part of the *Global Opportunities for Danish SMEs in Emerging Markets* project (www.godsem.dk), which is funded by *Industriens Fond* with 4 million DKK.

The survey will take about 15 minutes. All data will be kept confidential and respondents will be kept anonymous. If you have any questions regarding the survey, please don't hesitate to contact us:

Saeema Ahmed-Kristensen (Professor): s.ahmed-kristensen@imperial.ac.uk

Jaap Daalhuizen (Assistant Professor) : jaada@dtu.dk

Xuemeng Li (PhD student): xuemli@dtu.dk

Thanks again for your time and efforts.

In this survey, a few relevant concept are defined as following:

Home market: the country where the company's headquarter is in.

Foreign markets: markets that are significantly different from your home market in many dimensions, such as social, cultural, economic, and political (for example, the Asian markets to a Danish company).

Product development process: the sequence of steps or activities which a company employs to conceive, design and commercialize a product.

Sources for product requirements: the sources from where the relevant information is captured to define requirements.

Perspectives of product requirements: perspectives that may raise requirements for a product, e.g. user perspective, regulatory perspective, technical perspective.

Survey II

Background information

Please fill in the following background about you and the company you are working in.

Home market: the country where the company's headquarter is in.

Foreign markets: markets that are significantly different from your home market in many dimensions, such as social, cultural, economic, and political (for example, the Asian markets to a Danish company).

* 1. Basic information

What is the name of the company where you work?

What is your current position in the company? (e.g. product manager, R&D director, and CEO)

* 2. What is the size of your company (number of employees)?

	less than 10	10-49	50-199	200-499	500-1000	more than 1000
Total number of employees	○	○	○	○	○	○
Number of **non-production** employees (please include people who are NOT directly engaged in production e.g. R&D and administration)	○	○	○	○	○	○

* 3. Which industry sector does your company belong to?

- [ ] Architecture, machinery, and transportation
- [ ] Furniture, retail and design
- [ ] IT technology and electronics
- [ ] Energy and environment
- [ ] Food, agriculture, and fisheries
- [ ] Health and life science
- [ ] Manufacturing
- [ ] Other (Please specify)

* 4. How much experience do you personally have in product development?

	0 - 5 years	5 - 10 years	more than 10 years
Product development in general	○	○	○
Product development for *foreign markets*	○	○	○

* 5. Which *foreign markets* does your company sell products to?

- [ ] China
- [ ] Brazil
- [ ] India
- [ ] Russia
- [ ] Southern Europe
- [ ] Eastern Europe
- [ ] USA
- [ ] Middle East
- [ ] Latin America
- [ ] Southern Asia
- [ ] Other (please specify)

* 6. What is your company's business status in *foreign markets*?
(Please choose the frequencies of each description according to your practice.)

	Never	Rarely	Sometimes	Frequently	Every time
We **sell existing products** to *foreign markets* (without changes in the design compared to the products that we sell to our *home market*).	○	○	○	○	○
We **adapt existing products** to *foreign markets* (with some changes in the design compared to the products that we sell to our *home market*).	○	○	○	○	○
We **develop new products** for *foreign markets*.	○	○	○	○	○

* 7. How much time does your company usually spend on capturing product requirements in a product development project?
(Please choose the percentage of the total project time.)

	less than 10%	10% - 20%	21% - 30%	more than 30%
For *home market*	○	○	○	○
For *foreign markets*	○	○	○	○

Survey II

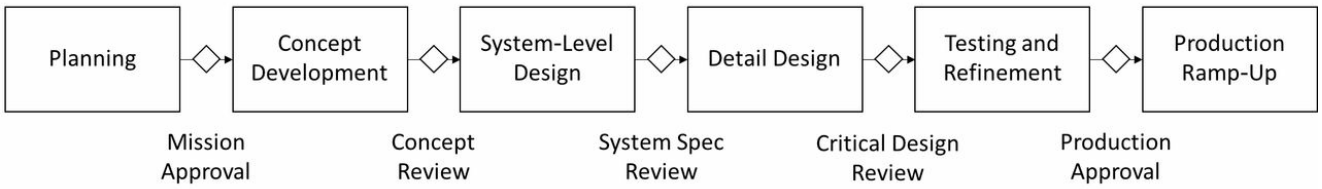
Product development process

Please answer the following questions according to the practice in your company.

