CHALMERS
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A Model to Determine and Improve an Organisation's Configuration Management Capability

Master's thesis in Quality and Operations Management

MATHIAS EDBERG & MIKKEL HÆGER

Department of Technology Management and Economics
CHALMERS UNIVERSITY OF TECHNOLOGY
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MATHIAS EDBERG & MIKKEL HÆGER

Supervisors: Björn Ivarsson and Pontus Ryd, Solvina AB
Academic supervisor and examiner: Mats Winroth, Supply & Operations Management, Chalmers University of Technology

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Department of Technology Management and Economics
Supply & Operations Management
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone +46 (0)31-772 1000

Abstract

This master thesis has enhanced the field of configuration management by developing a model that can evaluate an organisations configuration management capability. It also verifies that the already existing theory in the field of configuration management is applicable in industries where the main goal is to preserve and develop the operational capability of its assets.

Solvina AB is a consultancy firm mainly working with clients in this industry. As a part of their service range, they advise clients in how to optimise their configuration management implementations to increase long-term operational capability and reduce project costs. This has become important for their clients in today's global market as companies are continuously forced to increase operational effectiveness and efficiency as markets grow more competitive. However, Solvina experiences difficulties as there exist no formal evaluation process to evaluate the configuration management capability and identify improvement areas in these industries.

Based on this background, this master thesis has firstly identified ten factors that are important to operate an efficient and effective configuration management. Based on these factors, an evaluation model has been developed. The model is simply a structured collection of activities that an organisation's configuration management implementation can be expected to include in order to be successful. It can identify an organisation's current configuration management capability and improvement areas. The model's design and structure is based on the ability to vary the depth of the analysis to make it a useful tool for all organisations in the industry, independent on size and available resources.

As future work, it is recommended that the model is further verified both with the practitioners of it and multiple interviewees to increase the granularity and reach the full potential of the model. Additionally, the data collection method needs to be further developed due to the barrier between the configuration management terminology and the industry terminology.

Keywords: Configuration Management, Maturity Model, Configuration Management Success Factors, Configuration Management Capability, Configuration Management Implementation

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Secondly, we would like to thank the companies and interviewees participating in the case studies conducted. We have met a lot of passionate people willing to share their knowledge with us, which have provided an understanding of the industry.

Lastly, we would like to thank our academic supervisor at Chalmers University of Technology, Mats Winroth, for his guidance and assistance throughout this thesis.

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Mathias Edberg

Mikkel Hæger

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List of Abbreviations

ALCM	Asset Life Cycle Management
CCB	Configuration Control Board
CCM	Configuration Change Management
CI	Configuration Item
CM	Configuration Management
CMMI	Capability Maturity Model Integration
CMMM	Configuration Management Maturity Model
KM	Knowledge Management
KNM	Knowledge Navigator Model
TQM	Total Quality Management

1
Introduction

In today's global market, companies are continuously forced to increase operational effectiveness and efficiency as markets grow more competitive (Stevens and Wright, 1991; Schuman and Brent, 2005). In order to adapt, changes are made to facilities, equipment and products, and the need to control these changes are important to preserve operational ability, product quality and to prevent accidents. The cost of not being operational ready can in some cases constitute up to 30 percent of the net present value (Deloitte, 2013). The issue can be demonstrated with an example, where a facility owner is conducting changes to its facility.

A facility owner has created a project to improve its current facility. The improvement is dependent on two suppliers, supplier A and supplier B, who are producing parts independently before the actual installation. To install the new equipment, the owner has ordered a complete production stop of the facility for a week. Customers have been informed, and the planned product volume has been reduced. As a result, the change will have no negative effects on business. It is crucial that the parts fit together during the installation, otherwise, the improvement project can cause major delays. To ensure this, the suppliers are given the same agreed requirement specification and blueprints of the current facility, see Figure 1.1. Delivery dates are set and the suppliers start developing and producing the parts.

During the development, two actions are taken creating issues when the equipment is installed. Firstly, the facility experiences a major breakdown during its operation, and the maintenance organisation is forced to modify the facility to quickly make it operational again. The modification is not documented, which leads to a misalignment from the communicated blueprints. Secondly, supplier A faces difficulties producing the parts as agreed and submit a change request. Project management sees no bigger issue with this change and decides to approve it. However, the change leads to a misalignment from the agreed requirement specification that supplier B is not informed about. As a result of these two actions, both suppliers are producing parts for an outdated version of the facility that no longer exist.

The facility closes its production and the suppliers begin to install the equipment. As expected, the parts do not match and cannot be assembled with the existing facility. The parts need to be modified, thus delaying the planned production one week which impacts both the facility's reputation and its profitability.

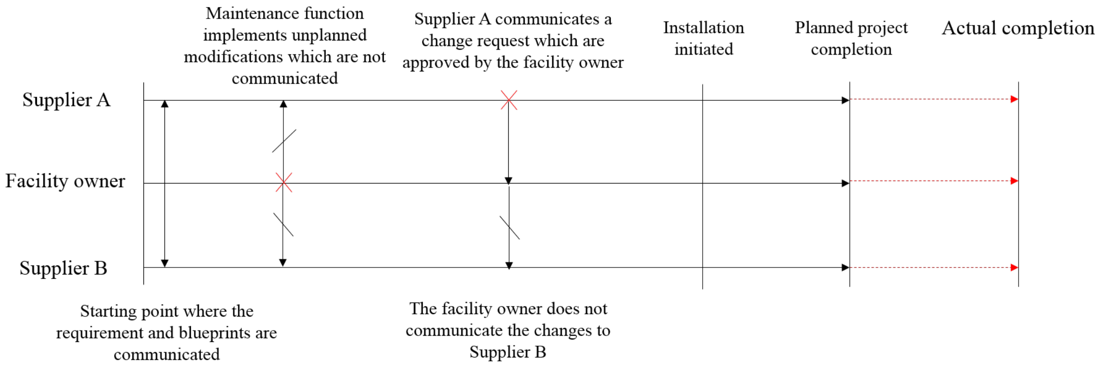

Figure 1.1: Facility change implementation example

The fact that multiple suppliers, working on different versions of the configuration concurrently, resulting in non-conformance of a facility is one of many issues that occur due to poor management of a facility's configuration (Ali and Kidd, 2013). Consequently, there is a need for a management system that can account for a facility's configuration and manage it efficiently and effectively. Configuration management (CM) is defined by the International Atomic Energy Agency (2003) as "the process of identifying and documenting the characteristics of a facility's structures, systems and components of a facility, and of ensuring that changes to these characteristics are properly developed, assessed, approved, issued, implemented, verified, recorded and incorporated into the facility documentation" which, consequently, would be a suitable management system to ensure that issues in the example could have been avoided.

1.1 Background

The term CM has been used by organisations for decades and originates from the U.S. defence industry during the late 1950's and early 1960's. At this time, the products developed became much more complex. A product's structure could not be administered by a single person or small group of engineers, which had been the case in the past (Leon, 2015; Berlack, 1992). The development projects of fighter planes and aerospace rockets often spanned over many years and included big organisations, where the product configuration needed to be shared with the entire value chain to reach the expected quality. As a result, CM was developed to handle these challenges.

An industry applying CM today is the software industry, which is characterised by high product complexity, rapid changes in design, and short product life cycles. CM makes program versions traceable in the development process and during maintenance, which reduces project lead times (Bartusevics et al., 2015). Thus, having a well developed CM, where changes are documented, software developers can be much more effective and efficient. Another industry dependent on CM is the nuclear industry. The systems operated are safety critical, where even a small accident can lead to catastrophic consequence. In order to eliminate any deficiencies and human failures, CM is needed (International Atomic Energy Agency, 2003).

Today, the majority of literature written on CM comes from the software, nuclear and aerospace industry, where the need is obvious for the survival of the organisation. However, there are few documented cases on organisations in other industries. One reason for this absence is that CM is considered by many professionals to be bureaucratic and administratively heavy (Berlack, 1992). It is associated with updating documentation of the facility, equipment or service that has been affected by a change, instead of considering it a value adding process used to secure the operational capability and reduce cost in a long-term perspective (Ljungqvist, 2013). Hence, companies do not implement, or mismanage their CM, and miss out on taking advantage of the benefits of a successful implementation. Therefore, further research needs to be conducted to determine if the established processes and success factors are generic, or if a particular industry could be biased (Ali and Kidd, 2013).

In addition, organisations have contrasting needs of CM and the amount of resources that can administrate the implementation varies. As Stevens and Wright (1991) describe it, every company needs CM to control its facilities but not every company needs a detailed CM implementation. The consultancy firm Solvina AB, has the same experience. Solvina AB mainly works with clients in the energy and process industry with both technical and organisational aspects (SolvinaAB, 2018). As a part of its service range, Solvina AB advises clients in how to optimise their CM implementations to increase long-term operational capability and reduce project costs. As the context of each company varies, the analysis of the current CM implementation requires varying amounts of resources to understand the situation and identify improvement areas. Thus, if the factors for a successful CM implementation can be identified and packaged into a process of identifying an organisations CM capability, this analysis would be more efficient. It would aid consultants, such as Solvina AB, to better understand its customer's CM capability and advise them in how to efficiently preserve and develop the operational capability of its assets.

1.2 Purpose

The purpose of this master thesis is to enhance the field of CM and to develop a model that supports organisations to efficiently preserve and develop the operational capability of its assets.

1.3 Problem Analysis & Research Questions

In order to fulfil the purpose of this master thesis, three research questions were formulated.

The first research question aims to identify factors that are important to operate an efficient and effective CM. The research question is formulated as follows:

- RQ1: What factors are important to achieve an efficient and effective CM?

To be able to improve an organisation's CM implementation, the current CM capability needs to be identified. The second research question therefore aims to determine if a model can be developed to diagnose an organisation's current CM capability. It is formulated as follows:

- RQ2: How can the current condition of an organisation's CM capability be identified?

When the CM capability has been identified, the model aims at identifying improvement potential in the implementation. The third research question was formulated as followed:

- RQ3: How can improvement areas for an organisation's CM capability be identified?

1.4 Delimitations

The research will first of all focus on industries where the main goal is to preserve and develop the operational capability of its assets. The industries included in this definition are companies in the paper and pulp, oil refinery, infrastructure, and energy industry. The research is delimited to configurations of owned production assets in industries. Thus, the product configurations and changes conducted to those will be excluded. In addition, the research will mainly focus the data collection to the organisations' maintaining, operating and engineering functions. Top management, IT, purchasing, financing and human resources will be excluded. These delimitations have been determined mainly due to the time constraint put on the research.

2
Method

This chapter includes the research strategy, design and methodology of the master thesis. Further, it presents how trustworthiness and ethics have been two important factors during the research.

2.1 Research Strategy and Design

The master thesis is based on the main steps in a qualitative approach described by Bryman and Bell (2015). The strategy was to generate research questions that aimed to guide the research. An iterative approach was used to collect literature and gather data from the industry that were used to develop concepts and reach answers to the research questions. A qualitative approach like this is recommended when aiming at generating new or contributing theory to the already existing theory Bryman and Bell (2015), which this thesis has done.

The research design, presented in Figure 2.1, gives an overview of the research process. A literature review was conducted, which created the theoretical framework. The theoretical framework, in combination with a data collection from case study 1, created the foundation for the model. A second case study, case study 2, was conducted to verify that the model fulfilled its intended purpose.

The research conducted leads to the answer of the three research questions at different stages. RQ1 was answered after creating the theoretical framework and conducting case study 1. RQ2 and RQ3 were answered after verifying that the model fulfilled its intended purpose in case study 2.

