A new perspective on the challenges of contract management information systems

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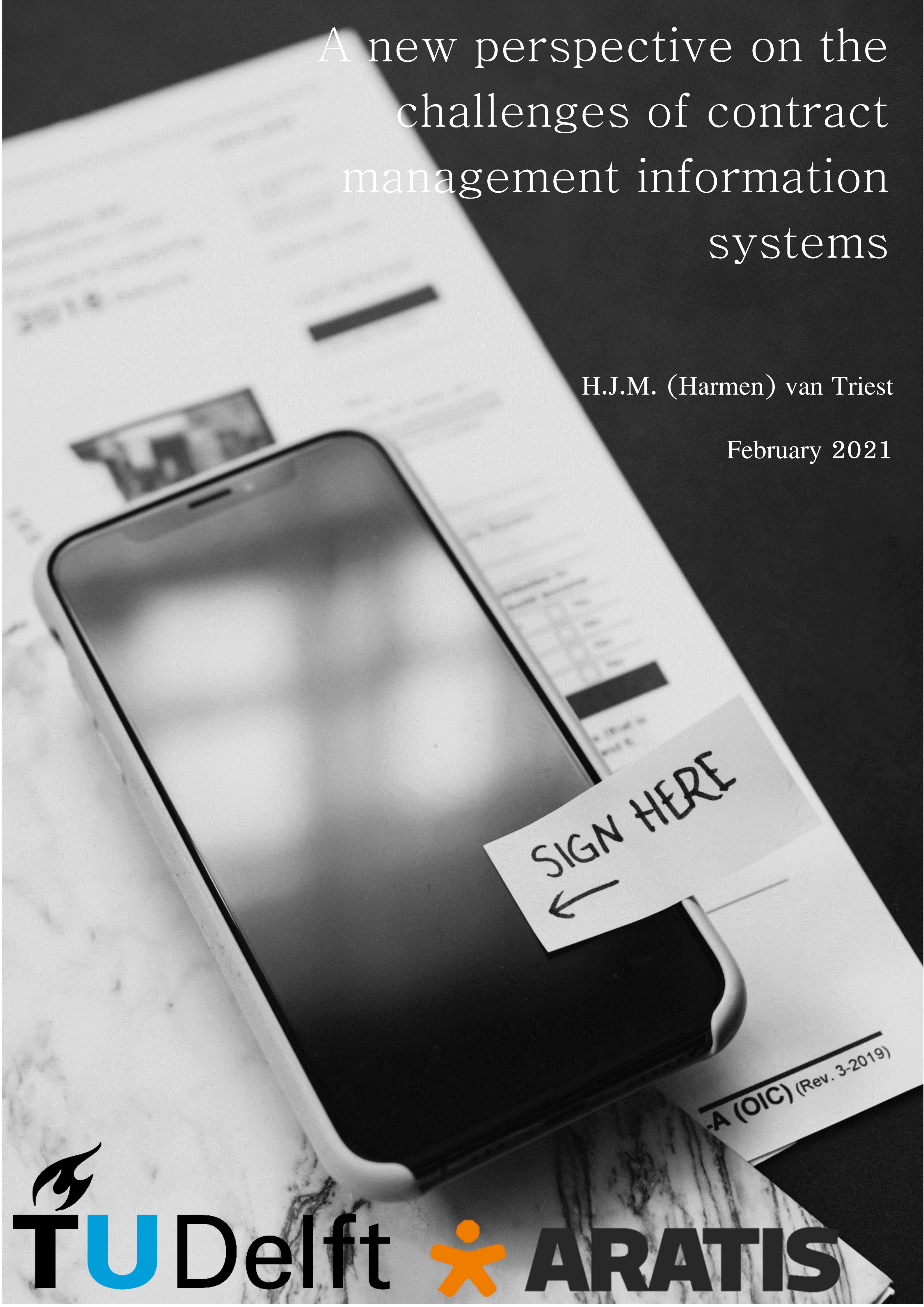

TU Delft ARATIS

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A new perspective on the challenges of contract management information systems

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Preface

Before you, you find a master thesis written as the conclusion of the master track Construction Management and Engineering as taught at the Delft University of Technology. The process of writing a graduation thesis is sometimes viewed as a serious challenge between two phases in life. It is a bridge that needs to be crossed before your time as a student ends and your professional life begins.