Product development process: the sequence of steps or activities which a company employs to conceive, design and commercialize a product.

* 8. Does your product development process include following stages or similar stages?
A generic product development process is used as reference here, but you may have different wording in your practice.

Generic product development process [Ulrich and Eppinger, 2011]



	Yes, it includes.	No, it doesn't include.	I don't know
A **planning stage** or similar: (preparation stage) begins with corporate strategy and includes assessment of technology developments and market objectives.	○	○	○
A **concept development stage** or similar: to define the target market, and to generate, evaluate and select product concepts.	○	○	○
A **system-level design stage** or similar: to define the product architecture and the decompose the product into subsystems and components.	○	○	○
A **detail design stage** or similar: to specify the geometry, material, and tolerances of all of the unique parts in the product and to identify all standard parts to be purchased.	○	○	○
A **testing and refinement stage** or similar: to construct and evaluate multiple preproduction versions of the product.	○	○	○
A **production ramp-up stage** or similar: to train the work force and to work out any remaining problems in the production processes.	○	○	○

If your product development process involves other stages, please specify here:

* 9. Is the product development process you use for *foreign markets* different from the one you use for your *home market*?

- ◯ Yes, we have a completely different process when developing for *foreign markets.*
- ◯ Yes, we adapt the product development process when developing for *foreign markets*.
- ◯ No, we use the same product development process without any changes for *foreign markets*.

Other (please specify)

Survey II

Product development process - part 2

Please answer the following questions according to the practice in your company.

Product development process: the sequence of steps or activities which a company employs to conceive, design and commercialize a product.

10. If you use a different product development process when developing for *foreign markets*, please describe how this process is different from the one used for your *home market*:

Survey II

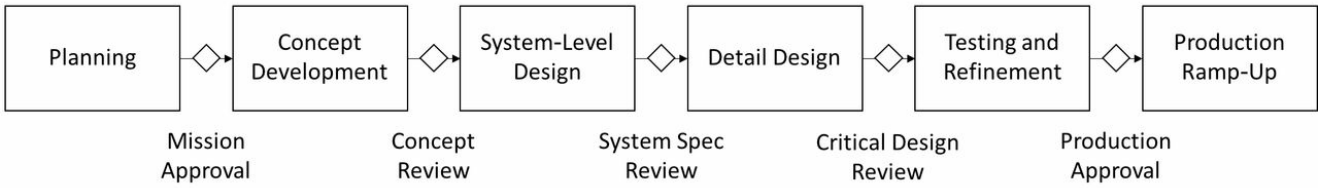
Requirement capturing practice in your company

Please answer the following questions according to the practice in your company.

Product development process: the sequence of steps or activities which a company employs to conceive, design and commercialize a product.

* 11. When do you define or change product requirements in your product development process? (Multiple choices are allowed)

Generic product development process [Ulrich and Eppinger, 2011]

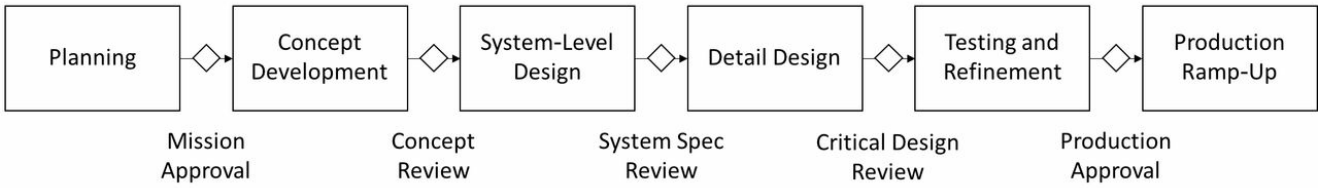


	at planning stage	at concept development stage	at system-level design stage	at detail design stage	at testing and refinement stage	at production ramp-up stage	N/A
Define product requirements when developing for your *home market*	☐	☐	☐	☐	☐	☐	☐
Define product requirements when developing for *foreign markets*	☐	☐	☐	☐	☐	☐	☐
Change product requirements when developing for your *home market*	☐	☐	☐	☐	☐	☐	☐
Change product requirements when developing for *foreign markets*	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

* 12. When do you capture information for defining or changing product requirements from the following information sources? (Multiple choices are allowed)