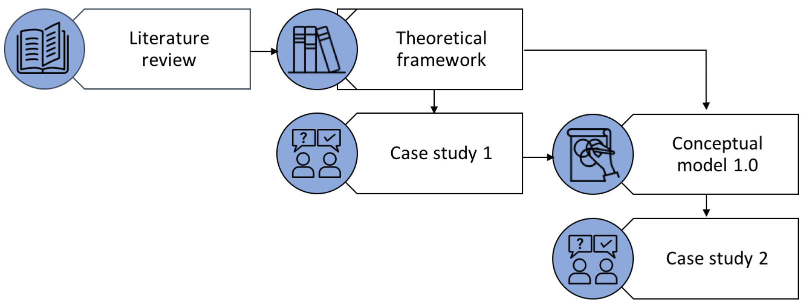

Figure 2.1: Outline of the research

2.2 Research Methodology

To reduce bias and to confirm that no misinterpretations have been made, data from multiple reference points have been collected (Bryman and Bell, 2015). The method used to conduct each step of the research is clarified in the following sections.

2.2.1 Literature Study

Based upon the presented background in Section 1.1, a literature study was conducted to form a theoretical background. The search was concentrated mainly around CM to create a broad perspective of the field and to answer the research questions.

In addition, the field maturity models was studied. The reason for this was to gather input on how the model could be designed. Other areas, strongly connected to CM, such as knowledge management, asset life cycle management, total quality management and project management (Niknam et al., 2013) were also included in the search to find possible synergies between management systems. Keywords such as *configuration management, maturity model, barriers and levers, asset life cycle management, success factors, project management, models and methods, process maturity and lessons learned* were searched for in order to create a suitable theoretical framework. The research engines used were mainly Chalmers library's database *Summon* and Google scholar. Here, articles published in scientific journals and e-books were reviewed.

2.2.2 Case Study

The case study was divided into two main parts; *case study 1, case study 2.* The methodology used for these studies is presented bellow.

2.2.2.1 Case Study 1

Case study 1 aimed at validating that the identified factors from the theoretical framework could be applied in the specific industry. Also, the character of the industry was analysed to develop an understanding of how the model could be developed to be effective in identifying the current CM capability and areas for improvement. Not taking the context in to consideration is a frequent product of failure when doing research (Johns, 2006). In addition, the interviews created opportunities to understand user preferences for CM activities (Hsieh et al., 2009).

Semi-structured interviews were used which enabled the interviewers to ask questions outside the prepared questions (Bryman and Bell, 2015). This led to more flexible interviews, where the authors could both guide the interviews and ask for more information if needed. This was important since the interviews were conducted with multiple companies and employees with different roles, where it was crucial to capture the specific context. In all the interviews conducted, one researcher acted

Interviews case study 1		
Industry	**Company**	**Title**
Infrastructure	Alpha	Project manager
Infrastructure	Alpha	Consultant
Pulp	Beta	Head of project management
Pulp	Beta	Project manager
Pulp	Beta	Project manager
Pulp	Beta	Facility owner
Consultancy	Solvina	Consultant

Table 2.1: List of interviewees case study 1.

as the interviewer, while the other had the responsibility to take notes.

To enhance the quality of the data, and reduce the risk of having to conduct an additional interview with the same interviewee, two actions were taken prior to the interview sessions. Firstly, an interview guide was created and pretested at Solvina AB, allowing questions and terminology to be improved before the interviews. Secondly, an interview introduction was handed out to all participants a week before the planned interview. The introduction included information about the purpose of the research, the interviewee's rights, general information about CM and a list of definitions and terms used in the interview questions. By handing out this information, an a common platform was created which gave the interviewees a chance to prepare for the subject and give more detailed descriptions of their contexts. The interviewees also felt more comfortable conducting an interview they had the possibility to prepare in advance.

Case study 1 included two anonymous companies and Solvina AB. The companies are presented under a pseudonym including the type of industry and title of the interviewees. In total, seven interviews were conducted during case study 1. The list of interviewees is presented in Table 2.1, the result of case study 1 in Chapter 4 and the interview template used in Appendix A.

2.2.2.2 Case Study 2

According to Sornette et al. (2008), case studies can also be used to verify findings. Therefore, another case study was conducted, case study 2, to verify that the model had been designed to answer research question 2 and 3. In total two interviews were conducted at the second case study, one at company Charlie and one at company Delta. New companies were chosen to verify that the result was transferable (Guba and Lincoln, 1985). In addition, the model was discussed with a consultant from Solvina AB to verify that it was adapted for its intended use in a user perspective.

The verification consisted of semi-structured interviews based on an interview template, created from the activities included in the model, see Appendix B. Semi-structured interviews were used for the same reasons as in case study 1. The inter-

Interviews case study 2		
Industry	**Company**	**Title**
Petro/Chemical	Charlie	Facility owner
Heat/Electricity Production and Distribution	Delta	Project manager
Consultancy	Solvina	Consultant

Table 2.2: List of interviewees case study 2.

viewees roles are presented in Table 2.2. The result of case study 2 can be seen in Section 5.3.

2.3 Model Conceptualisation

The model is built on the factors identified in the theoretical framework combined with the outputs from case study 1. The model design is developed from various existing maturity models, see Section 3.4, and learnings from case study 1. In addition, during the development of the model, weekly meetings were held with Solvina AB. Solvina's input was essential to make the model easily operated for a user and a tool that its consultants wanted to use.

2.4 Trustworthiness

Guba and Lincoln (1985) describe trustworthiness as an important factor for good results in qualitative research and have identified four criterias that ensures a trustworthy research; *credibility, transferability, dependability and confirmability.* This thesis aimed at fulfilling these criterias. Transferability was considered to be of greatest importance as this thesis aimed at providing research in an area of contextual uniqueness for CM. Firstly, to assure transferability, a detailed definition of each context was essential to provide. Secondly, triangulation was used by using different sources of data in the study, which gave the possibility to compare and validate data. The triangulation also ensures credibility (Bryman and Bell, 2015).

To ensure the trustworthiness of the research, the model was verified through interviews to see if it filled its intended purpose and detect issues connected to the design. Dependability was ensured by strictly following the methodology of the research and thoroughly documenting each operation and finding. Furthermore, the research was audited by the project supervisor at Chalmers and Solvina AB.

2.5 Ethics

Diener and Crandall (1978) identify four main areas of ethics; *deception, invasion of privacy, lack of informed consent and harm to participants* which was all kept in mind during the whole research. Abusing the data gained from the interviewees would not only affect the specific individuals but possibly also affect the safety of the companies. Therefore, all documents and knowledge gathered from the companies were handled with extra care and no information that could affect the safety of the companies and its personnel were published. To ensure that sensitive information were handled correctly, each interviewee had the possibility to exclude parts of the interview answers after the interview if requested.

Moreover, the researchers informed all participants of how long the expected participation would take, that the participation was voluntary, what the acquired data would be used for, the purpose of the research and the nature of their involvement in the research. This information was communicated with all the interviewees one week in front of the interviews.

3

Literature Review

In the following chapter, the theoretical framework, including the identified factors found important to achieve an efficient and effective CM is presented. The theoretical framework presents an extensive review of two main sections, *configuration management* and *maturity models*. The section configuration management aims to present the general theory of the management system. The section maturity models presents models for assessing the condition of an organisations current management system. The section configuration management success factors contains the factors found important for CM. These factors are further validated in case study 1.

3.1 Configuration Management

CM is the process of identifying and documenting components of a facility and ensure that changes made to it are properly developed, assessed, implemented, verified and incorporated into existing documentation (International Atomic Energy Agency, 2003). When this facility is under construction, operation, maintenance or testing the configuration can be used to ensure that it stays in line with the documentation. It helps responsible stakeholders to make accurate decisions and perform risk assessments accurately throughout the whole product life cycle (Burgess et al., 2005). Furthermore, it reduces risk of shutdowns and extended outages, as well as reducing lead times of maintenance (International Atomic Energy Agency, 2003). According to the International Atomic Energy Agency (2003), CM promotes a safety culture and facilitates regulatory reviews which, consequently, makes this management system useful in the industry. Proponents of CM see it as a necessity in product design, product development and manufacturing (Stevens and Wright, 1991).

However, there are some difficulties with CM, which makes it rather bureaucratic, costly and administratively heavy (Burgess et al., 2005). For example, if a safety standard is updated there are normally procedures and equipment that are affected by the change and, consequently, all related documents have to be changed. Normally, that is an administratively heavy process and, thus, often neglected (International Atomic Energy Agency, 2003). Similar with the example described above, documentation that must be updated when an equipment or procedure is changed. Consequently, there are a lot of documents that must be updated if changes are made in a system. Hence, many consider CM to be a costly approach with lower output than input (Burgess et al., 2005). The result of this is that many companies do not implement CM into their organisations.

3.1.1 Configuration Management Process

The general CM process can be divided into five sub processes; *configuration identification, configuration change management, configuration status accounting, configuration audits, and CM planning*, see Figure 3.1. These sub processes need to be coordinated to achieve an effective process.

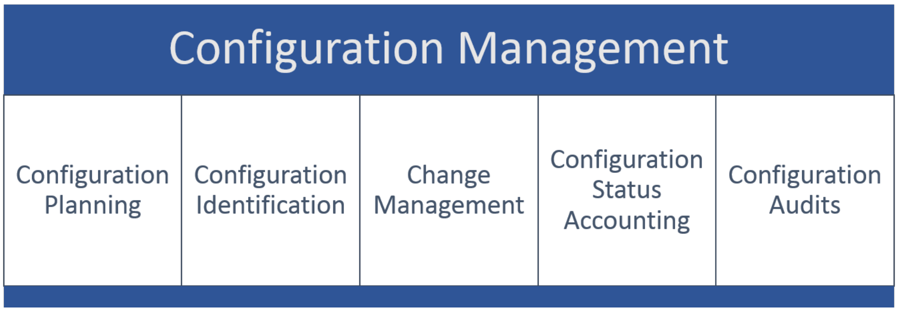

Figure 3.1: Configuration Management Process

3.1.1.1 Configuration Identification

To be able to manage the configuration of a facility, its consisting items need to be identified and divided into configuration items (CIs). This process is called configuration identification (SANS ISO 10007, 2003). All CIs combined create a complete configuration of the facility.

It is important that CIs are defined to such an extent where the level is significant enough for assuring quality at the same time as being manageable for the available resources (Institute, 2007). In addition, the number of configuration items should be adapted to the ability to control each item, risk, regulatory requirements, procurement condition and the interrelationship between items (SANS ISO 10007, 2003).

For each CI, the configuration information creates the baseline (SANS ISO 10007, 2003). The configuration information describes each CIs functional and physical attributes including its interrelationship with other CIs. Documents normally included are requirement specifications, blueprints, part lists, software documents and operating instructions. The baseline is the latest agreed configuration information and can be used as a reference for future activities. If a change was to effect a CI, it is important that the configuration information is updated and a new, future state is agreed upon that guides the process of changing it. The detail level of the baseline is dependent on the level of control needed, risks, regulatory requirements and procurement conditions.

As with any information, the baseline needs to be structured correctly to be used efficiently (Institute, 2007). Normally, a standardised documentation process is implemented to ensure that both the current baseline and older baselines are accessible to get a historical perspective of the changes made. Therefore, the documentation plan covers a taxonomy scheme identifying version, hierarchical position and date stamps.

3.1.1.2 Configuration Change Management

In the case of wanting to change a CIs configuration, a configuration change management (CCM) process is used to control the change. The CCM process is used to manage changes to an already decided future state, where all changes to the configuration must be controlled (Institute, 2007; SANS ISO 10007, 2003). An uncontrolled change process can create a misalignment between the physical configuration and configuration information defined for each CI. A model of the CCM process is illustrated in Figure 3.2.