My journey started some time ago while taking a course on collaboration in the construction sector. This course taught me many things and activated my interest in construction contracts and contract management. At the same, a search for an internship position led me to ARATIS, a consultancy company that is specialized in this field. It resulted in a great internship period where I conducted research on combining systems engineering and collaboration models.

This internship was a smooth process and became the basis for a longer time at ARATIS. My next project was to be my final master thesis. This process was started off by finding a fitting scope for my research. With some guidance, this was quickly set on contract management and information systems. Next, a graduation committee needed to be composed. This led me to three very interesting and helpful people. Gladly, they agreed to be part of my graduate committee.

Here we are, about eight months later, with a completed master thesis. This process of conducting comprehensive research has brought high ups and sometimes some low downs. It has taught me that keeping going is the most important thing, it has also shown me the value of constructive criticism, and it taught me how hard but necessary it is to change things that took hours and hours to complete in the first place. These are all lessons I will take to heart during the rest of my professional career.

Next to these valuable lessons, I have also had the pleasure to meet a lot of very interesting and people during this research project. These people were a crucial part of the realization of this research. I want to thank my supervisors Shahnam and Michiel at ARATIS for their patience, their supportive attitude to my research, and their trust in me by offering me a permanent position. My committee, Paul, Erik-Jan, and Sander, for the interesting and challenging conversations, which brought me very useful feedback. And finally, all interviewees who took time out of their day to provide me with the in-depth information I needed for my research.

On a personal note, I want to thank everyone that supported me while writing this thesis. My parents, sister, friends, roommates, colleagues, and my girlfriend, you were all very important to me during this demanding time.

This research has brought me a lot of good things, and I hope readers of the report can derive similar value from its results, which may be educational or professional.

Harmen van Triest

Rotterdam, the 25th of January, 2021

Executive Summary

One of the cornerstones of construction project delivery is contract management. It can be directly related to business and project performance (Muhammad et al., 2019). Nevertheless, contracts and contract management have proven to be a complex and risky undertaking. It has been named as one of the main causes of conflict in the construction sector (Jaffar et al., 2011). To mitigate these problems, information systems have been implemented in contract management. Nevertheless, these systems are not fully delivering on their promises. Evidence that overall costs were reduced or an improvement in project performance is very limited (Zhai et al., 2009), and contemporary information systems have often failed to realize their goals (Mutschler et al., 2008). These developments indicate that the implementation process needs optimization.

Preliminary research identified two socio-technical theories that are useful for analyzing human-system interactions during the implementation and use of information systems. Activity theory provides the framework for the analysis of human-system interaction. At the same time, boundary objects seem to be involved when multiple specialists transfer knowledge through the use of objects. Information systems are highly involved in this process. Therefore boundary objects are also included as a focus of this research. These two theories should provide a new perspective on the challenges concerning contract management information systems.

To subsequently investigate and improve this implantation of contract management information systems, the following research question was created:

How can construction contract management be improved by analyzing the implementation of supporting information systems using socio-technical perspectives?

In order to answer this question, interviews with contract management specialists were held to gather data on the implementation process. This data was structured in a codebook and consequently analyzed using a general timeline of the change process. This analysis brought a few bad practices to light:

- Support for the system users was severely lacking
- Wrong tactics were used to incentivize system use
- Responsibilities were unclear, and accessibility of necessary knowledge was limited
- Solutions were often late and ineffective or only partly effective
- Turnkey solutions rarely functioned as desired
- Boundary objects are often not handled correctly

Generally, the implementation process was characterized as *unstructured* and *reactive*.

Next, these lessons learned were applied to create a set of recommendations that should improve current practices. The first set of recommendations was aimed at creating the right information system. The creation of a development team is key in facilitating this process. By sharing responsibility over multiple specialists under the guidance of a system coordinator, the information systems can be correctly created. Next, Including feedback from users, keeping the system as simple as possible, and using proper specifications make sure the information system is fit for purpose.

The second set of recommendations cover the realization of the requirements for the correct supporting infrastructure for the information system. This consists of the introduction of a few new roles under the support team and some supporting tools to align the supporting structures with the

users. This supporting infrastructure requires the introduction of system ambassadors, a system developer, a system coordinator, and a trainer. The necessary supporting mechanisms are two-stage training, system meetings, clear and targeted manuals, and rules, and finally, the securing of common interpretations.

