Chapter 7

Summary and discussion

This final chapter consists of two sections. The main findings will be summarized in §7.1, structured around the four research objectives. After this §7.2 will discuss these findings in more detail. Finally, §7.3 elaborates on the directions for future research. Since this thesis is based on journal articles, the reader can find the detailed discussions, conclusions and avenues for further research at the end of each chapter.

7.1 Summary of the main findings

The aim of this thesis is as follows:

“To contribute to the academic knowledge on specific process improvement concepts for EPCM contractors”.

Four research themes are identified that address practical questions raised by EPCM contractors as Stork GLT and that fill several gaps in the literature. The following sub-sections summarize the main findings.

7.1.1 Process improvement concepts for EPCM contractors

The first research objective was to explore the characteristics of EPCM contractors, and to identify suitable process improvement concepts. Chapter 2 describes several important characteristics of EPCM contractors. They deliver output that is highly customized and low in volume. The technologies that are used are often at the boundary of existing knowledge. Furthermore EPCM processes are typically complex and dynamic, and engineering, construction and maintenance activities are often organized in projects. The supply network that is used is highly integrated with suppliers that are of-
ten very powerful. More importantly they control the entire asset lifecycle, which has at least two implications: (i) EPCM processes are highly integrated within the asset lifecycle, and (ii) opportunities for learning over the asset lifecycle appear. It is found that process maturity frameworks are capable of dealing with these characteristics. One particularly well-known process maturity framework has been developed in the software development industry: the capability maturity model integrated (CMMI). CMMI describes the stages firms can use to progress from immature processes to process maturity. A gap analysis has been carried out to see whether and where such process maturity frameworks need amendments. The result of this analysis is given in table 2.1. It is concluded that at a general level CMMI can substantially support EPCM process improvement, but that the framework needs to be enhanced with respect to important EPCM process areas such as logistics and maintenance.

The three remaining research themes follow from this preliminary study, and are also based on the identification of the key challenges Stork GLT was facing: engineering change management, condition based maintenance and incentive contracts for process improvement. These research themes will be summarized in the next sub-sections.

7.1.2 EPCM product design, process design and engineering change management

The second research objective was to explore the relationship between EPCM product design, process design and engineering change management. In chapter 3 it is argued that EPCM contractors like Stork GLT are in a constant balancing act between stability and variety: the nature of the project gives rise to product design stability (e.g. design reuse) and process stability, whereas engineering changes introduce -by definition- variety in these product designs and the way the project is executed and maintenance is carried out. Chapter 3 describes a multiple case study of Stork GLT and ASML into the question how they deal with this balancing act. It was expected that the positioning of the product delivery strategy of each of the two firms would play an important role. To describe product delivery strategies, the classification scheme of Muntslag (1993) was adopted, which consists of two specific dimensions. The first refers to the type of engineering work that is done independent of a specific customer order (i.e. the breadth of generic design information). The second entails the degree to which a client is allowed to change the custom-built product (i.e. the depth of specific design information). In general, the less work that is done independent of a customer order, and the more the client is allowed to change in the design, the harder
the control problem the EPCM contractor may face.

The case data points at significant differences between the two firms. Stork GLT is able to minimize the amount of engineering changes and to simultaneously stabilize design by focusing on generic design information, and it is able to keep processes relatively stable by linking generic project execution plans to generic design information. Also, although it follows a product delivery strategy that gives much freedom to the client, it does not suffer from large amounts of engineering changes since most of the changes were included in the generic design that was used after delivery of the first pilot plant. ASML is confronted with a high number of different engineering changes, and due to this, designs are hard to stabilize. Platform maintenance management only partly resolves this problem. Process stability is low due to improvisation (and consequently process variety) and problems with respect to engineering change planning. Based on cross-case analysis, the following conclusions were drawn: (i) the way these firms are able to successfully deal with engineering change depends on the coupling of upstream and downstream lifecycle phases (e.g. when a planning buffer exists between engineering and construction, construction is able to absorb engineering change without problems), (ii) product delivery strategies only partially mitigate any (in)balance between stability and variety: it is the specification freedom a customer takes rather than receives that determines how influential engineering changes will be, (iii) regardless of the amount and size of engineering changes, the maintenance of generic design information was found to be an important factor in the retaining balance in product designs, (iv) different types of frontloading may be needed to reduce the influence of engineering changes on downstream phases.

7.1.3 Condition based maintenance process improvement

The third research objective was to explore and explain the relevant factors that influence the implementation of condition based maintenance technology for process improvement. During the period in which the current research took place, Stork GLT was going through a transitional phase. An increasing number of gas production facilities were handed over to NAM and put into use, and databases were being filled with data on plant behavior and failures. At the same time demands in terms of plant reliability and availability were growing so that the criticality of predictability and fewer maintenance stops was increasing as well. The use of condition based maintenance technology was considered crucial for tackling this process improvement challenge.