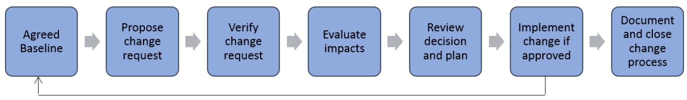

Figure 3.2: Configuration Change Management Process (Institute, 2007)

From the already agreed baseline, a formal change proposal, *submit change request*, may be initiated by a customer, supplier or by the organisation. The change request should include a description of the change proposed and include the information requested by the process. The information is later used to evaluate the change for affected functions in the organisation in step three, *Verify change request*, and four, *Evaluate impacts*, where the change request is verified and evaluated. Factors such as cost, complexity, interfaces to other CIs, and risks should be evaluated. It is also important to analyse the impact on efficiency and safety of the project where the change is conducted.

In the next step, *Review decision and plan*, the purpose is to consider the proposed change and the total impact on the organisation and the facility configuration. The authority responsible for the review, also called configuration control board (CCB), is responsible for verifying that the change can be accepted based on the evaluation. The change request is either approved or rejected. If the change is approved, the next step in the process is to implement the change, *Implement change if approved*. This step includes making sure that CIs are updated and that the activities connected to the change is planned which creates the new baseline. The new baseline is thereafter communicated with involved stakeholders. In the last step of the process, *Document and close change process*, the change is properly documented and made accessible to the organisation. A typical report created in this phase should include all CIs included and agreed upon in a baseline, information about status and historical changes to them, together with naming, numbering and version handling of CIs should be included.

3.1.1.3 Configuration Status Accounting

The process of configuration status accounting ensures that an organisation maintain consistency among the physical and documented facility configuration by recording configuration identifications and change activities (SANS ISO 10007, 2003). This ensures that the baselines are up to date and the organisation can handle the facility efficiently. The configuration status accounting should ensure that the latest status and important information about specific CIs are available to stakeholders in the organisation (Wasson, 2007). It is also important that the historical records are kept traceable for future development project's development (SANS ISO 10007, 2003).

3.1.1.4 Configuration Audits

Configuration audits ensure that the physical system resembles the documented baseline. This is a way of capturing failures and implementation problems that is not in line with the CM plan (SANS ISO 10007, 2003). The audits verify the performance and control consistency of the configuration documentation against the product (Wasson, 2007). Normally, a configuration audit consists of two types of audits, a functional audit and a physical audit (SANS ISO 10007, 2003). The functional audit verifies that CIs have the functional character that was defined, and to see if the performance of the CIs meet the stated requirements. The physical audit verifies that the delivered CIs have the physical character that was defined.

3.1.1.5 Configuration Management Planning

A CM plan for each CI in the configuration, can be seen as the foundation of the CM process. The plan includes all CM processes, defined responsibilities and authorities. This information coordinates activities that affect each item (Wasson, 2007; SANS ISO 10007, 2003). By creating a CM plan, the organisation can visualise an agreed state of the facility which is fundamental to achieve an efficient, repeatable and predictable CM process during a product's life cycle (Quigley and Robertson, 2015). SANS ISO 10007 (2003) gives an example of the content that a configuration management plan should include:

- An introduction to the item where related documents is included.
- The agreed policies affecting the CI includes the responsibilities and authorities.
- Configuration identification processes
- Change control processes
- Configuration status accounting processes
- Configuration audit processes

3.1.2 Roles and Responsibilities

An organisation working with CM should define the roles and responsibilities needed to conduct the CM processes (SANS ISO 10007, 2003). The description of roles and responsibilities in an organisation should be precise and supported by top management. The roles and responsibilities depend much on the context where the CM is implemented, however, the conventional roles are described below.

According to Institute (2007), the role connected to CM in a project is generally the facility owner who act as the configuration manager responsible for the status of the CIs and handles communication with project stakeholders. For smaller projects, where the communication with stakeholders and activity planning are minimal, the project manager may also act as a configuration manager. For bigger, complex projects, the CCB verifies proposed changes before initiation (International Atomic Energy Agency, 2003). Normally, multiple stakeholders are part of this authority, but a common factor is that the representatives are dependent on the success of the project and have much to lose if the change is unsuccessful (Stevens and Wright, 1991). In larger organisations, it is also recommended to have a responsible for the CM program. The objective is to prioritise, direct, and monitor the development and implementation of CM at the facility (International Atomic Energy Agency, 2003).

3.2 Configuration Management Success Factors

From the current literature, factors for a successful CM implementation have been identified. Table 3.1 presents a summary of the factors with the connected references. These factors created a platform for developing the interview questions for case study 1 and later to develop the model. A short description of the factors is presented below.

3.2.1 Processes

The main processes, described in Section 3.1.1, are according to multiple authors an important factor for a successful CM implementation (Ali and Kidd, 2013; International Atomic Energy Agency, 2003; Ljungqvist, 2013; Niknam et al., 2013). CM planning is one of the most essential parts and the foundation of the CM process, see Section 3.1.1.5. For an example, a lack of a CM plan is described to be common and results in difficulties in the CM implementation (Ali and Kidd, 2014).

The lack of flexibility in a CM implementation is considered a risk as participants may create informal processes of handling the configuration or not handling it at all (Ali and Kidd, 2014). Therefore, CM processes should be adapted to the each individual scenario. The International Atomic Energy Agency (2003) suggests an approach where each change is graded depending on the safety, complexity,the economic impact of potential errors, and that the processes need to context specific and clearly defined for each function. The requirements put on building a spaceship are considerably higher than changing light bulbs in office facilities. A graded approach for change projects, where different processes should be applied depending on the safety, complexity and economic impact that an error would result in, should be developed.

List of authors	
Factors	Authors
Processes	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (International Atomic Energy Agency, 2003), (Ljungqvist, 2013), (Niknam et al., 2013), (SANS ISO 10007, 2003)
Organisation	(Ali and Kidd, 2013), (Ljungqvist, 2013), (Niknam et al., 2013), (Martini and Pellegrini, 2005)
Defined roles and responsibilities	(Ali and Kidd, 2014), (Ljungqvist, 2013), (Niknam et al., 2013), (Wasson, 2007), (SANS ISO 10007, 2003)
Stakeholder involvement	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Ljungqvist, 2013), (Niknam et al., 2013), (Martini and Pellegrini, 2005), (Bergman and Klefsjö, 2010)
Management support	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Ljungqvist, 2013), (Niknam et al., 2013), (Wasson, 2007), (Bergman and Klefsjö, 2010), (Martini and Pellegrini, 2005)
CM awareness and culture	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Bergman and Klefsjö, 2010), (International Atomic Energy Agency, 2003), (Martini and Pellegrini, 2005), (McManus and Wood-Harper, 2003)
Strategy, mission and policies	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Ljungqvist, 2013), (Niknam et al., 2013), (SANS ISO 10007, 2003)
Communication	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Institute, 2007)
Training	(Ali and Kidd, 2013), (International Atomic Energy Agency, 2003), (Niknam et al., 2013)
Support systems	(Ali and Kidd, 2013), (Ali and Kidd, 2014), (Ljungqvist, 2013), (Niknam et al., 2013), (Martini and Pellegrini, 2005), (Gupta and Rao, 2011)

Table 3.1: List of categorised factors.

3.2.2 Organisation

This factor includes the organisation's hierarchy, structure, and size (Ali and Kidd, 2013). It has strong connections to the factor defined roles and responsibilities, Section 3.2.3, since it includes how the human resources are organised (Ljungqvist, 2013). Furthermore, Ljungqvist (2013) describes that the organisational factor drives the need of implementing CM, and should also include requirements for how the personnel should work, together with a competence strategy. The structure and size of a CM organisation depends on the total number of employees, needs and requirements (Watts, 2009).

3.2.3 Defined Roles and Responsibilities

It is crucial for a successful CM implementation to define and deliniate roles and responsibilities (International Atomic Energy Agency, 2003; Niknam et al., 2013). In fact, many CM implementations are inefficient due to the lack of a centralised body of governance (Ali and Kidd, 2014). Project managers can, as an example, undermine change processes if the changes made are not questioned by an official authority responsible for the long-term result. The authority should also be evaluated to control that the corresponding task is carried out correctly. The roles suggested can be seen in Section 3.1.2.

3.2.4 Stakeholder Involvement

CM is mainly operated by the facility owner, but in many cases the input is delivered from numerous suppliers and subcontractors. Therefore, these stakeholders need to be involved where agreements of expected quality, time of delivery and cost need to be defined (Ljungqvist, 2013; Ali and Kidd, 2013, 2014). In major configuration changes, stakeholders should be familiar with the standard CM terminology and have direct access to knowledge support. Stakeholders should also attend regular CM meetings to be informed of change decisions (Niknam et al., 2013). Certain projects also require a cross-functional collaboration among stakeholders.

3.2.5 Management Support

To have a successful CM implementation in an organisation, top management needs to understand the importance of CM and all the benefits it brings. Top management is responsible for including CM in the strategy, and also dedicate the needed resources for the CM organisation's operations and continuous improvements (Ali and Kidd, 2013; Albacete-Sáez et al., 2011). By allocating the needed resources and giving the authority to conduct the activities, top management sends a signal to the organisation that CM is prioritised and important to increase quality and reduce errors and cost. It is also suggested that to management should support its employees and recognise their efforts. More specifically, make them aware of the possibilities for professional development in CM (Ali and Kidd, 2013).

3.2.6 CM Awareness and Culture

Strongly connected to both management support, see Section 3.2.5, and communication, see Section 3.2.8, is the factor CM awareness and culture. The awareness of CM is not only important inside an organisation, but also for external customers. By making the customers and stakeholders aware of CM and its benefits, projects and products have the chance to be delivered with higher quality (Ali and Kidd, 2014).

A strong company culture is seen as a crucial success factor by multiple authors. A strong safety culture, as an example, is important in facilitating industries International Atomic Energy Agency (2003). Safety culture is about focusing on unreliable data that can have a negative effect on the facility, which can be avoided by creating a culture that generate, communicate, and verify reliable information. A strong company culture also leads to profitable results and more reliable outputs (Ali and Kidd, 2013). By having a culture that allows people to grow, share knowledge and develop their skills, it is easier to reach goals and visions (Sachs, 2018).

3.2.7 Strategy, Mission and Policies

To reach an effective process implementation, it is important to have a clear vision and mission to guide both stakeholders and employees to follow the established guidelines and rules (Ali and Kidd, 2013). In addition, a CM strategy should be implemented that applies to the entire business, but also for each organisational level (Niknam et al., 2013). By defining key performance indicators for each level, performance can be measured to reach the milestones and goals for the entire organisation. Measurements are important to track progress and to investigate if the whole life cycle of a process is reliable (Watts, 2009).

3.2.8 Communication

Clear and effective communication is described as an important factor for a functioning CM. This includes both internal and external communication (Institute, 2007).

By communicating the benefits and importance of CM both verbally and written, an implementation has a bigger chance of being accepted (Niknam et al., 2013). Formal processes such as documentation guidelines and structure for sharing knowledge and experiences should be defined. In addition, organisations sharing the same CM terminology also have a bigger chance of success with its implementation (Institute, 2007). Ali and Kidd (2013) further argue that if efficient communication can be achieved, project lead-times will be reduced, and the decision making will be simplified.

3.2.9 Training

A commonly considered factor in the literature is the importance of training. Having trained and experienced CM personnel is vital to make sure that processes are followed (Burgess et al., 2005). Niknam et al. (2013) argues that regular CM-related training and activities should be conducted, both for new employees but also continuously for more experienced employees. The aim is to maintain the knowledge inside the organisation and develop the employees understanding of the benefits of CM. In addition, best practices can be shared and spread inside the organisation (International Atomic Energy Agency, 2003). Training activities should include information about processes, support systems and tools, ways of communicating and guidelines for systematic ways of working.

3.2.10 Support Systems

According to multiple authors, a support system is essential to operate CM effectively (Ali and Kidd, 2014; Martini and Pellegrini, 2005). A support system normally assists CM practitioners with operations such as naming, numbering, version handling and change traceability (Niknam et al., 2013). The support system should be integrated with other IT systems and the information contained in the system should be easily available through a suitable system interface Niknam et al. (2013); Institute (2007). It is also important that the validity of the information contained in the system is quickly verifiable (Ljungqvist, 2013).