Finally, to make the recommendations more usable, they were transformed into the tool-support implementation (TSI) roadmap. This roadmap transforms the recommendations into a two-phase strategy that managers can apply in their projects. The first phase ensures the right conditions to build the correct information system. Consequently, the second ensures the right conditions to create the right supporting structures. Following this roadmap should ensure the proper creation and implementation of a contract management information system.

Finally, to bring these conclusions back to the starting point, the following answer to the main research question is provided. Contract management can indeed be improved with an analysis of the implementation process based on socio-technical perspectives. The application of this new perspective brought a new set of problems concerning the implementation of contract management information systems to light. By showing what went wrong, changes could be recommended in order to improve current practices. Therefore, the importance of these challenges lies in the fact they need to be addressed to gain the benefits that information systems are supposed to have. To realize this goal of the research, the recommendations, and tool-support implementation roadmap have been constructed. When these recommendations are applied by using the TSI roadmap, the presumed benefits of information systems should finally be unlocked. As a result of these benefits, current contract management practices are likely to be improved.

Management Samenvatting

Eén van de hoekstenen van de resultaten van bouwprojecten is contractmanagement. Contract management kan direct gerelateerd worden aan bedrijf en project resultaten (Muhammad et al., 2019). Maar contracten en respectievelijk contractmanagement zijn gebleken erg complexe en risicovolle activiteiten te zijn. Het is benoemd als een van de belangrijke oorzaken van conflicten in de bouw sector (Jaffar et al., 2011). Om deze problemen op te lossen zijn informatiesystemen geïmplementeerd in contractmanagement teams. Toch blijken deze systemen hun beloofde waarde niet op te leveren. Er is weinig bewijs dat de uiteindelijke kosten zijn teruggedrongen of dat project resultaten werkelijk zijn verbeterd (Zhai et al., 2009), tegelijkertijd hebben hedendaagse informatie systemen vaak gefaald om hun doelen te bereiken. Dit geeft aan dat dit proces toe is aan verbetering.

Voorbereidend onderzoek heeft twee socio-technische theorieën aangewezen die nuttig zin gebleken voor het analyseren van interactie tussen mens en systeem tijdens de implementatie van informatiesystemen. Activity theory bevat een raamwerk voor de analyse van de mens systeem interactie. Tegelijkertijd lijken boundary objects betrokken te zijn als informatie uitgewisseld wordt via objecten tussen verschillende specialisten. Informatiesystemen zijn veel betrokken in deze processen, daarom zijn boundary objects ook betrokken in dit onderzoek. Deze theorieën zorgen voor een nieuw perspectief dat nieuwe uitdagingen op het gebied van informatiesystemen en contractmanagement zal identificeren.

Om dit onderzoek uit te voeren is de volgende onderzoeksvraag opgesteld:

Hoe kan contractmanagement in de bouwsector verbeterd worden door de invoering van informatie systemen te analyseren met een socio-technisch perspectief?

Om deze vraag te beantwoorden zijn interviews met ervaren contract managers afgenomen om data te verzamelen over het veranderingsproces. Deze data zijn vervolgens gestructureerd in de codeboek en geanalyseerd in de vorm van een tijdlijn van het veranderingsproces. Deze analyse heeft de volgende problemen aan het licht gebracht:

- Ondersteuning van de gebruikers was zeer gebrekkig
- De verkeerde strategieën werden toegepast om gebruikers te voertuigen
- Verantwoordelijkheden waren onduidelijk en de juiste kennis was niet toegankelijk
- Oplossingen kwamen vaak te laat of hadden niet het gewenste effect
- Kant en klare systemen functioneren zelden zoals bedoeld
- Boudary objects worden vaak niet goed gebruikt

Over het algemeen kan gesteld worden dat het invoeringsproces van de systemen *ongestructureerd* en *reactief* was.