Generic product development process [Ulrich and Eppinger, 2011]



	at planning stage	at concept development stage	at system-level design stage	at detail design stage	at testing and refinement stage	at production ramp-up stage	We don't capturing information from this information source
From **customers and users** for your *home market* (e.g. product users, buyers and people influence the purchasing processes or decisions)	☐	☐	☐	☐	☐	☐	☐
From **customers and users** for *foreign markets* (e.g. product users, buyers and people influence the purchasing processes or decisions)	☐	☐	☐	☐	☐	☐	☐
From **internal stakeholders** for your *home market* (e.g. engineers, designers, managers, manufacturers and suppliers)	☐	☐	☐	☐	☐	☐	☐
From **internal stakeholders** for *foreign markets* (e.g. engineers, designers, managers, manufacturers and suppliers)	☐	☐	☐	☐	☐	☐	☐
From **information on products** for your *home market* (e.g. existing products, and competitive product specifications)	☐	☐	☐	☐	☐	☐	☐

	at planning stage	at concept development stage	at system-level design stage	at detail design stage	at testing and refinement stage	at production ramp-up stage	We don't capturing information from this information source
From i**nformation on products** for *foreign markets* (e.g. existing products, and competitive product specifications)	☐	☐	☐	☐	☐	☐	☐
From **governmental regulations and standards** for your *home market*	☐	☐	☐	☐	☐	☐	☐
From **governmental regulations and standards** for *foreign markets*	☐	☐	☐	☐	☐	☐	☐

Other (please specify)

Survey II

Your opinion on requirement capturing

Please answer the following questions according to the your experience and knowledge about product development.

Sources for product requirements: the requirement origins, from where the relevant information is captured.

Perspectives of product requirements: perspectives that may raise requirements for a product, e.g. user perspective, regulatory perspective, technical perspective.

* 13. How much do the product requirements defined from the following perspectives contribute to product development?

	no contribution	slight contribution	moderate contribution	significant contribution	essential contribution
Requirements defined from **user and customer** perspective when developing for your *home market*	○	○	○	○	○
Requirements defined from **user and customer** perspective when developing for *foreign markets*	○	○	○	○	○
Requirements defined from **competition perspective** when developing for your *home market*	○	○	○	○	○
Requirements defined from **competition perspective** when developing for *foreign markets*	○	○	○	○	○
Requirements defined from **regulatory perspective** when developing for your *home market*	○	○	○	○	○
Requirements defined from **regulatory perspective** when developing for *foreign markets*	○	○	○	○	○

Other (Please specify)

* 14. How difficult is it to define product requirements when considering the following perspectives?

	not at all difficult	slightly difficult	somewhat difficult	very difficult	extremely difficult
To define requirements from **user and customer perspective** in your *home market* is	◯	◯	◯	◯	◯
To define requirements from **user and customer perspective** in *foreign markets* is	◯	◯	◯	◯	◯
To define requirements from **competition perspective** in your *home market* is	◯	◯	◯	◯	◯
To define requirements from **competition perspective** in *foreign markets* is	◯	◯	◯	◯	◯
To define requirements from **regulatory perspective** in your *home market* is	◯	◯	◯	◯	◯
To define requirements from **regulatory perspective** in *foreign markets* is	◯	◯	◯	◯	◯

Other (Please specify)

Survey II

Thank you for taking the time to complete this survey

More information about our research - 'Global Opportunities for Danish SMEs in Emerging Markets: Strategies and Methods for Adaptive Product Development' project can be found on: www.godsem.dk

15.

Invitation to further collaboration

If you are interested in receiving the analysed results from us, please get in contact.

Name	
Email	
Telephone	
Other	

Appendix E – Interview guide for Study Two

访谈计划及问题

一、基本信息介绍

1. 介绍研究背景及需要的信息

本次访谈服务于丹麦国际机遇和产品创新研究项目。该项目由丹麦工业基金会资助，由丹麦科技大学工程管理学院的研究团队负责。本次研究的主要目的是了解企业在面向不同市场进行产品开发时的差异与类同，提出新的设计方法以支持企业优化面向新市场的产品开发活动。所有收集到的信息仅供学术研究用途并将做匿名处理。