3.3 Related Management Processes

CM correlates with general principles and success factors in other management systems such as asset life cycle management (ALCM), knowledge management (KM), and total quality management (TQM), and should be applied together with CM to take advantage of the synergies Niknam et al. (2013). Commonly discussed success factors are, for instance, committed leadership, communication and defined roles and responsibilities. In addition, literature from these fields have been used to strengthen the categorisation of factors. Below, the three connected management systems are briefly described.

Asset Life Cycle Management
ALCM processes support an organisation in effectively handling both tangible- and intangible assets during its entire life-cycle to optimise the long-term profitability (Schuman and Brent, 2005). For a physical asset, this includes processes in the design phase, operations, maintenance and in the end of the life cycle. Intangible assets, such as human capital, intellectual property, financial assets, and brand recognition, can also be handled with the same processes.

Knowledge Management
Experience and knowledge gathered from projects and personal experiences should be shared to increase the productivity and gain a competitive advantage. KM is

seen as the process of capturing, sharing and using valuable information in an organisation (Zou and Lim, 2002). An organisation adopting KM aims to continuously learn, improve and use lessons learned, and as a result, reduce time consumption and reach a higher maturity level in the organisation (Shokri-Ghasabeh and Chileshe, 2014).

Total Quality Management
TQM is widely discussed in literature, and is defined as the way of working towards higher customer satisfaction with reduced resources and costs (Bergman and Klefsjö, 2010). This is achieved through various models, tools and methodologies, and is based on six core values described as the cornerstones of TQM. The cornerstones of TQM are *committed leadership, focus on customers, base decisions of facts, focus on processes, improve continuously* and *let everybody be committed*. These values are the basis for being competitive in markets. The focus on continuous improvements together with meeting customer needs, the organisation can achieve increased profitability and productivity in the longer term (Benavides-Velasco et al., 2014). Furthermore, Bergman and Klefsjö (2010) describe that organisations who have successfully deployed TQM have a better financial development than other organisations who are seen as average. If the organisation works systematically in the right way with the cornerstones as a basis, the internal and external customers will be more satisfied, and the total usage of resources will be reduced.

3.4 Maturity Models

In all organisations, improvement of the processes and progress over time is essential (Niknam et al., 2013). To measure and identify improvement potential, multiple models have been developed to address the task. These models are called maturity models and consist of various ways of identifying a company's performance. The maturity models described by Niknam et al. (2013) and Paulk et al. (1993), that are partly suitable for CM or related to, are the capability maturity model integration (CMMI), configuration management maturity model (CMMM) and the knowledge navigator model (KNM). These maturity models are shortly described below to give the reader a perspective of how a CM implementation is diagnosed with this kind of tool.

3.4.1 Capability Maturity Model Integration

The main goal of CMMI is to help identify improvement areas and provide guidance in process improvement in a project or for an entire organisation. CMMI consists of a set of models that are developed by the Software Engineering Institute (Chaudhary and Chopra, 2016). The CMMI process improvement approach helps organisations increase productivity and quality, together with helping make more predictable budget forecasts. By using the CMMI, an organisation is able to define the most important elements, measure goals and work more efficiently. The CMMI model helps organisations understand what to do to achieve more effective processes and manage the development, but has no focus on how to do it or who is responsible.

The CMMI models consists of multiple process areas, where the areas are divided into maturity levels. A process area is defined as *"A cluster of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making improvement in that area."* by Team (2010). By mapping an organisations processes and connecting them to the process areas, the models are able to specify what processes are needed to track progress and reach goals. The maturity levels provide a way to describe the overall performance, and gives an indication of what areas are most important to focus on. Five maturity levels exist, and for each level a description of what an organisation is expected to achieve is defined below (Team, 2010):

- Level 1, Initial
  At this level, processes are usually chaotic and organisations in this level have the tendency to abandon processes if there is a time crisis. Organisations performing at this level are dependent on individuals to succeed and are unable to keep stable and replicable processes.

- Level 2, Managed
  At maturity level 2 there are more structure compared to level 1, and processes are executed according to plan and controlled at defined points. The focus is on including the right people and stakeholders, together with the right amount of resources. As a result, the products, services or processes fulfils the specified standards and descriptions, also during stressed periods.

- Level 3, Defined
  At this level, standards, processes, methods and tools are well established and used as a base for achieving consistency over time. The process standards are tailored to suit the organisations projects, and are more deeply described than for level 2. This includes more defined, and more proactively managed processes.

- Level 4, Quantitatively Managed
  At level 4, specific measures for the processes are collected and analysed. These results are used to see and understand the performance throughout the life cycle of a product or process. By focusing on the quantitative measurements, the organisation can discover what improvements generate the most value for the business. Predictions are based on statistical techniques, and are therefore more reliable compared to level 3

- Level 5, Optimising
  At the highest maturity level described in CMMI, continuous improvement of processes performance is in focus. Data is collected from multiple projects to identify gaps in performance, and these gaps are used to establish more

reliable processes and reduce variations in outcomes. All improvements are measured by quantitative techniques and compared to the target to reach the wanted quality.

3.4.2 Configuration Management Maturity Model

Niknam et al. (2013) suggest a maturity model that specifically assess the maturity level of an organisation's CM implementation. According to the assessment process, an organisation's CM implementation is evaluated based on 25 factors that Niknam et al. (2013) claim should be included in an implementation to be successful. The existence of each factor is assessed and the complete CM implementation is given one out of four defined maturity levels. Each level is described in detail below.

- Level 1, Initial
  CM and its processes is unfamiliar to the majority of the organisation's personnel and no specific strategy or goal is in place. As a consequence, the processes are conducted ad hoc and vary between responsible personnel as it is up to each individual to decide the amount of time and resources that should be put on managing the configuration baselines. No training program is in place and the commitment and understanding of CM from top management is low. Looking at the support system, there is often no functions supporting CM elements. If there exist support system for CM at all, it is often created in a decentralised part of the organisation that use it only to its own advantage.

- Level 2, Managed
  For bigger projects the organisation has incorporated elements of CM and has implemented them in the strategy and policies connected to the project. The implementation of these processes are often initiated by experienced personnel with earlier knowledge. However, the organisation does not learn from finalised projects and many of the CM processes are in certain projects neglected. Also, stakeholders have not yet been involved on the CM processes. A CM terminology is introduced but the number of individuals familiar with is limited. The responsibilities and roles connected to the management system varies depending on the knowledge of the individuals in a project. The support system is adapted to CM, but is limited to the project.

- Level 3, Standard
  At this level, the understanding of CM is growing to the point where a CM strategy and policies are loosely spanning over multiple projects and the organisation. A CM plan is implemented for the facility's complete life cycle, where the processes are implemented in the majority of the projects and suppliers are involved to ensure quality. If changes to the CM plan are made it is managed by a standardised process. However, the management system is still reliant on CM experts for managing activities and no systematic way of continuously improving is in place.

CM is understood and supported by top management and the adequate resources needed for operations are allocated. Roles and responsibilities are defined, and the right level of control over CIs and projects are adapted to the specific complexity and need. A standardised CM terminology is in place and the personnel have a possibility to access a support system that provide them with documented baselines. The system is used over multiple projects and is a part of the general IT system for other functions in the organisation.

- Level 4, Optimising
  At the highest level, optimising, CM has become a central part of the organisation. The CM strategy and policies are implemented on a strategic, tactical and operational level. The process is measured to evaluate that goals are reached and from regular assessments the processes are improved continuously.

  Standard terminology, processes, roles and responsibilities are defined over the whole organisation and stakeholders are familiar with the CM terminology and processes. The process of making changes in projects follow a clear methodology where requirements are put on cross functional communication between functions and stakeholders to assess the impact of a change.

  Roles are defined that are responsible for providing training opportunities and developing the processes by gathering information about current activities and benchmarking against related industries. The processes are also flexible, the CM organisation can both be centralised or decentralised depending on the complexity. The CM implementation is supported from top management and enough resources are allocated for running the operations and working on improvements.

  CM is considered when choosing the general support system in the organisation. The compatibility for CM functionality is controlled against other parts of the support system and is also available globally. Procedures are taken to ensure that using and modifying current configurations are done without any loss of validity.

3.4.3 Knowledge Navigator Model

KM has become an important business initiative (Hsieh et al., 2009) and multiple maturity models have been developed to support these implementations. Hsieh et al. (2009) have developed the Knowledge navigator model (KNM) as an evaluation framework for assessing KM implementations. The framework is built on three main management objectives, culture, processes and IT infrastructure that have been pointed out as managerial determinants for a successful KM implementation. Each determinant has five maturity levels; Level 1 Knowledge chaotic stage, Level 2 Knowledge conscientious stage, Level 3 KM stage, Level 4 KM advanced stage, Level 5 KM integration stage.

To determine the maturity level of an organisation's KM implementation, the authors define 68 activities and practices connected to 16 key areas. Each activity is connected to a management objective and a maturity level. The evaluation of an organisation is conducted through a developed questionnaire where one question is connected to one activity. The maturity level is evaluated for each activity.

4

Configuration Management in the Industry

This chapter presents results from case study 1. Firstly, Solvina's view and impression of what is needed to effectively analyse and improve a CM implementation is presented. Secondly, data from company Alpha and Beta is presented. The companies' character, challenges and the analysis of how they perform in each success factor is described.

4.1 Solvina AB

Solvina's engineering management department has experience in advising organisation how to optimise its CM processes to increase long-term productivity and to minimise operation and project cost. Consultants from the department have therefore been interviewed to understand their perspective of the industry. In addition, the ambition is that the finalised model can be used as a tool for Solvina. Therefore, insights in how consultants normally work with clients is also studied.

Solvina's viewpoint is that the optimal CM implementation varies as each organisation has different needs. However, two factors are found fundamental for the success of the implementation. Firstly, it needs defined and documented processes for each operation of the five main processes described in Section 3.1.1.5. Secondly, these processes need to be connected to defined roles with documented responsibilities. Most important is that the facility owner acts as an active stakeholder and takes the responsibility as the owner of its assets. The owner also has the responsibility to act as decision maker in the CM processes. To effectively manage these responsibilities, each owner needs to have the competence, authority and adequate personnel to be able to fulfil the commitment the responsibility imply. With these factors in place, an evaluation can be made whether the processes are applied by the organisation and if they are effective in its context. Solvina points out that these factors are applicable in any organisation as they are independent of the size of the CM implementation.

Regarding Solvina's work process, the consultants express a need for a tool, suggestively a model that can support them in their work. It is important that the model is flexible as the resources available for an analysis differs. Normally, the clients are not aware that an effective CM process could be the solution for many of its current challenges. As a result, Solvina only gets access to one interviewee and can only take a glance at the documented processes which makes the current maturity models redundant and inapplicable. The developed model needs to be applicable in these cases.

4.2 Company Alpha

Company Alpha owns and facilitates infrastructure. The size of its facility requires a decentralised organisation with multiple functions, where the asset is handed over between functions during its planning-, operation- and maintenance phase. The organisation is divided into five main function, see Figure 4.1. The functions, planning, investments and big projects are mainly planning and conducting projects. The functions operation and maintenance have the main responsibility to preserve the operational capability and conduct changes on the current facility.

