PRODUCT IMPLICATIONS OF DESIGN OFFSHORING

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1. INTRODUCTION

Changes in the world's economy towards the end of the 20th century (e.g. the rise of countries like China and India), politics (e.g. the breakup of the Soviet Union), and telecommunication (e.g. the Internet) enabled fast communication and documentation sharing across vast distances.

These factors and an increased global competition and consumer market have enabled companies to have production and development networks which span the globe. Ideally, a company should be able to have production and development centres where conditions are most favourable with regard to cost, market and competences. However, this global disintegration should not impact customers, and the final cost and product quality should remain as high as if development and the production process were fully integrated.

Globalisation in engineering companies often takes place through offshoring of, at first, low value functions involving production. Only later has more value-adding functions, such as design and R&D, followed. In this paper we will investigate two types of offshoring; captive offshoring and offshore outsourcing. Captive offshoring is when companies relocate their business functions abroad to own facilities and thereby keep control of what is moved. Offshore outsourcing occurs when companies relocate their business functions abroad to another company which provides a dedicated service [1]. To ease readability we will refer to the first case as offshoring and the second case as outsourcing.

There is a lack of literature on how companies deal with offshoring and outsourcing to create potential benefits [3]. Hence, this paper investigates product implications of offshoring and outsourcing using case studies to illustrate how potential benefits are sought.

2. LITERATURE REVIEW

Global product development started with the offshoring wave in the 1990s and has since grown [2]. Today, a majority of manufacturing companies offshore or outsource not only production but also large parts of their product development, including R&D activities [4]. The key difference between conventional and global product development is the increased reliance on virtual collaboration across time zones and cultures [2].

Many companies move from offshoring simple tasks to gradually offshoring more complex tasks. According to Eppinger [2] this development is a clear strategic move where first simple tasks are moved, then integrated tasks, complete modules or subsystems, thereafter derivative products and finally new global products [2].

According to Eppinger, there are 10 success factors for global product development; (1) Management priority to offshoring, (2) Process modularity so work packages can be segregated, (3) Product modularity so interfaces can be clearly defined, (4) Core competences are identified, (5) Intellectual property is identified, (6) Data quality so one system or database is a 'source of truth' for all the globally disbursed teams, (7) The infrastructure and other technical equipment is up to date and of the highest

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standard, (8) Governance and project management to coordinate and manage the projects, (9) Need for a collaborative culture and (10) Organisation change management is needed to plan, train and educate staff [2].

Research within offshoring of design has focused on different aspects of this. Managing distributed design teams and working virtually has been a key element [5, 6]. In management literature, the focus has been on potential benefits through offshoring mainly by having cost reductions, easy reach to growing foreign markets like for example India and China, and gaining new competences [7]. Case studies on offshoring have shown an increasing trend for companies to not only offshore production, but increasingly to offshore high value adding functions like design and R&D.

Knowledge transfer is often a key element when offshoring to ensure information globally is kept up to date. Knowledge transfer approaches can be separated into two main categories; explicit knowledge transfer and knowledge transfer through personalization. Explicit knowledge can be written down, but knowledge which is transferred through personalization relies on human factors [8, 9]. Knowledge which is tacit is silent and cannot be easily transferred. Transferring knowledge through personalization is difficult in offshore situations as the teams are globally distributed.

This literature review shows that while the offshoring literature is plentiful, the literature on how companies actually implement global product development is limited, and what actions they take to try and gain as much benefit from the offshoring endeavour as possible is also limited. Through case studies the specific aims of this paper are to:

1. Understand the impact offshoring and outsourcing can have on the product.
2. Investigate how this impact was handled in the case companies.
3. Illustrate possible product improvements through offshoring and outsourcing.
4. Illustrate which factors seem to influence the success of global product development, drawing on the ten success criteria presented by Eppinger [2].

3. EMPIRICAL METHOD

The nature of the research questions suggested a case study approach due to the explorative nature of an area wherein unknown factors and elements are sought [10]. For consistency, all companies were large international corporations with headquarters and ownership in Denmark. The cases were all engineering, business to business (B2B), companies which produced different products. Table 3.1. shows the case companies, their type of company, the position of the interviewees, and the number of interviews. Please note that the companies are anonymous by request from the participants.

By interviewing top managers in a CEO, vice president or key managerial position from different departments (e.g. procurement, manufacturing, engineering, sales and marketing), a multifaceted

Table 1. Description of cases.