Vervolgens zijn deze problemen gebruikt als basis voor aanbevelingen die het huidige proces moeten verbeteren. De eerste set van aanbevelingen is bedoeld om de bouw van het juiste systeem te faciliteren. Het opzetten van een ontwikkelingsteam is cruciaal gebleken om dit proces te faciliteren. Het delen van verantwoordelijkheid onder begeleiding van een systeem coördinator zijn belangrijke voorwaarden voor dit proces. Daarnaast zijn het meenemen van feedback van gebruikers, het systeem simpel houden en gebruik maken van de juiste specificaties ook uitgangspunten die zorgen voor een passend systeem

De tweede set van aanbevelingen dekken de realisatie van de voorwaarden voor de juiste ondersteuning van het systeem. Dit bestaat uit de introductie van een ondersteuningsteam met een aantal nieuwe rollen en een aantal nieuwe gereedschappen. Voorwaarden voor deze ondersteunende infrastructuur zijn de introductie van een aantal nieuwe rollen, de systeem ambassadeur, de systeemontwikkelaar, een systeem coördinator en een trainer. De noodzakelijke ondersteuningstools zijn twee-staps-training, systeem besprekingen, het gebruik van doelmatige en gestructureerde handleidingen en als laatste het veiligstellen van gezamenlijke interpretaties.

Om deze aanbevelingen meer werkbaar te maken in de dagelijkse praktijk, zijn ze getransformeerd in de tool-support implementatie (TSI) roadmap. Deze roadmap bevat een twee-stap strategie die managers in de praktijk op hun projecten kunnen toepassen. De eerste stap verzekert de juiste condities voor het bouwen van het juiste systeem. De tweede stap zorgt ervoor dat de juiste ondersteuningsmechanismen aanwezig zijn. Het volgen van deze roadmap moet op deze manier zorgen voor een juiste implementatie van de informatiesystemen.

Uiteindelijk kan het volgende antwoord op de hoofdvraag geformuleerd worden. Contractmanagement kan inderdaad verbeterd worden met een analyse van het implementatie proces gebaseerd op een socio-technisch perspectief. Het toepassen van dit perspectief heeft een nieuwe set van problemen op het gebied van contactmanagement informatiesystemen aan het licht gebracht. Door te laten zien wat verkeerd ging, is de basis gelegd om de huidige situatie te verbeteren. Om dit doel van het onderzoek te realiseren zijn aanbevelingen gedaan. Deze aanbevelingen zijn vervolgens geïntegreerd in de TSI roadmap. Het toepassen van deze aanbevelingen Door middel van de TSI roadmap zijn bedoeld om de voordelen van informatiesystemen in contractmanagement te realiseren. Als gevolg van het verkrijgen van deze voordelen zou contractmanagement in het algemeen betere resultaten kunnen voortbrengen.

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1 - Research set-up

1.1 Introduction

“Clark Construction, the general contractor for the $2.5 billion mixed-use development, The Wharf, in Washington, DC, has filed a $5 million breach of contract lawsuit against architect Perkins Eastman alleging the design documents for the project's first phase contained substantial errors and omissions.” (Construction Dive, 2018)

“A dispute over change orders has led to a multi-million lawsuit between Austin-based HVAC contractor Dynamic Systems Inc. According to the lawsuit, a series of change orders altered the scope of the original work, increasing the total price from $17.8 million to $22.5 million. Dynamic claims those changes left them on the hook for over $4.6 million in additional work costs.” (levelset.com, 2019)

“Or a bit closer to home the zuidasdok project: “The Zuidasdok project located on the Zuidas in Amsterdam is going to result in cost overruns between 700 million and one billion euros. The contract with the consortium ZuidPlus (Heijmans, Fluor en Hochtief) has been dissolved, and the project will be tendered again in sub-projects” (Spoorpro.nl, 2020).

It is not uncommon to read items like this about construction projects that experience billions of extra costs and years of extra time. Hence, the construction sector became widely known for substantial budget overruns and delays, and inefficiencies in general. A whole host of reasons has been shown to be responsible for these inefficiencies, but generally, fragmentation (Fellows & Liu, 2011) and collaboration issues are strongly represented. These aspects have been researched on many different occasions with very useful results. A lot of ground has been covered to improve collaboration and efficiency in construction projects, think of developments like new forms of collaboration (DBFM, Alliances) and the use and implementation of (digital) information systems. At the same time, these new concepts and especially information models, are still in development (Abbasnejad & Moud, 2013) and can be improved upon.