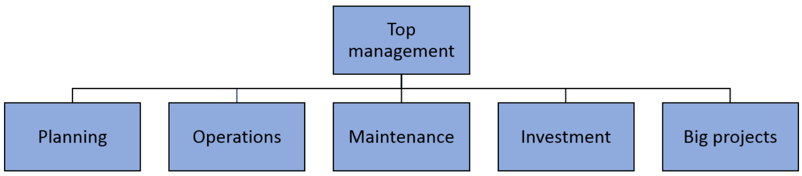

Figure 4.1: Organisation functions company Alpha

4.2.1 Challenges

On one hand, the majority of the projects conducted at company Alpha is characterised by lead times of multiple years and budgets between 1 to 20 billion SEK. 12 of the last 13 bigger projects conducted have been finished during the planned lead time and the deviation from the budget was positive in total. Clear communication and a strong management system is seen as two of the success factors according to the organisation. On the other hand, company Alpha suffers from operation disturbances. Specifically, one critical part of the infrastructure experience delays off ten percent on all deliveries made. One of the underlying reasons for these delays have been identified as weaknesses in the physical assets operated by the company. These weaknesses are also detected during smaller projects conducted by the operational and maintaining function. Due to this difference, the interviews are conducted with employees working in the operational and maintaining functions, which the analysis will be mainly focused on.

On a company level, the change management maturity varies between functions. The planning and investment functions have high maturity, shown by its positive big project results. However, the operating and maintaining function is experiencing difficulties. In addition, the organisation faces communication challenges due to the size and geographical locations of functions. As a result, physical assets are "thrown over the wall" between functions where the long-term ownership suffers.

On the project level, the understanding of change management practices are limited in operating and maintaining functions. The challenges are normally not technical but rather concerning coordination between the stakeholders of the project. Bigger change projects under the control of these functions are divided into smaller projects where the overall coordination is varying. In addition, the company procures through public contracts, where the knowledge of project management practices can vary between contractors. One of the causes for the operation disturbances have also been identified by management as a lack of control over "crucial components" for the facility, which could indicate that the lack of CM has been identified to some extent.

4.2.2 Factors

Firstly, according to the interviewees, CM is not a known term in the operating and maintaining functions. CM is instead seen being introduced at project level, where single champions drive their own processes. However, insufficient resources and low awareness of CM makes this hard to implement. The low awareness is also enhanced by the fact that company Alpha outsourced much of its maintenance and change operations to entrepreneurs, where these kind of questions are not prioritised. In total, this indicates a low awareness of CM and that no training is conducted.

Regarding the roles and responsibilities connected to CM in the organisation, projects managed by the operation function are generally split up in to smaller projects, where the facility owner is represented by the planning function. The role's main focus is cost management, and as a result, an active ownership that could be expected from the owner is not sufficient. This fact is enhanced by the geographical distance between functions. Much of the responsibility is also handed over to the entrepreneurs that conduct changes. These examples indicate that the defined roles and responsibilities are lacking in the CM implementation. Also, stakeholder involvement could be greatly improved.

Top management has shown interest in CM indirectly as resources have been invested in analysing the current operational issues that are currently experienced. However, no direct support for CM processes can be identified.

Regarding the CM processes, they are both poorly defined and executed. According to the interviewed project leader, it is difficult to locate requirement specifications and descriptions of the facility. This indicates poor configuration identification, status accounting and audits made on the facility's configuration items. In addition, there exist no official change management processes. At best, monthly meetings are conducted on the initiative of single project managers with the purpose of giving an update of the projects current situation. However, this information is rarely documented.

The support system for the facility's documentation is scattered between systems and the format varies. As a result, documentation is hard to access and is not reliable if found. In lack of a complete support system that supports CM, project managers create their own tools to support their projects.

4.3 Company Beta

Company Beta has a long history of producing a variety of products from timber. During this case study, one of company Beta's facilities producing softwood pulp and hardwood pulp have been analysed. The company is one of the leading actors in this industry and during the last years, big investments have been done to maintain the position. The investments result in improvement projects conducted at the facility which are characterised by short implementation lead times, where the complete facility needs to shut down. These shut downs are planned years ahead, where the planned product volume is delegated to the company's other facilities. It is crucial that the planned projects can be conducted during the installation, otherwise, the improvement projects can cause major delays. In addition, the projects might not be conducted before the next shutdown, sometimes years later, which delays the economic return on the tied capital to the project. In conclusion, if a planned project fails and cause a continuation of the shut down, the company may suffer big losses. To avoid this, company Beta is currently developing its project processes which this analysis will be focused on.

4.3.1 Challenges

Company Beta faces three major challenges connected to its project processes. Firstly, the requirement specifications defined in the beginning of some projects don't always reach the required quality to keep the project on budget and inside the planned time frame. According to the interviewees, the reason for this is that a facility owner has insufficient resources to be an active participant during pre studies to projects. The time taken to orient the engineers in the documentation of the affected facility is also time consuming and often not prioritised. These issues leave important aspects out of the requirement specification.

Secondly, company Beta currently uses multiple subcontractors in projects conducted. The subcontractors are required to deliver complete documentation of the delivered equipment according to the contract written between the parties. However, the project managers often experience that the documentation is delayed for months, even years. Consequently, the facility documentation is in many cases inconsistent with the physical configuration before the facility goes back to operation. This results in issues when maintaining and developing the equipment later on.

Thirdly, operating the current support system is time consuming. The organisation currently has no standard or training for handling the support system and the included facility documents. The knowledge of changing the documentation only lies with a few experienced employees, and as a result, new employees are dependent on colleagues for all work tasks connected to the facility documentation. This issue creates bottlenecks during projects and the documentation process is not always prioritised, which leads to irregularities between the documented facility and the physical configuration. In addition, when employees change position or retire from the company, the organisation risks losing valuable knowledge which is currently not passed on.

4.3.2 Factors

The organisation is aware that the established processes is of great importance to effectively run the company's facilities. However, the awareness of CM and its processes is low. The interviewed project leaders are for an example not aware of the CM terminology.

Taking a closer look at the roles and responsibilities, these are delegated to employees in the organisation. The organisation is characterised by employees that are strongly connected to the company and feel responsible for their work task. The facility owners participate in decision making regarding their equipment. However, as mentioned, they have insufficient resources to be active participants which results only in a focus on the economic impact of the projects.

Top management gives the authority to improve project processes. However, if top management dedicates enough resources for the activities included in the processes is unclear. On one hand, one interviewee mentioned a constant struggle getting the resources needed, including the right people, time and financial resources. On the other hand, other interviewees were satisfied with the resources dedicated.

Regarding the continuous improvements in the organisation, employees normally learn from their own projects. Changes and updates during a project are spread to all involved parts during project meetings but there is no platform or organised workshops where these experiences is spread between members of other projects.

According to the interviewees, the requirement specifications in the pre studies need to be improved. The challenges of the facility documentation being inconsistent and that facility owners only focusing on economic aspects of the facility indicate a low maturity of the configuration identification processes. In addition, the time taken to control the documentation of the affected facility is too long indicates that the configuration status accounting procedures need to be strengthened. Also, there is no standardised way of documenting and saving facility information which also indicates this.

Regarding the configuration change processes, no formal process to approve the change is conducted if changes are made to the facility included in the project, rather it is up to the project manager to make a decision. Decisions made are rarely documented. This indicates that the change process needs to be improved. The newly developed project processes include parts of the processes that can be expected from a CM implementation. However, the efficiency could be greater.

Regarding company Beta's support system, the organisation operates with an online document handling system where access is given to project members. Although Beta operates this system, it is not used in an efficient way. An example of this is that employees need to informally learn from each other how to document and locate information about the facility.

4.4 Context Conclusions

In conclusion, company Alpha and Beta are different in what characterises their business and project processes. However, many similarities are identified that indicate that they are experiencing similar challenges due to their CM activities.

The need for a documented CM process and connected roles and responsibilities are crucial. Company Alpha's poor CM processes become evident in the challenges the project leaders are facing during initial change projects. The importance of these factors is seen in Company Beta's project handbook, where processes are well documented and applied. However, the efficiency could be higher if, for example, baselines are used in the configuration change management process.

Facility owner's responsibility to maintain the configuration of its assets are absent in both cases. Facility owners limit their responsibility in projects to controlling cost and in owning their assets when conducting changes to it. In many cases, the requirements put on change projects in the facility are vague and leads to issues during and after the project is finished.

What also is noticeable on both cases is that the recognition of CM is low. In both cases CM is driven by autonomous project leaders and CM terminology is not used. Two other factors are also clearly important due to this challenge. Firstly, training is necessary to build competence. Secondly, top management is not aware of CM and does not understand the importance of it, which in turn, neither gives the resource nor the authority to stakeholder to implement the processes.

In conclusion, by analysing the support system of the two companies, the differences are noticeable. Company Alpha's support system does not support CIs. The documents of each CI i scattered between multiple systems, also this is an important factor for the CM implementation. The importance of this factor is seen in Company Beta's support system, where a support system exists for CIs and changes to these can be tracked. However, the support system could have been more efficient if it supported all CM processes such as configuration change management documentation.

Regarding the validation of the identified factors in the literature review, it is concluded that they are central for CM implementations in the industry. It is evident that the organisations are neither efficient nor effective if these factors are not taken in to consideration. This is evident as the connection between the experienced challenges and the lacking of the factors are strong, which the conclusions above demonstrate. In addition, this conclusion correlates with Solvina's view on what is needed for a successful implementation. As a result, RQ1 has been answered as the factors important to achieve an efficient and effective CM has been identified.

What is also seen as an important observation is Solvina's addition to the already identified factors. The CM processes need to be documented and connected to defined roles. The facility owner needs to be an active stakeholder in the organisation and take the responsibility to act as the owner of its assets. The employee given the role also needs the right competence and be given authority and resources from top management to effectively manage its responsibility.

Another observation is that the factors vary between functions in the organisation. Some parts, such as company Alpha's project organisation is using CM efficiently, although the operating and maintaining functions' maturity are lower. This implies that the existence of factors are not binary as it can exist at some functions of the organisation. This conclusion will be taken in consideration in the design of the model.

5

Configuration Management Model

The developed model is based on information gathered from the literature review and data from case study 1. By analysing the factors for a successful implementation of CM, together with the experiences from the organisations, the model has taken form.

The model is a structured collection of activities that an organisation's CM implementation can be expected to include in order to be successful. The model and its activities are presented in Figure 5.1 and 5.2, and is intended to identify an organisation's CM capability and identify improvement areas where the organisation has a potential to develop. The model is primarily intended for organisations that operates in industries where the main goal is preserve and develop the operational capability of its assets. The following sections present the building blocks of the model. First the model design is presented in Section 5.1 followed by the model practice in Section 5.2. Thereafter, case study 2 is presented, where two organisations are analysed to verify the functionality of the model, see Section 5.3. The chapter is then concluded with a discussion in Section 5.4.

5.1 Model Design

The model is divided into three main dimensions which the identified factors have been categorised under. Each factor creates a sub category consisting of activities that are expected to be included in a CM implementation, see Section 5.1.1 for a detailed description of the dimensions and groups.

Before the data collection, depending on how extensive the analysis is going to be, one out three activity levels are chosen. For each level, the number of activities included in the analysis varies. The levels are described in Section 5.1.2.

During the data collection, the fulfilment of each activity in an organisation's CM implementation is evaluated separately and ranked on a performance scale. This performance scale is presented in Section 5.1.3.

The design is based on the models and performance levels presented in Section 3.4.