如有任何相关问题欢迎联系：李雪萌（丹麦科技大学博士生在读），邮件：xuemli@dtu.dk，电话：+45 28590882。

更多项目信息可以访问项目网站：http://godsem.dk

感谢您的参与！

相关术语的解释说明：

本地市场：企业所在地的市场。（企业熟悉了解的环境）

海外市场：与本地市场在文化，社会，经济，政治等方面有显著不同的海外市场。（如欧洲市场）

产品开发流程：企业构想，设计，开发，商业化新产品的一系列活动及步骤。

需求来源：产品需求的来源，从哪里可以获取确定产品需求所需的信息。

需求视角：从什么样的视角来看待产品，用于组织收集有相同特征的一类个体对于产品的要求。例如用户的视角，技术的视角，法律法规的视角等。

注：文件中红色部分为举例说明文字。

2. 询问被访者基本信息并填写访谈记录表

公司名称：		公司成立年份：
公司规模： 总员工数：		非生产制造员工数：
公司本部所在地：		所属行业：
访谈地点：		访谈日期：
开始时间：	结束时间：	时长：
采访者：		
访谈形式：		是否录音：
被访者姓名：		在公司工作时间：
电话：		电子邮件：
职位：		在该职位的时间：
产品开发相关经验：		
面向海外市场的产品开发相关经验时间：		
其他备注：		

二、关于产品开发模型/流程的问题

1. 您公司产品主要面向哪些市场进行产品开发？
2. 您公司产品有销售到哪些海外市场？
3. 您公司是否有针对海外市场开发新产品？如有请说明是哪些海外市场？
4. 您所在公司销售怎样的产品到海外市场？
   - 情形 A：直接销售现有产品到海外（产品不经过任何改动）
   - 情形 B：改进现有产品并销售到海外（产品经过部分改动）
   - 情形 C：面向海外市场开发新产品

您所在公司销售到海外的产品大约有百分之多少是情形 A？_____%
您所在公司销售到海外的产品大约有百分之多少是情形 B？_____%
您所在公司销售到海外的产品大约有百分之多少是情形 C？_____%

5. 请描述您公司的产品开发流程（最好可以提供产品开发流程图文件）。包含几个步骤，每一步的大概内容。
6. 您公司是否使用不同的或改进过的产品开发流程进行面向海外市场的产品开发？如果是，请解释不同之处在哪里。

三、关于设计需求提取的问题

7. 请描述您公司是如何提取产品需求的？您所在公司是否有提取需求的标准流程？如果该流程包含哪些步骤及活动？如果没有，请以具体项目为例描述产品需求的提取确认过程。
8. 以下确认产品需求的活动分别是在产品开发流程中的哪一步或者哪几步进行的？

需求提取活动	产品开发流程步骤
信息收集：从不同来源收集相关信息	
分析信息：分析解决信息中的冲突，疏漏，重复，不连贯等问题	
细化需求：细化信息为具体正式的产品需求	
验证需求：验证信息是否与信息来源本意保持一致	