Chapter 4 describes the exploratory part of the research objective. A single embedded case study at Stork GLT led to a typology of condition based maintenance approaches consisting of two dimensions: the type of data used
(i.e. process data versus failure data) and the type of underlying model (i.e. statistical models versus analytical models). Both the advantages and requirements for successful use of the various approaches are identified. An overview of these can be found in table 4.4. One of the main findings is that each of the four approaches within the typology requires different types of knowledge. In some cases (e.g. the use of statistical models with failure data) only basic maintenance execution capabilities are needed, whereas in other cases (e.g. the use of analytical models with process data) integration of process engineering and maintenance engineering knowledge is needed.

Chapter 5 describes the explanatory part of the research objective. Eight postulates were developed that were considered important for the implementation of condition based maintenance technology for process improvement. A multiple case study was conducted at five companies in the process industry, including Stork GLT. We found mixed results as to which postulates can be supported. Table 5.5 provides an overview of these results. One of the main conclusions is that these companies only apply the different condition based maintenance approaches as a supporting tool instead of a dominant maintenance concept. Technical systems and workforce knowledge are aligned in a decision making process that is largely based on mutual adjustment. Managerial systems (e.g. training, procedures) only support these systems to a limited extent.

7.1.4 Managerial incentives for process improvement

The fourth and final research objective was to describe and analyze optimal managerial incentives for process improvement, considering competition between heterogeneous firms. EPCM contractors such as Stork GLT are stimulated to continuously improve processes and reduce costs since their budgets for project execution gradually reduce (i.e. the repeatability gain) and they receive a certain percentage of every euro they stay within budget (i.e. the budget incentive). It was decided to undertake a study into the exact workings of incentive mechanisms that stimulate process improvement. In order to keep the study within a reasonable scope it was decided to reside to a relatively simple representation of reality: duopolistic Cournot competition. Chapter 6 presents a mathematical framework in which the behavior of two rivalrous owner-manufacturing manager pairs is modeled. Each of the firm owners offers his manufacturing manager an incentive contract that involves a bonus for cost reducing process improvement. After receiving the incentive contract, both manufacturing managers enter the competitive arena and decide on process improvement levels and the product quantities that will be put onto the market. The key idea of the chapter is that the incentive contracts act as a strategic commitment device: when the owners offer their
manufacturing manager the incentive contract they not only influence the behavior of this manager, but also the behavior of his rival’s manager.

The study’s main findings are as follows. First of all, it is found that in a Nash equilibrium, the incentive contract always includes a strictly positive bonus for process improvement. In other words, if the owner has a choice to punish or reward the manager for his process improvement undertakings, he will always opt for a reward. Second of all, using a so-called strategic form expression of the game, it is found that the outcomes resemble a prisoner’s dilemma: if one of the firm owners uses an incentive contract for process improvement, the other firm owner will do so as well. This interaction eventually leads to profits that are strictly lower than the situation in which none of these owners would employ these incentives. The reason for this is that the incentive contract leads to an over-emphasis on process improvement. The main conclusion is that process improvement incentives act as a competitive weapon vis-à-vis the rival at the expense of overall industry profits. It is also shown that these results hold in situations where the two firms are heterogeneous in terms of process improvement cost.

7.2 Discussion

The research that is undertaken is strongly inspired by Stork GLT. This firm serves as the base case in chapters 2 (process improvement concepts for EPCM contractors) and 4 (exploratory study on condition based maintenance process improvement), and is part of a multiple case study in two other chapters: the firm is compared with ASML in chapter 3 (engineering change management) and with four other firms in the process industry in chapter 5 (investigating condition based maintenance practices in industry). However, the contributions of these studies are not limited to Stork GLT only, but extend to EPCM contractors in general. The research presented in chapter 2 has two implications for process improvement concepts that are suitable for EPCM contractors. Firstly, they should not be limited to only a part of the asset lifecycle (e.g. design engineering). Secondly, they should be able to facilitate learning over asset lifecycles (e.g. a process improvement leading to significant lead time reduction of a commissioning activity should be judged on its generalizability, documented and transferred to other projects). We will now shortly discuss the specific academic contributions that are made in the chapters 3-6.