Lvl	Factors	ID	CM activities	Performance Level			
				I	II	III	IV
		P	Processes				
1	Documented	P1	Basic CM processes are defined				
2	*Planning*	P1.1	CM planning processes are defined				
3		P1.1.1	CM planning processes include; - Coordination of future CM baselines for each CI - Activities that govern the CI - Defined responsibilities and authorities connected to the activities				
2	*Identification*	P1.2	Configuration Identification processes are defined				
3		P1.2.1	Processes identify CIs with a graded selection criterion				
3		P1.2.2	Processes ensures that scope and boundaries are defined for new CIs				
3		P1.2.3	The number of CIs are optimised for the ability to control the complete configuration				
3		P1.2.4	Processes identify interrelationships between CIs				
3		P1.2.5	Processes for establishing baselines are defined				
2	*Status Accounting*	P1.3	Configuration status accounting processes are defined				
3		P1.3.1	Processes ensures that requirement specifications are defined for CIs				
3		P1.3.2	Processes maintain consistency among; - Requirement specifications - The physical configuration - The configuration documentation for each CI as changes are made				
3		P1.3.3	Processes maintain the consistency of interrelationships between CIs				
3		P1.3.4	Processes enables traceability of changes on CIs and configurations				
3		P1.3.5	Processes protect the facility configuration information from manipulation and authorised changes				
3		P1.3.6	Processes ensures that CIs are governed by the defined baselines				
3		P1.3.7	The process of naming, numbering and version handling of CIs are managed during changes				
2	*Change*	P1.4	Configuration Change Management (CCM) process are defined				
3		P1.4.1	The CCM process include the following steps when conducting change; - Submit and verify change request - Evaluate impacts - Review decision and plan - Implement change if approved and update baseline - Conclude change process				
3		P1.4.2	The Change process include a Change Control Board (CCB) for review and decision making on configurations				
2	*Audit*	P1.5	Configuration Audit processes are defined				
3		P1.5.1	Processes verifies that CIs physical configuration correlates with its configuration documentation				
3		P1.5.2	The process verify that Configuration management activities are conducted				
1	Roles	P2	Roles and related competence requirements are connected to the CM processes				
1	Application	P3	The CM processes are applied				
1	Effectiveness	P4	The CM processes are effective				
2	Stakeholder involvement	P5.1	CM processes ensures cross-functional collaboration between concerned stakeholders				
3		P5.1.1	CM processes ensures, in major configuration changes, that key suppliers are required to provide a configuration management plan				

Figure 5.1: Model design part 1

		O	**Organisation**				
1	Responsibilities	O1	Responsibilities are assigned to positions in the organisation				
2		O1.1	The facility owner has the responsibility to act as the owner of its assets				
3		O1.1.1	The facility owner/Top CI owner delegates the ownership down to sub CI owners				
3		O1.1.2	The facility owner is a member of the CCB and act as a decision maker in projects where CIs are changed that affects its assets				
2		O1.2	An owner of the CM processes is defined				
3		O1.2.1	The process owner has the responsibility to maintain and continuously improve the CM processes				
1	Authority	O2	Owners with a delineated responsibility have the authority to implement the CM processes and make decisions regarding its CIs				
1	Competence	O3	Owners with a delineated responsibility have the competence to implement and verify the CM processes				
1	Staffing	O4	The organisation has adequate time and resources to implement and verify the CM processes				
2	CM awareness and culture	O5.1	Recognition of the importance of CM				
2	Strategy, mission and vision	O6.1	CM is included in the organisation's strategy				
3	Communication	O7.1.1	CM strategy, processes and terminology are communicated with stakeholders				
3		O7.1.2	Promotion of CM's latest standards, lessons learned, best practices and internal & external benchmarks				
3	Training	O8.1.1	CM is included in general training of project leaders and facility owners				
		S	**Support system**				
1	Support system	S1	A support system exists				
2		S1.1	A support system facilitates the CM process				
3		S1.1.1	Availability of the facility CI information and change documentation				

Figure 5.2: Model design part 2

5.1.1 Activity Groups

The activity groups consider three primary dimensions; Processes, Organisation and Support system. A reason for this is that the CM factors and activities found important in the literature review and case study 1 can span over these dimensions. The dimensions are divided into sub categories consisting of the identified factors, see Figure 5.3.

Processes
Four sub categories are included under the first dimension, processes; documented, role, application and effectiveness. Firstly, a CM implementation needs defined and documented CM processes. Secondly, these processes need to be connected to defined and documented roles and responsibilities. Activities under this sub category investigates that each CM process has a dedicated role with a related competence requirements connected to it. Thirdly, the application of the process should be examined. Experience from the interviewed industry implies that even though a process is documented, the processes are not applied. The forth step is to question if the CM processes are effective.

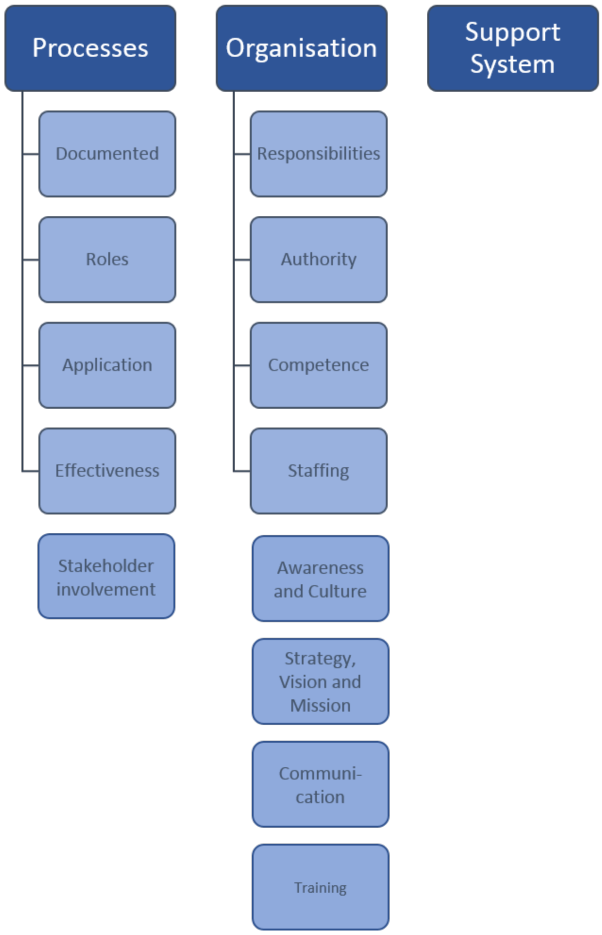

Figure 5.3: The three dimensions and connected sub categories

The connection between the dimensions, process and organisation, is found under the sub categories roles and responsibilities. The role and connected competences is defined for each activity and the delineation of that responsibility needs to be found in the specific organisation. This dimension also consists of one independent factor; stakeholder involvement.

Organisation
The dimension organisation comprises, first of all, four sub categories; *Responsibilities, Authority, Competence and Staffing.* Firstly, the organisation needs to assign employees to the defined roles connected to the CM processes. Secondly, the role needs authority to conduct the activities connected to the processes. This authority is given by top management. Thirdly, the model investigates if the employee with responsibility and authority has the competence to implement the CM processes. Lastly, the model questions if the organisation has enough resources to staff the CM processes. Thus, to effectively manage a responsibility, each role needs to have the competence, the authority and adequate resources to be able to fulfil the commitment that the responsibility implies. This dimension also consists of four independent factors; *CM awareness and culture, Strategy, mission and vision, Communication, Training.*

Support System
Under the category support system, the activities intend to evaluate the system that support the CM implementation. It is important to understand to what degree the organisation benefits from its system and in what extent this system is being utilised between different parts of the organisation.

5.1.2 Activity Level

When analysing an organisation's CM implementation, the resources available for the task vary from case to case according to the interviews at Solvina AB, see Section 4.1. In a situation where the analysis is limited by a shortage of resources, it is not possible to study each activity in the model. Therefore, the activities included in the model are divided into three levels. At level 1, the analysis is general and the activities found most crucial are included. If more resources are available, and a deeper analysis is possible, a level 2 or 3 analysis is recommended. For each level, the analysis becomes deeper, and the number of activities increases. In addition, each activity is given a number that identifies which activity level it belongs to, which is illustrated in Figure 5.4. Activity P1 belongs to activity level 1, P1.1 to activity level 2 and P1.2.1 to activity level 3. Colours are also added to enhance the grading.

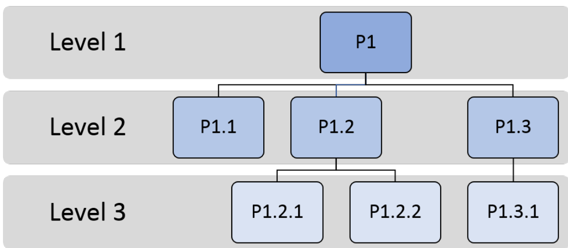

Figure 5.4: Activity levels

5.1.3 Performance Level

From the industry experience, it is evident that an organisation can reach the fulfilment of an activity at certain levels. Thus, the fulfilment of each activity in the model cannot be binary. As a result, a four level scale was developed for the evaluation of each activity of the model, see Figure 5.5. The scale developed is based on a combination of the maturity description in the CMMI, see Section 3.4.1, and the CMMM, see Section 3.4.2.

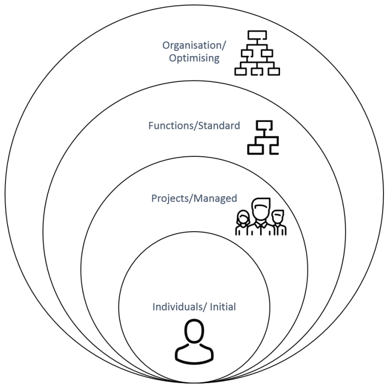

Figure 5.5: Performance levels

- Level 1, Individuals/Initial
  An organisation at level one is characterised by chaotic processes were they are abandoned when time and resources are scarce. The execution varies between personnel, and the organisation is dependent on champions understanding the importance of CM. This can often be seen in decentralised parts of the organisation, where the implementation is only used for its own advantage. The implementation is unstable and is not systematic repeatable.

- Level 2, Projects/Managed
  At maturity level 2, there is more structure compared to level 1. Processes are executed according to plan, even during times when the organisation is overburdened. Bigger projects have understood the need for the elements of CM, and have implemented them in the strategy and policies connected to the project. Processes are created due to earlier knowledge of experienced personnel.

- Level 3, Functions/Standard
  At this level the CM processes are well established at function level and is used as a base for achieving consistency over time. Proactive processes are tailored to suit the organisation's projects. However, the management system is still reliant on CM experts for managing activities and no systematic way of continuously improving is in place.

- Level 4, Organisation/Optimising
  At level 4, the CM implementation is a central process for the complete organisation and well known by employees and stakeholders. The processes are adapted to each function of the organisation and is independent of champions.

5.2 Model practice

In practice, three steps; *Planning, Data collection* and *Analysis* are conducted when using the model, see Figure 5.6. A guideline for how to conduct these steps is presented in Appendix E. This section presents the general model practice.

Figure 5.6: Three steps of using the model

To gather the information required to analyse an organisation's CM implementation, multiple data collection methods may be used. This includes document and support system observations, interviews and focus groups among others. To get an overall view of the organisation, documentation and support system observations are recommended to start with. Activities included in activity level 1 can be evaluated by observing documented processes, documented roles and responsibilities and the support system. This method is resource efficient and the information gained gives a general understanding of the maturity level and the primary focus areas to improve. By gathering data directly with employees in the organisation, a deeper knowledge about the activities can be found. Therefore, it is suggested that an analysis on level 2 or 3 is collected either through interviews or focus groups. An interview template used to collect data is presented in Appendix B.

In addition, as the data collection is entirely qualitative and mainly based on the instinct of the user, the result should be treated as an indication of an organisation's CM capability. Thus, it shall not be seen as a fact sheet, rather a platform for discussion.

5.3 Analysis and Verification

To verify that the developed model fulfilled the desired purpose, a new case study was conducted. The analysis was conducted at level two through semi-structured interviews based on the presented interview template in Appendix B.

The following sections include the analysis of the two companies, a verification result and learning from the interviews. The section focus on verifying the model and not on each specific analysis of the companies.

5.3.1 Analysis Case Study 2

The two organisations involved in the verification were company Charlie and Delta. A presentation of the two organisations together with an analysis are presented in Section 5.3.1.1 and 5.3.1.2.

5.3.1.1 Charlie

Company Charlie is a producer of polyolefin, base chemicals fertilisers and polyethylene. The company's facility has been running for multiple decades and is continuously improved to handle the market demand.