One aspect that influences fragmentation and collaboration in the construction sector has largely remained in the shadows. This is also the common factor of the problematic examples shown above, and this factor is contracting and contract management. It is known that contractual issues such as different interpretations (Passera & Haapio, 2013), contractual changes, extensions of time, administration, and management (Jaffar et al., 2011) are some of the main causes of problems and litigation in the construction sector. In order to mitigate these problems, information systems were introduced to support contract management of construction projects.

However, information systems within the construction sector have often underperformed or even led to new problems (Zhai et al., 2009). Therefore, it is very interesting that the combination of these two elements of information systems and contract management has one thing in common. They both rely on human interactions. The system interacts with a user, and contract management needs input from many different people to succeed. However, not much else is known about this interaction within this context of contract management and information systems.

Therefore, this research aims to explore this human system interaction during the introduction of information systems in contract management. Consequently, the lessons learned can be applied to contract management practices by joining the worlds of contract management and information systems in a structured approach.

1.1.1 Problem statement

Contract management can be considered as a cornerstone of project delivery. The concept of contract management is directly associated with business performance (Muhammad et al., 2019). The benefits of proper contract management have been identified in various studies. One example is the ability of contract management to significantly lower the risk exposure to both the client and contractor (Haapio & Siedel, 2013). A second example lies in productivity, operational efficiency, and efficiency, which can only be achieved when a proper contract management system is applied. Thirdly, financial optimizations, which are captured in change orders, need contract management in order to be realized (Muhammad et al., 2019).

On the other hand, this area of contract management has also been identified as one of the main causes of conflict in the construction sector next to behavioral problems and technical problems (Jaffar et al., 2011). Definition, interpretation, and clarification of the contract are widely considered to be very difficult between the parties involved, and these contractual disputes represent a significant portion of litigation in many projects (Diekmann & Girard, 1995). Research has shown that these contracting matters generally relate to a set of aspects such as variations, extensions of time, payment, specifications & availability of information (Kumaraswamy, 1997).

Recently, the construction sector has undertaken various efforts to combat these problems, with the implementation of building information systems as being a very promising solution. Information systems have shown to be an effective tool in improving the key performance aspects of project delivery. Similarly, data has shown that cost, time, communication, coordination, and quality (Bryde et al., 2013) can all be improved by the application of these systems.

Nevertheless, information systems and their implementation and use in contract management are far from being fully developed. Recent studies have identified some areas of attention. Firstly, Liu, et al (2017) stated that a better understanding of the collaboration process could lead to better information modeling technologies. Evidence of overall cost reductions or improved project performance related to IT in construction is very thin (Zhai et al., 2009). And similarly, contemporary information systems have often failed to realize these goals (Mutschler et al., 2008).

Why these systems are rarely successful and how this happens remains two be discovered. Two aspects that are closely tied to contract management, and information systems and human-system interactions are Activity Theory and Boundary objects (Bharosa et al., 2012). An analysis from the perspective of these theories could prove useful in improving contract management performance by using information systems.

1.1.2 Research objective

The objectives of this research project can be described in three ways.

The first objective is to explore the background and complexities of what contract management actually entails. Literature is everything but in agreement on what activities and phases are actually to be included as contract management. A clear representation of what contract management is and which complexities are involved in it is, therefore, a necessary basis for the following analyses.

The second objective is to explore the challenges of implementing an information system in contract management through a sociotechnical lens of activity theory and boundary objects. This unexplored perspective can provide new insights into the challenges during the introduction of contract management information systems. These results can consequently be used to make recommendations to improve this process.

The final objective is to create a workable implementation strategy to support contract management that captures the previous findings. Based on clear and structured processes from the first step that also captures the sociotechnical element of contracting from the second step.

1.1.3 Deliverables

The objectives of scientific research can be considered as quite abstract and intangible. Accordingly, the following specific and concrete deliverables have been described:

- A clear exploration of the main processes and complexities in contract management
- An exploration of the current state of information systems that are used in contract management
- An analysis of information systems in contract management from a human-system interaction perspective, concluding in an overview of current approaches and challenges.
- Recommendations to improve the implementation of a supporting information system in contract management.
- A feasible strategy to improve the implementation of contract management information systems.

1.1.4 Research question

From the previously discussed research objective and deliverables, the following research question has been formulated. This question will be answered at the end of this research.