Company synonym	Type of company	Interviewees' positions	Nr. of interviews
X1	B2B telecommunication manufacturer	Vice presidents, daily managers	3 interviewees
X2	B2B construction manufacturer	Top level managers, daily manager	3 interviewees
X3	B2B electronics and mechanical manufacturer	CEO, vice president, daily managers	4 interviewees
X4	B2B electronics and mechanical manufacturer	CEO, vice president, daily managers	4 interviewees
X5	B2B construction manufacturer	CEO, vice presidents, daily managers	9 interviewees
X6	B2B construction manufacturer	Top level managers, daily managers	12 interviewees

Table 2. Example from the coding scheme.

Category	Code (subcode)	Definition
Knowledge transfer	Type (codified, personalization)	Codified knowledge can be written down while personalization is knowledge which is transferred through human factors
Unforeseen difficulties	Type (Misunderstandings, delays)	The difficulties the companies encountered which were seen as leading to an impact on the product
Product implications	Type (quality, functionality)	The effect on the product

perspective is gained. As the CEO and vice presidents are often the main (or sole) deciding force with regards to offshoring, the perspective of the daily managers — who were responsible for implementation and the daily management — provided a functional perspective on global production and development.

4. DATA COLLECTION

The primary data source was 35 interviews; semi-structured questions were asked but the interview was open for new information. There was little or no documentation available, which meant the interviews were the primary data source. The questions were related to preparation, decision making, impact, and factors seen as leading to success. Not all interviewees were asked all the questions, as some questions were only relevant for certain groups. All the interviews lasted ca. 1 hour, and were audio recorded, transcribed, and coded. The codes were based on an intense literature study whenever possible. As there has been little investigation into this area of global product development, many of the codes were derived from the data. Table 4.1. shows an example of the codes used where the first code shown is from literature [8] and the last 2 emerged from the dataset.

5. RESULTS

The case companies had several points of similarity. X1, X3 and X4 produced smaller components in large batches, while X2, X5 and X6 delivered large scale engineering projects according to each customer's specifications. Most of the case companies went through the same process; manufacturing was moved first, and then the other phases followed. X1, X4 and X5 offshored/outsourced the entire function for the whole company (e.g. all of production) while X1, X2, X3, X6 only did so for certain projects/product lines or specific parts of a product.

Figure 1 compares the companies' offshoring and outsourcing activities to the generic product development model [11]. X1 first offshored all of production, parts of production ramp-up, testing and refinement, detailed design, then outsourced all embedded IT, offshored parts of the system level design and finally outsourced all of production. X2 created an engineering office in China to serve the market there. Later detailed design for foreign projects drew on engineering resources from this location. X3 offshored parts of production, production ramp-up, and then parts of testing and refinement. X4 was a small company which outsourced all of production and production ramp-up. After being brought by a large multinational cooperation, X4 offshored production instead. X5 outsourced all production. In the 1990s X5 had brought a company which had a subsidiary in India. Over the years this office grew to offer engineering services to both local and global assignments. The Indian office now does most of the system level design and all subsequent phases up to production for all standardized products. In 2010 the office also started to receive R&D assignments. X6 followed the same path as X2 though for a subsidiary in China.