The current challenges experienced by the organisation are connected to its outsourcing of project management and maintenance department. The analysis of the company's CM implementation is presented in Appendix C. According to the analysis it can be concluded that Company Charlie attains a mature configuration management implementation. The CM processes are well documented, and the responsibility for conducting these processes are delineated to employees in the organisation which seem to take their responsibility with the exception from the maintaining and operating function which, for example, comes with late suggestions that deviate from the agreed baseline. This issue can originate from two reasons. Firstly, improvement potential can be found in the processes of including stakeholders in the change management process. Secondly, not enough resources are given to the operating and maintaining function to be able to give their input in time. The processes for these activities should therefore be analysed further and improvement should be made.

Moreover, the documented configuration is currently spread between several support systems, some even physical. However, actions have already been taken at company Charlie to improve this issue.

5.3.1.2 Delta

Company Delta is an energy producer and attain facilities producing and distributing district heating, cooling and electricity. A part of company Delta's strategy, is the vision to operate, maintain and develop its facilities for long term ownership.

The organisation experiences one challenge that could indicate that the CM implementation is not working as efficiently as it could. The facility configuration is not currently documented, which becomes an issue conducting change projects involving the equipment. This results in difficulties finding spare parts for old equipment and the knowledge of the facility is lost when employees retire or transfer to another position.

The analysis of the company's CM implementation is presented in Appendix D. According to the analysis, company Delta attains a lower maturity level compared to company Charlie. On one hand, the processes are documented quite extensively. On the other hand, the processes are applied irregularly and are not as effective as they could have been according to the interviewee. The underlying reason for this could suggestively be due to a number of organisational issues. Firstly, some employees given responsibility do not have the competence needed to implement and verify the CM activities. For example, facility owners have difficulties defining requirements when ordering new equipment. This could indicate that the facility owner cannot conduct its task as owner of its assets. Secondly, the responsible employees are overburdened with other tasks and priorities. As an example, the interviewee express that adding the documented configuration of new equipment and changes it to the support system is often not done according to the processes.

Regarding the support system, the organisation has a general support system that aims to support all activities conducted in the organisation. However, it does not support the CM implementation effectively according to the interviewee.

5.3.2 Verification Result

In conclusion, after conducting the analysis of Charlie and Delta, the current condition of an organisation's CM capability can be identified by using the developed model, which answers RQ2. The case study shows two diversified analysis results, where the current condition of each factor gives an indication of the CM capability. It is also possible, through the analysis made from the interviews conducted, that the result of the model can be used as an identifier of improvement areas. By this, the model also answers RQ3. An evident example is the case of company Delta that clearly has its greatest improvement potential under the dimension organisation.

What can also be concluded is that the structure and design of the model also made the data collection and analysis effective for the analyst. By only conducting one interview in each organisation and conducting a small analysis on the collected data, the current condition of the companies and improvement suggestions are possible to present.

5.4 Model Discussion

During the verification of the model, three observations were made. Firstly, the interviewees did not attain all the needed information to conduct the analysis. This indicates that to do a complete analysis, employees with different roles and responsibilities should be interviewed to complement each other's answers.

Secondly, the documented processes should be investigated before the interviews to create a more accurate analysis. Prior to the interviews with both company Charlie and Delta, this was not possible which made it difficult to gather all the needed information. The guideline document presented in Appendix E is therefore recommended to be used.

Thirdly, it became obvious that general CM terminology, described by authors in the academic world, is not established out in the industry. Therefore, to be able to collect data, the interview template needed to be translated to an adapted industry terminology, see Figure 5.7.

The already established theory and the model are written with a generalised CM terminology, creating the CM interface. Each activity in the model was then translated to the language used in the industry to increase the understanding and quality of data collected. The possibility to create the model in the industry terminology was evaluated, however, was discarded as the connection to already existing theory would be weak and create confusion for consultants and specialists trained in the

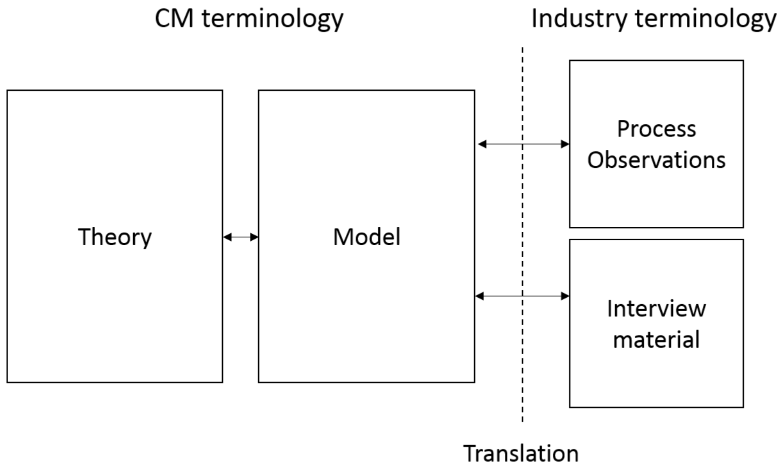

Figure 5.7: Terminology barriers

CM terminology. Multiple terminologies also exist out in the industry, which would make the model biased and specifically adapted to the observed cases. In addition, since the model is built on a generalised CM terminology, where processes tend to be comprehensive rather than explicit, the expected depth of the analysis was not reached. The model could suggestively be used as a starting point for analysing CM implementations. It could also be argued that the model is adapted to analyse organisations with lower CM maturity where processes firstly need to be implemented rather than improved.

A discussion of challenges experienced by the organisations during the interviews led to valuable insights about the CM implementation. In addition, the interviewees showed a greater interest when an improvement could possibly solve the challenges that were experienced.

6

Conclusions, Recommendations and Further Research

The purpose of this master thesis was to enhance the field of CM and to develop a model that supports organisations to efficiently preserve and develop the operational capability of its assets. This master thesis has answered the three research questions formulated. It has identified factors that are important to operate an efficient and effective CM, and presents a model that diagnose an organisation's current CM capability. From this analysis, the model is able to identify improvement areas. The following chapter presents the conclusions, recommendations and further research from this master thesis.

The theoretical framework presents ten factors to operate an efficient and effective CM; *Processes, Organisation, Defined roles and responsibilities, Stakeholder involvement, Management support, CM awareness and culture, Strategy, mission and vision, Communication, Training and Support systems.* The interviews conducted, at company Alpha, Beta and Solvina AB in case study 1, validates that the factors identified in the literature review are central in a CM implementation in the analysed industries. This answers RQ1, and was later used as a foundation of the conceptualised model. The interviewees showed great interest and a positive position regarding the subject, and indicated that there is a need of an easy way to unveil areas to improve.

The verification process shows that the developed model can identify the current CM capability in an organisation, answering RQ2. It also acts as a platform to find improvement potential, answering RQ3. Already established models have been developed to analyse the maturity level of organisations, but no model is suited for this type of industry and not as flexible. The model's design and structure is based on the ability to vary the depth of the analysis. By dividing the activities into three levels, the analysis can be customised to the needs of the customer depending on the situation of the organisation, resources, and time available. This means that the model can be used on all organisations in industries, where the main goal is to preserve and develop the operational capability of its assets, independent on size and resources.

To achieve the full potential of the model, it is suggested that an extensive verification is conducted both with the practitioners of the model and multiple interviewees to increase the granularity. Suggestively employees at middle and top management level and consultants at Solvina AB, to gather more aspects and knowledge about the CM implementation. By doing this, it is possible to verify the function of the third activity level.

Furthermore, the interview template for the data collection needs to be further developed due to the barrier between the CM terminology and the industry terminology. To avoid this, the translation should be enhanced, and make the gap between the theory and language used in the industry smaller.

Discussion of challenges experienced by the organisations during the interviews led to valuable insights about the CM implementation. Therefore, it is suggested that the identification of challenges is incorporated either in the model or as a complementary part in the future.

As a result of this master's thesis, new research possibilities have been identified. Firstly, as the research conducted in this thesis has focused only on organisations operating in industries where the main objective is to preserve and develop the operational capability of its assets, further research can include other industries. By studying differences and similarities between various industries, the model can be further improved. Secondly, by conducting multiple case studies, the design and functionality could be further improved.

Bibliography

Albacete-Sáez, C. A., Mar Fuentes-Fuentes, M., and Maria Bojica, A. (2011). Quality management, strategic priorities and performance: the role of quality leadership. *Industrial Management & Data Systems*, 111(8):1173–1193.

Ali, U. and Kidd, C. (2013). Critical success factors for configuration management implementation. *Industrial Management & Data Systems*, 113(2):250–264.

Ali, U. and Kidd, C. (2014). Barriers to effective configuration management application in a project context: An empirical investigation. *International Journal of Project Management*, 32(3):508–518.

Bartusevics, A., Novickis, L., and Leye, S. (2015). Models and methods of software configuration management. *Applied Computer Systems*, 17(1):53–59.

Benavides-Velasco, C. A., Quintana-García, C., and Marchante-Lara, M. (2014). Total quality management, corporate social responsibility and performance in the hotel industry. *International Journal of Hospitality Management*, 41:77–87.

Bergman, B. and Klefsjö, B. (2010). *Quality from customer needs to customer satisfaction*. Studentlitteratur AB.

Berlack, H. R. (1992). *Software configuration management*. Wiley Online Library.

Bryman, A. and Bell, E. (2015). *Business research methods*. Oxford University Press, USA.

Burgess, T., McKee, D., and Kidd, C. (2005). Configuration management in the aerospace industry: a review of industry practice. *International Journal of Operations & Production Management*, 25(3):290–301.

Chaudhary, M. and Chopra, A. (2016). *CMMI for Development*. Springer.

Deloitte (2013). Operation go-live! mastering the people side of operational readiness. pages 2–3.

Diener, E. and Crandall, R. (1978). *Ethics in social and behavioral research*. U Chicago Press.

Guba, E. and Lincoln, Y. (1985). Naturalistic inquiry (vol. 75). *Beverly Hills, CA: Sage*.

Gupta, P. and Rao, D. (2011). Best practices to achieve cmmi level 2 configuration management process area through vss tool. *International Journal of Computer Technology and Applications*, 2(3).

Hsieh, P. J., Lin, B., and Lin, C. (2009). The construction and application of knowledge navigator model (knm™): An evaluation of knowledge management maturity. *Expert Systems with Applications*, 36(2):4087–4100.

Institute, P. M. (2007). Practice standard for project configuration management. Project Management Institute.

International Atomic Energy Agency (2003). Configuration management in nuclear power plants. Technical report.

Johns, G. (2006). The essential impact of context on organizational behavior. *Academy of management review*, 31(2):386–408.

Leon, A. (2015). *Software configuration management handbook*. Artech House.

Ljungqvist, T. (2013). Enhancing the Configuration Management capability. `http://www.cmforum.se/wp-content/uploads/2013/10/Enhancing-the-CM-capability.pdf`. Accessed 23 Jan. 2018.

Martini, A. and Pellegrini, L. (2005). Barriers and levers towards knowledge management configurations: A case study-based approach. *Journal of Manufacturing Technology Management*, 16(6):670–681.

McManus, J. and Wood-Harper, A. (2003). *Information systems project management: Methods, tools and techniques*. Pearson Education.

Niknam, M., Bonnal, P., and Ovtcharova, J. (2013). Configuration management maturity in scientific facilities. *International Journal of Advanced Robotic Systems*, 10(12):404.

Paulk, M. C., Curtis, B., Chrissis, M. B., and Weber, C. V. (1993). Capability maturity model, version 1.1. *IEEE software*, 10(4):18–27.

Quigley, J. M. and Robertson, K. L. (2015). *Configuration Management: Theory, Practice, and Application*. CRC Press.

Sachs, L. (2018). "Personality matters - Lessons Learned in Configuration Management Consulting". `https://www.cmcrossroads.com/article/lessons-learned-configuration-management-consulting`. Accessed 07 Feb. 2018.