In chapter 3 it is found that there exist various strategies to differentiate between specific and generic design knowledge. Process improvement literature that helps EPCM contractors to make good decisions regarding this issue is in an early stage. CMMI, for example, gives guidance on how to
document engineering changes and changing product requirements, but no practices are given that help a firm with the feedback of initiated engineering changes to generic design information. In addition, CMMI advocates the reuse of product components, but how these reuse decisions should be made and what role engineering changes may play is unclear. This is an area where CMMI can be significantly improved.

The research presented in chapter 4 and 5 contributes to the literature in several ways. Various existing assumptions about the use of condition based maintenance are challenged. It is also found that condition based maintenance is not yet an integral part of the maintenance policies of the firms that are investigated. Instead it serves in nearly all situations as a supporting tool for decision making. The research departed on several main assumptions, namely that different knowledge areas (process (control) engineering, maintenance engineering, maintenance execution) are needed in order to successfully use the different types of condition based maintenance. Our findings also suggest that even if these knowledge types are present, successful use of condition based maintenance is difficult. This may be explained by the inherent complexity of the underlying technical system, the operational conditions under which these systems are used (e.g. stable flow or many starts and stops) and the abundance of additional factors that may explain the values of the condition monitoring indicators. A parallel with the underlying structure of CMMI can be easily drawn. At a fundamental level this framework assumes that as a firm progresses towards higher levels of process maturity it gains increasing understanding of the underlying processes and how well these processes perform. Condition based maintenance may be interpreted as a set of mature process areas that require much understanding of the processes it attempts to monitor and control. Higher level CMMI process areas may give some guidance towards successful condition based maintenance (e.g. process areas related to quantitative measurement of process performance, statistical analyses and causal analysis of failures) but do not eliminate the structural problems firms face while implementing condition based maintenance.

In chapter 6, the main contribution to theory is that our models predict that due to the interaction between competitors firm owners offer positive incentives for process improvement. They thereby face a prisoner’s dilemma: they offer these not because they want to but because they have to. So far this finding has not been described in literature and it points at the potential existence of any negative effects of these contracts, particularly the overemphasis on process improvement. This finding cannot be readily transferred to the EPCM setting since the type of competition these EPCM contractors face is different. However, this finding does demonstrate two
7.3 Future research directions

In every chapter of this thesis, suggestions for future research have been made. Each of these suggestions serves its purpose in the context of that particular chapter. In general one potentially fruitful avenue for further research would involve the linkages between the sub-themes of this thesis.

Much research has been done on the effects of using process maturity frameworks in the software industry. However, more research is needed on the factors that play a role in the successful adoption of these types of frameworks by EPCM contractors. One of the key questions in such a research project would involve the effect on engineering change management. Many process maturity frameworks incorporate practices to control changes to designs, requirements and plans. However, in the innovation management literature it is widely assumed that process management makes a firm less capable of dealing with exploration (which can be defined as the search for and use of new types of knowledge currently not existing within the firm). Since an engineering change is in principle a product innovation (or a process improvement, depending on the chosen perspective), one may argue that the same type of relationship holds for engineering change. An interesting research question, for example, would be to what extent such types of process standardization hinder successful (e.g. rapid) execution of large engineering changes.

Linking process maturity frameworks and condition based maintenance processes would also be an important research subject. It was found in the various case studies that condition based maintenance activities are generally not executed using formalized processes, and this may well be explained by the fact that condition based maintenance merely serves as a decision support tool for maintenance rather than a standalone maintenance concept. Maintenance interventions are actually based on. It is likely that EPCM contractors who commit themselves to condition based maintenance can base their process design on principles derived from process maturity frameworks.
The models on managerial process improvement incentives can be extended in several directions. One main research direction would be to investigate the effect of these models in Bertrand price competition whereby product quality may also play a role\(^1\). Furthermore, it would be interesting to explore the role of incentives for a firm’s investments in condition based maintenance technology, particularly in situations where a mutually influencing relationship between the maintenance ‘department’ and the operations ‘department’ exists. For instance, in line with Balasubramanian and Bhardwaj (2004) one could model the bargaining process between maintenance and operations when the objective of maintenance is to keep total maintenance costs as low as possible, whereas operations focuses on the maximization of plant availability. Our model also suggests that in Cournot competition an overemphasis on process improvement may exist. It would be interesting to see whether this result also holds for EPCM contractors. For example, under which circumstances would higher levels of process maturity have a negative effect on the profitability of these firms?

In existing process improvement literature, EPCM contractors such as Stork GLT do not receive the attention they may deserve. It is hoped that this thesis contributes to the literature on this type of firm, and that the multidisciplinary studies presented in this thesis will inspire other researchers to undertake research in this complex yet interesting setting as well.

\(^1\)Some early work that addresses this issue has been presented by the author at the 21\(^{st}\) Production and Operations Management conference in Vancouver, Canada.