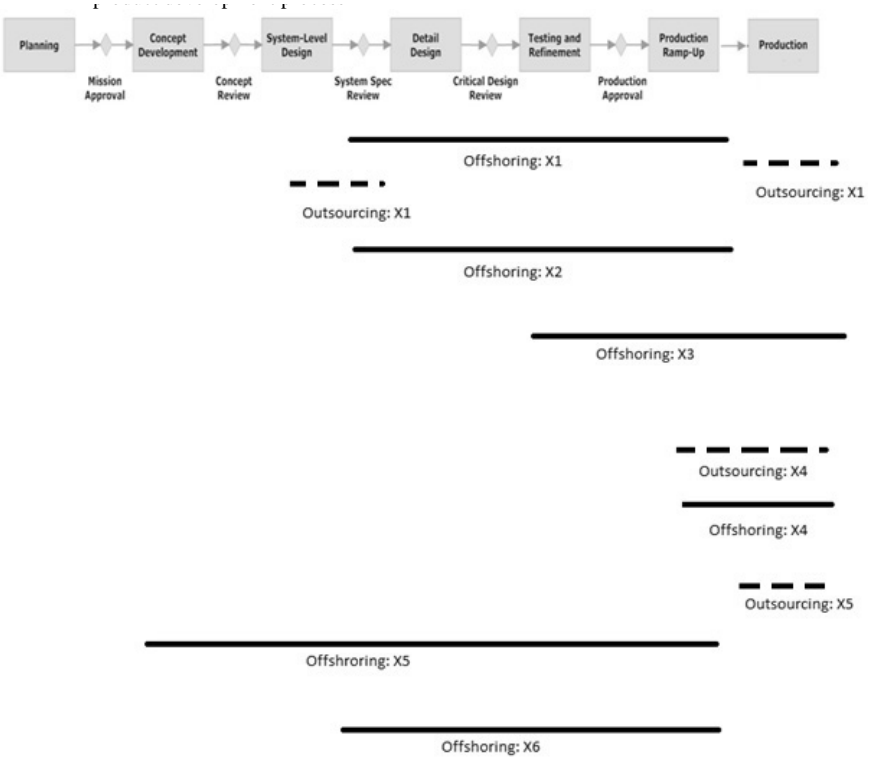

Figure 1. Company details for offshoring (full line) and outsourcing (dotted line) from the product development process.

5.1. Impact on the product

The case companies experienced both desired and undesired impacts on the product. The negative impacts were related to complications associated with the move itself while others were a result of the adhoc solutions the companies implemented to avoid these complications. Undesired impact factors caused by moving design were (1) reduced quality, (2) more rework and (3) greater delays. Undesired impact factors caused by attempts to resolve these included (1) repeating work in several locations by having more control and security, (2) more time spent on communication and documentation and (3) reduced functionality of the product. Desired impacts the companies observed were lower costs and if the motivation to move design had been caused by access to specific competences then these companies also experienced increased functionality of their products. An unexpected (adhoc) positive impact factor observed by most of the case companies was an increased understanding of the foreign market and consumer needs which enabled the company to modify the product to better serve that market. Furthermore, by moving the design process abroad many companies observed they could develop a more efficient process which could be implemented globally.

X1 experienced both positive and negative impact factors. The company saw an increase in the functionality of their product when they outsourced embedded IT to a specialist corporation in India. The motivation had been to gain competences not found in-house, and this had succeeded as expected. A positive though unexpected outcome of offshoring design had been that the design could be made simpler while keeping the desired product functionality. A manager from X1 explained it like this, "*[It's a positive thing about how] very different the culture is [. . .]. So when you see a problem and you can't solve it, you just get around it. [. . .]. That's in many cases very positive, [. . .]. It is that it is the same for design [. . .]. They [the Chinese colleagues] can make much more simple setups*." The negative impacts X1 experienced were related to difficulties with quality, rework, and delays in

the design and development of some of their products which had caused an increase in development time and cost. A manager from X1 explained how they resolved this by reducing functionality in the product, "*There are definitely some specific mechanical methods that we do not implement because we know this is going to be produced in China and it's going to be handled in China and it won't work, that's for sure. So we are reluctant to use some advanced technologies*." The motivation for offshoring had mainly been cost savings on additional engineering staff.

X2 experienced quality issues and increased rework in the development and design phase when they offshored work to their Chinese office. A top manager from X2 explained that this was mainly due to miscommunication, "*The biggest challenge is to keep everybody informed about everything, because all the informal communication will not happen. [. . .] The written communication can be difficult [. . .] and misunderstandings can easily occur. And then if their English is different from our English it can also be a challenge*." Motivation was mainly cost reductions when the engineering work was offshored to the Chinese office, and market access when it was local Chinese projects.

X3 experienced quality issues and delays. A vice president from the company explained that it was hard to use the same methods abroad as in Denmark, as these methods were not known abroad. Motivation to move abroad had in this case been cost savings.

X4 experienced delays, increased rework and quality issues. A manager explained, "*Production has become more complex. We didn't consider the long shipping time which added to the cost of producing in China. [. . .]The physical distance meant transport and communication took more time. There was a big cultural difference. [. . .]They did not get much documentation from us as it was in Danish so we also had big quality problems; they didn't have any knowledge of the processes we used*." Motivation to outsource was here cost savings.