例如，该企业在概念设计阶段（产品开发流程步骤）收集信息，则填写：

需求提取活动	产品开发流程步骤
信息收集：从不同来源收集相关信息	概念设计

以上活动的分布在面向国内市场和海外市场是是否有差异？如果有，请描述具体的不同在哪里。
没有差异

9. 您认为通过以下视提取出来的需求对产品开发的成功影响有多大？
请以 1-5 分进行打分，5 分为影响巨大，1 分为没有影响

视角	对产品开发的影响	
	本地市场	海外市场
用户以及客户		
市场竞争		
法规制度		
技术 （新技术应用）		

例如，该被访者认为通过用户以及客户视角提取出来的产品需求对产品开发的成功在本地市场有巨大影响为 5 分，在海外市场影响普通为 3 分，则填写：

视角	对产品开发的影响	
	本地市场	海外市场
用户以及客户	5	3

10. 您认为通过以下视角提取需求的过程分别有多困难？

请以 1-5 分进行打分，5 分为非常困难，1 分为不困难

视角	提取需求的困难程度	
	本地市场	海外市场
用户以及客户		
市场竞争		
法规制度		
技术（新技术应用）		

例如，该被访者认为通过用户以及客户视角提取产品需求的过程在本地市场不困难为 2 分，在海外市场非常困难 5 分，则填写：

视角	对产品开发的影响	
	本地市场	海外市场
用户以及客户	2	5

11. 您所在公司一般从哪里来源提取用户视角的设计需求？（例如，直接询问客户，设计师自己观察提出需求等）

12. 您所在公司一般从哪里来源提取市场竞争视角的设计需求？（例如，竞品分析，市场调研等）

竞争产品分析，性价比

13. 您所在公司一般从哪里来源提取法规制度视角的设计需求？（例如，咨询律师，研究法规文件等）

14. 您所在公司一般是在产品开发的哪一步或者哪几步从以下来源收集信息以便提取产品需求的？

需求来源	产品开发流程步骤		我们的需求提出过程中不涉及这个来源
	本地市场	海外市场	
外部客户，包括产品使用者，购买者以及影响产品购买决策的人			
内部成员，包括公司员工（工程师，设计师，管理层等）以及供应商和生产商			
产品信息，现有产品的信息研究，包括公司已有产品以及竞争产品			
政府法规以及行业标准			
其他信息，请补充 技术，新技术，新材料			

例如，在本地市场该企业在项目筹划阶段和概念设计阶段向外部客户收集信息，在海外市场该企业仅在概念设计阶段向外部客户收集信息，则填写：

需求来源	产品开发流程步骤		我们不从这一来源收集需求信息
	本地市场	海外市场	
外部客户，包括产品使用者，购买者以及影响产品购买决策的人	项目筹划，概念设计	概念设计	

如果该企业在收集需求信息的时候不包含某一信息来源则选择标注‘我们不从这一来源收集需求信息’：

需求来源	产品开发流程步骤		我们的需求提出过程中不涉及这个来源
	本地市场	海外市场	
外部客户，包括产品使用者，购买者以及影响产品购买决策的人			√

15. 在面向本地市场和海外市场的需求提取过程是否还有其他的差异？如果有，请说明不同之处在哪里。
16. 是否有其他关于面向海外市场提取产品开发需求的意见及建议？

四、结束

感谢参与者的合作。之后会将访谈信息总结发给参与者。询问如有需要是否可以联系参与者对不清楚的地方做进一步的解释说明。如可能，请提供以下文件（仅作研究用途，如有必要可以签署保密申明）：

- 产品开发流程文件
- 一个产品开发项目的需求文件以及项目报告（可以选择企业认为最成功的案例）

Appendix F – Templates for the PRE toolkit

Appendix F-1 Templates for the PRE toolkit - The perspective table

The perspective table - Phase 0: Collect input

Perspective Table

Perspective	Definition	Simple Personas
User	Customer needs and users' expectations about the product's capabilities, experience, aesthetics, usability, etc.	 **Actor:** **Role:** **Name:** **Age:** **M/F:** **Occupation:** **Motivation:**
Organisational and business	Business concerns that affect the product design, such as the strategic plans, business situations, financial status, and marketing.	
Competition	The concerns about competition situation and competitive landscape in the target market.	
Regional infrastructure	The condition of the services and facilities in the region that are necessary for the product to function, e.g. roads, electrical grids, water supply and telecommunications.	
Technical	The technical aspects that a product must fulfil, e.g. technical functions, technical performance and engineering requirements.	
Regulatory	The governmental regulations, certifications, and international and regional standards on issues such as safety/health, environment/ ecology, disposal and polity.	
Other external stakeholders	Expectations concerning the product from external stakeholders involved in the product life cycle, excluding users but including suppliers, manufacturers, distributors, business partners etc.	

Appendix F-2 Templates for the PRE toolkit - The requirement table

The requirement table - Phase 1: Categorise Requirements and Identify Gaps								
Requirement Table								
		User	Organisational and business	Competition	Regional infrastructure	Technical	Regulatory	Other external stakeholders
Existing Requirements	What are the existing requirements?							
Additional requirements	What additional requirements are needed for Chinese market?							
Identified gaps	What information is missing in order to generate requirements for Chinese market?							

Appendix F-3 Temaplates for the PRE toolkit - The task table

The task table - Phase 2: Make an Action Plan					
Task Table					
No.	Type		Identified gaps and requirements that need to be validated from previous phase	Clarification	Sources
	Identify a new requirement	Validate an existing requirement			
T1					
T2					
T3					
T4					
T5					
T6					
T7					
T8					
T9					
T10					

Appendix F-4 Templates for the PRE toolkit - The action plan

The action plan - Phase 2: Make an Action Plan						
Action Plan						
Source	For Tasks?	Who?	How?	Time	Priority	Comments