SANS ISO 10007 (2003). Configuration management in nuclear power plants. Technical report.

Schuman, C. A. and Brent, A. C. (2005). Asset life cycle management: towards improving physical asset performance in the process industry. *International Journal of Operations & Production Management*, 25(6):566–579.

Shokri-Ghasabeh, M. and Chileshe, N. (2014). Knowledge management: Barriers to capturing lessons learned from australian construction contractors perspective. *Construction Innovation*, 14(1):108–134.

SolvinaAB (2018). Solvina Homepage. `http://www.solvina.com/`. Accessed 23 Jan. 2018.

Sornette, D., Davis, A. B., Kamm, J. R., and Ide, K. (2008). A general strategy for physics-based model validation illustrated with earthquake phenomenology, atmospheric radiative transfer, and computational fluid dynamics. In *Computational Methods in Transport: Verification and Validation*, pages 19–73. Springer.

Stevens, C. A. and Wright, K. (1991). Managing change with configuration management. *Global Business and Organizational Excellence*, 10(4):509–518.

Team, C. P. (2010). Cmmi® for development, version 1.3, improving processes for developing better products and services. *no. CMU/SEI-2010-TR-033. Software Engineering Institute*.

Wasson, J. (2007). Configuration management for the 21st century. *CMIIC, Institute of Configuration Management*.

Watts, F. B. (2009). *Configuration Management Metrics*. William Andrew.

Zou, P. X. and Lim, C.-A. (2002). The implementation of knowledge management and organisational learning in construction company. In *Advances in Building Technology*, pages 1745–1753. Elsevier.

A

Interview Template for Case Study 1

No.	Question	Answer
1	What is your official role?	
2	How many years have you worked here?	
3	Can you briefly describe the process of a project?	
4	What challenges do you face?	
5	How many projects are finished in estimated time?	
6	What does the process look like to ensure the facility's documentation?	
7	What happens if a change that differs from the project definition needs to be done?	
7.1	How is this information shared with other stakeholders?	
8	How are changes done to the facility's equipment documented?	
8.1	Who is responsible for documenting this change?	
8.2	How is the new documentation of the facility controlled during and after a project?	
9	How is the documented facility checked against the physical facility?	
9.1	Who is responsible for this control?	
10	Does project leaders work in the same way?	
11	Do you have all the needed information about the facility to execute your projects?	
12	If you need information from other projects, is this information available?	
13	Is the facility owner represented in the decision-making processes?	
14	What requirements are made for subcontractors when it comes to reporting the changes that have been made to the plant?	
15	Are the subcontractors represented in project meetings?	
16	How do you measure success in projects?	
17	Does the organisation's strategy describe how to reach the goals decided?	
17.1	Is the strategy continuously communicated?	
18	Do you get all resources needed in the projects you are a part of?	
19	How do you keep information, documentation, drawings and historical changes about the plant?	
19.1	Is this system available for all parts of the organisation?	
19.2	Is the documented information searchable and available?	
19.3	Is this information consistent with the actual physical facility?	
20	Is the long term benefit of documenting communicated?	
21	How do you work with continuously improvements?	
22	Depending on the size of the change project, does the change process differ?	
23	Do you think that the processes could be more flexible?	
24	Is Configuration Management a term used in your organisation?	
25	Is Asset Life Cycle Management a term used in your organisation?	
26	What do you think is needed to solve your challenges?	

B

Interview Template for Case Study 2

No.	Question	Answer
1	What is your official role?	
2	How many years have you worked here?	
3	What challenges do you face?	
4	How many projects are finished in estimated time?	
5	Are there defined processes that make sure to define a plan for the plant that: - Coordinates planned agreed properties of the facility (Baselines) - Connects activities that control the facility (management, status management, changes) - Connect roles to these activities (responsibilities)	
6	Are defined roles and required skills linked to the processes?	
7	Are there defined processes for defining requirements specifications on existing and new parts of the plant?	
8	Are there any processes that ensure that the scope and interfaces are defined for the plant?	
9	Are there any processes for setting up points when you agree on what the plant looks like? (Baselines)	
10	Are there any processes to ensure that the physical and documented composition of the plant complies?	
11	Does the process ensure that naming, numbering and version handling of the parts of the plant are handled during changes?	
12	Are there any processes for managing plant changes that deviate from existing plans?	
13	Is there a process for controlling and maintaining the physical condition of the plant?	
14	Are there any processes that verify that the documented and physical facility is in agreement with each other?	
15	Are there any processes to ensure cross-functional cooperation for the above processes?	
16	Are roles and defined skills requirements linked to these processes?	
17	Are the processes applied?	
18	Are the processes effective?	
19	Are there clearly assigned roles for different positions in the organisation?	
20	Does the facility owner delegate the ownership?	
21	Is it clearly defined who is responsible for the processes?	
22	Do employees with an assigned responsibility have authority to implement and verify the processes?	
23	Do employees with an assigned responsibility have the competence needed to implement and verify the processes?	
24	Is it allocated enough resources and time to implement and verify the processes?	
25	Is there awareness about the importance and benefits of working with CM?	
26	Is CM included in the company strategy?	
27	Do you have a support system for saving / sharing information in the organisation?	
28	Does this system facilitate work with the various processes?	
29	Are information about the parts of the plant and change documents available?	

C

Analysis of Company Charlie

This appendix includes the performance level of company Charlie for activity level 1 and 2. The analysis works as a basis for discussion on where to improve the CM implementation.

Lvl	Factors	ID	CM activities	Performance Level I	II	III	IV
		P	**Processes**				
1	**Documented**	**P1**	Basic CM processes are defined			x	
2	*Planning*	**P1.1**	CM planning processes are defined			x	
2	*Identification*	**P1.2**	Configuration Identification processes are defined			x	
2	*Status Accounting*	**P1.3**	Configuration status accounting processes are defined			x	
2	*Change*	**P1.4**	Configuration Change Management (CCM) process are defined				x
2	*Audit*	**P1.5**	Configuration Audit processes are defined		x		
2	Stakeholder management	**P1.6**	CM processes ensures cross-functional collaboration between concerned stakeholders			x	
1	**Roles**	**P2**	Roles and related competence requirements are connected to the CM processes			x	
1	**Application**	**P3**	The CM processes are applied			x	
1	**Effectiveness**	**P4**	The CM processes are effective			x	
		O	**Organisation**				
1	**Responsibilities**	**O1**	Responsibilities are assigned to positions in the organisation			x	
2		**O1.2**	The facility owner has the responsibility to act as the owner of its assets			x	
2		**O1.3**	An owner of the CM processes is defined			x	
1	**Authority** *(Mgmt support)*	**O2**	Owners with a delineated responsibility have the authority to implement the CM processes and make decisions regarding its CIs			x	
1	**Competence**	**O3**	Owners with a delineated responsibility have the competence to implement and verify the CM processes			x	
1	**Staffing** *(Mgmt support)*	**O4**	The organisation has adequate time and resources to implement and verify the CM processes			x	
2	**CM awareness and culture**	**O5.1**	Recognition of the importance of CM		x		
2	**Strategy, mission and vision**	**O6.1**	CM is included in the organisation's strategy		x		
		S	**Support System**				
1	**Support system**	**S1**	A support system exists			x	
2		S1.1	A support system facilitate the CM process			x	

D

Analysis of Company Delta

This appendix includes the performance level of company Delta for activity level 1 and 2. The analysis works as a basis for discussion on where to improve in the future.

				Performance Level			
Lvl	Factors	ID	CM activities	I	II	III	IV
		P	**Processes**				
1	**Documented**	P1	Basic CM processes are defined			x	
2	*Planning*	P1.1	CM planning processes are defined			x	
2	*Identification*	P1.2	Configuration Identification processes are defined			x	
2	*Status Accounting*	P1.3	Configuration status accounting processes are defined			x	
2	*Change*	P1.4	Configuration Change Management (CCM) process are defined			x	
2	*Audit*	P1.5	Configuration Audit processes are defined		x		
2	Stakeholder management	P1.6	CM processes ensures cross-functional collaboration between concerned stakeholders			x	
1	**Roles**	P2	Roles and related competence requirements are connected to the CM processes	x			
1	**Application**	P3	The CM processes are applied		x		
1	**Effectiveness**	P4	The CM processes are effective		x		
		O	**Organisation**				
1	**Responsibilities**	O1	Responsibilities are assigned to positions in the organisation		x		
2		O1.2	The facility owner has the responsibility to act as the owner of its assets	x			
2		O1.3	An owner of the CM processes is defined	x			
1	**Authority** *(Mgmt support)*	O2	Owners with a delineated responsibility have the authority to implement the CM processes and make decisions regarding its CIs			x	
1	**Competence**	O3	Owners with a delineated responsibility have the competence to implement and verify the CM processes		x		
1	**Staffing** *(Mgmt support)*	O4	The organisation has adequate time and resources to implement and verify the CM processes		x		
2	**CM awareness and culture**	O5.1	Recognition of the importance of CM	x			
2	**Strategy, mission and vision**	O6.1	CM is included in the organisation's strategy		x		
		S	**Support System**				
1	**Support system**	S1	A support system exists			x	
2		S1.1	A support system facilitate the CM process	x			

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Guidelines for the Model

This document describes the process of determining the configuration management (CM) capability with the conceptualised model created by Edberg and Hæger (2018). The process consists of three steps; *planning, data collection and data analysis.*

1. **Planning**
   After receiving an inquiry of conducting a configuration management capability analysis from a client the following questions should be considered;

   (a) How extensive should the analysis be? Three levels of analysis can be chosen. At level 1, the analysis gives an overview of the CM implementation in general. An analysis at level 2 and 3 is deeper if that is desired. Determine which level of analysis is suited for the specific case. The following factors should be considered;
      i. The amount of resources that have been given for the analysis (In a situation where the analysis is limited by a shortage of resources, an analysis on level 1 is firstly recommended).
      ii. Specific needs that the client has or want to focus on.

   (b) What process documents need to be analysed

   (c) What stakeholders have the relevant information and need to be interviewed?
      i. Top- or middle management, employees working with the process (middle management normally have a good understanding of the questions asked during the interviews).
      ii. Which functions should be included?

   The answers to these questions should result in a plan for the upcoming data collection.

2. **Data collection** The data collection consists of two parts; Documentation review and interviews.

   (a) **Documentation review**
   The organisation's documented processes should be reviewed to be able to evaluate activities under P1 and P2 in the model. If the terminology is unknown an the CM processes cannot be found, it is suggested that the review is initiated in the project management processes.

(b) **Interviews**
The two following steps are recommended to be conducted before the interviews:

i. A short introduction of Configuration management is presented for the interviewees. Normally, the interviewees have no knowledge of the field or terminology and research have shown (Edberg & Hæger, 2018) that introducing CM has led to more valuable interviews by creating a common platform for discussion and give the interviewee a possibility to prepare for the interview. This suggested presentation (The Power Point file XXX) can be presented before, either over Skype or in person, and should not take more than 30 minutes to conduct.
ii. That the documentation review is carried out. If this can be done, it is possible to adapt the interview material and save time during the interview. During the interviews the following steps should be taken: The two following steps are recommended to be conducted during the interviews:
iii. Discuss current challenges that the organisation is experiencing. These challenges can later be connected to the activities in the model.
iv. Follow the interview template, see Appendix B. The template includes questions connected directly to each activity in the model.

The interviews can also be replaced by discussion in a focus group if the amount interviewees would be extensive.

3. **Data analysis**
The data is analysed by evaluating the organisation performance of each activity described in the model. Fill out the performance level for each activity according to the four levels described by Edberg & Hæger (2018). It is recommended that a comment is made for each activity where a motivation for the decision is presented.

It is also recommended that the challenges discussed is connected to the specific activity where the issue originates.

Use this analysis as a platform for discussion and not as a fact sheet. An organisation is continuously developing which needs to be reflected in the model.