X5 experienced delays, increased rework and quality issues. A daily manager from X5 explained how these issues were caused by communication difficulties, "*[. . .] [Communication] is too fragmented. The timing makes it hard for somebody to get a question from one group to the other. We can't be sure we get this question from one group to the other.*" He elaborated on the issue of misunderstandings in communication by explaining he has contact with the Indian manager but doesn't know how

Table 3. The causes of the impact factors.

Cause	Comment
Motivation	Motivation to offshore can be to gain cost reductions, to reach new markets or to gain new or additional competences [8]. To gain competences seems to provide fewer difficulties, perhaps because the company knew precisely what they wanted, why, and for what.
Product separation	The ease of separation of the tasks and functions influences the level of difficulty with offshoring and outsourcing. The easier it is to separate the product or process into clearly defined modules, the easier it is to separate and later integrate these as also pointed out by Eppinger [2].
Hardware vs. software	Software has a shorter implementation time, is easier to move virtually, and has a longer history of offshoring and outsourcing than product development and design of hardware products. Software can have an iterative development cycle while changes in hardware design require all sequences in the development is redone sequentially. This means software often encounters fewer difficulties than hardware [12].
Culture	Culture can affect communication. Two types of communication cultures exist; low-context (LC) and high-context (HC) communication [13]. In HC communication most of the information is in the physical context or internalized in the person while very little is in the coded and explicit part of the message. LC communication is the reverse; most of the information is vested in the explicit code. China and India are HC communication cultures, while Denmark is LC which could make virtual communication more difficult if these differences are not considered [13].
Virtual collaboration	Virtual collaboration makes informal information and personalization in knowledge sharing difficult. This means a higher level of reliance on written communication. Difference in culture, noticeable in communication therefore become a factor and rules for knowledge sharing have to be developed which considers this.

knowledge is shared or communication in the subsidiary. Motivation was cost savings and being closer to the local market.

X6 experienced delays, increased rework, and quality issues. A manager sent to China to supervise a project illustrated this was mainly caused by communication problems, "*They don't see quality like we [Danes] do. They haven't grown up [like that]. They don't have the same sense of details [like we Danes have].*" Motivation was cost savings and being close to the local market.

The causes of these impact factors can be seen as a result of motivation, product separation, culture, and virtual collaboration of knowledge and information (see Table 3).

5.2. Control actions

Many of the case companies attempted to counteract these unwanted implications by making changes to the product and its development. One approach was to make the product development process more explicit.

5.2.1. Making the product development process more explicit

Four approaches were found:

(1) Adopting codification as an approach to knowledge transfer.
This was done by employing simple methods and tools known to engineers abroad and at the Danish headquarters, and by making the process more explicit through more documentation, processes and converting implicit knowledge to explicit knowledge [14]. Most case companies tried to counteract the added complexity with a more explicit development process which meant detailed documentation of processes and procedures. The interviewees meant this would ensure quality and facilitate communication. This lessens the chance of misunderstandings based on culture as well as the impact of physical distance as everyone can prefer back to the documentation. This was one of the success factors mentioned by Eppinger [2]-

(2) Creating a more simple product design.
A complicated design, employing many mechanical or other specific parts, is harder to communicate and debate virtually and across cultures when the engineers also come from a different educational culture. The complexity of the products designed abroad was limited, to reduce risks involved with advanced technologies and ease communication. This approach was only employed when gaining competences was not one of the motivations to offshore or outsource. A lack of trust in the foreign engineers by the Danes was often an influencing factor in implementing this solution.

(3) Bridging distance between design and production.
Another approach was to bring design and production back into close contact and avoid cultural misunderstandings, delays and misinformation. Several of the case companies moved more development and design tasks abroad after they had moved production to ensure production and design engineers kept in contact. This approach was taken by X1 and X,4 and one X3 would implement in the future. This had not been planned when the company first decided to move abroad. The CEO from X3 explained, "*The main reason for moving the white collar jobs [engineers] were to support the labour [production].*" A top manager in X4 said, "*[. . .] if we move production we have to move engineering and development will have to follow.*"

(4) More security and quality checks.
Another approach was to develop detailed procedures to be followed in regard to security and quality checks of the work produced abroad. While this would catch many of the flaws it also required additional resources and time.

This risk of counteracting the negative impact factors by making the development process more explicit was the time and cost spent on creating new and updating existing documentation. Furthermore, not all information and knowledge could be documented which made it difficult to employ the solution in all cases. Finally, unexpectedly moving more high value adding functions abroad could impact the

Table 4. Success criteria for offshoring design.

Found in the case studies	Comments
Knowledge properties of the product	What type of knowledge is needed and how it can be shared virtually can indicate the ease of transferring knowledge
Company characteristics	The size of the company and history with globalization can impact the success with offshoring design
Motivation	Moving design abroad to gain specify competences may be easier as the parameters of the transaction (what, why and when) are clearly defined
Communication channels	The intensity in communication can enhance difficulties. This confirms the theories put forth by [15]
Communication culture	The difference in communication culture between the collaborating partners can influence the ease of communication

value chain in ways the company had not foreseen. Even the case companies which had moved main parts of their R&D abroad had issues with communication, information and knowledge which could indicate this solution merely moved the difficulties but didn't resolve them.

5.3. Possibilities to make product improvements

The following possibilities for improvement to the product while initialising the control actions on the product development process were discovered;

1. Unnecessary complexity in the product development process can be addressed by making the process explicit.
   This can make the development process more efficient.
2. Updated documentation as a part of the codification process.
   Existing documentation can be updated and current work-arounds can be uncovered. Starting from 'a blank page' also enables new and better ways of doing things which could be implemented elsewhere in the company. The interviewees from X3 said they had become locked in routines and offshoring provided an opportunity to redesign the development processes more efficiently.
3. Increase the product portfolio and functionality.

Moving design abroad to gain additional competences not found in-house can increase the company's product portfolio and create a product with increased functionality. X1 is an example of this (see Section 5.1).

5.4. Success criteria for design offshoring

When a company considers captive offshoring or offshore outsourcing of product design certain features of the product and company characteristics can indicate possible areas of difficulty with moving design abroad. The motivation for moving engineering tasks abroad, complexity in the development process and knowledge properties for the product being considered for offshoring or outsourcing are all parameters which can indicate where the company could encounter difficulties. Furthermore, possible solutions to counteract these difficulties can also be evaluated already at this stage. For a company with different communication cultures a heavy reliance on documentation in knowledge sharing may for example be difficult. These findings therefore indicate that a company can make a more informed decision when offshoring design to foreign or local suppliers by considering more factors than the 10 listed by Eppinger [2]. In other words we can propose the following success criteria in addition those proposed by Eppinger (see Table 4).

6. VALIDITY OF THE RESULTS

The companies were in different sectors and in different stages of offshoring and outsourcing. The size of the companies also varied; X4 had been a small company which had later been bought by a large corporation. The challenges faced when moving design abroad may be influenced by the size of the company. It was felt that by conducting interviews in a number of companies the research would be strengthened despite these unavoidable differences. Interviewees from the same company can have different perspectives depending on their own gain or loss in regard to power, position and knowledge as well as personal experience. Choosing participants from different positions tries to address this. The difference between choosing to offshore or outsource were beyond the scope of this paper. IP rights, organisational culture, and control can influence knowledge sharing, transfer and generation in an outsourcing situation contrary to offshoring.

7. CONCLUSIONS AND FURTHER RESEARCH

This paper used case studies of six multinationals which offshored design to own or suppliers' locations in low-cost countries in order to investigate the impact on the product when doing so. The study showed that the product implications are tied to the changes to the product development process and that they can be both negative and positive.

When the motivation is to gain competences the chances of product improvements like increased product functionality and increased product portfolio is greater. Furthermore, software and modularity offshoring creates less negative impact factors. Difficulties are related to misunderstandings, miscommunications, quality issues and delays. In an attempt to counteract this, companies often attempt to make the development process more explicit and lower the product functionality by employing less complex design methods and tools. Doing so can create product improvements through increased awareness of product knowledge and reduction in unnecessary complexity in the development process. However, implementing these control actions could also have a negative impact on the product through the creation of unforeseen and unwanted changes to the product's functionality without resolving the issues of communication, knowledge transfer, quality and delays.

These finding suggest an addition of success factors to those proposed by Eppinger [2] which include the communication culture, knowledge properties of the product and the motivation for moving out.

As companies continue to globalise product design and development a greater focus in engineering education on global product development and the influence it has on the product and the option for product improvements through offshoring is needed. Further research is needed to understand the key characteristics of the product and the development of it which determines success or failure in an offshoring situation. Further research is also needed to develop a decision framework for engineering offshoring which includes product features, product implications and potential product improvements and is planned as a part of this research.

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