How can construction contract management be improved by analyzing the implementation of supporting information systems using socio-technical perspectives?

1.1.5 Sub-objectives and questions

Objective 1 – Discover what activities are involved in contract management and processes and roles are involved. This provides insight into the complexities of contract management and the functionality that the supporting information systems need to deliver.

Question 1 – Which complexities and challenges are involved in contract management?

Objective 2 – Find out which information systems are currently used to support contract management. What functionality do they deliver and how they are used is important in the analysis of the human-system interaction. Finally, the challenges related to these systems need to be addressed to indicate where improvements can be helpful.

Question 2 – Why are information systems implemented, with which functionality do they provide to support contract management, and what challenges do they create?

Objective 3 – Use activity theory and boundary objects to analyze the process of the implementation of information systems that aim to support contract management.

Question 3 – What new information concerning the implementation of information systems in contract management can be identified using an activity theory and boundary object lens?

Objective 4 – Use the theories to propose solutions to improve contract management practices.

Question 4 – How can activity theory and boundary objects help to solve the identified problems in contract management?

Objective 5 – Integrate these recommendations into an information system implementation strategy.

Question 5 – What would these recommendations look like when they are combined into an integrated implementation strategy?

1.1.6 Scope

To perform this research in a predefined window of time, some trade-offs have been made in respect of the scope. The important aspects of this delineation are discussed next.

The first important consideration is that contract management exists in all sectors where humans interact. This ranges from a supply contract for goods to consulting services and complex works and plants (The World Bank, 2018). Thus, it is important to note that this research will focus on contract management within the construction sector. The construction sector is unique for a few reasons. Firstly, although technologies may be well known, the context for each construction project will be unique. Consequently, there is a need to be flexible to accommodate different needs from different stakeholders. Secondly, management teams are often formed in an ad hoc manner, changing from project to project (Emes et al., 2012). This results in complex contract management challenges in all construction projects that do not transfer well to other sectors. These are just a few examples of why the construction sector is interesting from a sociotechnical perspective, and consequently, the scope will be limited to this industry.

The second aspect considering the scope is the scale of the construction projects, which the results are aimed at. Because they use a smaller management team, small projects don't have the funds nor the need for intricated contract management approaches. Thus, small construction projects under the European threshold for the tender obligation of €5.350.000 (Parliament, 2014) are considered out of the scope for this research.

Due to limitations in time, another consideration is made according to the scope of contract management in this research. Contract management is a complex undertaking that contains a myriad of sub-activities (CIPS, 2007). Not all these activities can be included as part of this research. Therefore a limited set of contract management activities will be includes based on further analysis.

The final aspect that is important for the scope of this research is excluding a maintenance period from the analysis. Integrated contracts like DBFM(O) have grown in popularity over the last decades. These types of collaboration also include a maintenance part in their respective contracts. Hence, this maintenance phase can also be considered to be part of contract management. Nevertheless, the maintenance element is very different from the preparation and realization phase. During this phase, different perspectives are present in different collaborations than during the previous phases. To keep the scope focused and realistic, it has been decided to leave out maintenance of works in this research.

1.2 Relevance of the study

This report aims to provide new knowledge and insights for the construction sector. This section discusses the relevance of its results on a social, scientific, and project level.

1.2.1 Social relevance

The social relevance of this research relates to including a human perspective in the construction sector, which is very much technology-minded (Ofori, 2008). The concept of a construction contract is often seen as a restraint by engineers in construction projects. One interviewee stated, “ in a perfect world, a contract would be signed, and put away for the remaining part of the project” (interview 5). However, human behavior makes this situation very improbable. Using this human perspective to improve contract management with a supporting information system creates new insight into the collaboration between specialists in general. Improving collaboration in contract management is a very attainable way of decreasing social conflicts in construction projects. Consequently, fewer conflicts could lead to better working environments for project members and a healthier basis for collaboration in the engineering-focused construction sector.

1.2.2 Scientific relevance

The scientific relevance of this research can be derived from how the theoretical concepts of activity theory, boundary objects, and information systems are combined. The following arguments make this research scientifically unique.

Firstly, it is important to note that combining activity theory and boundary objects is not unique. Activity theory and boundary objects have a clear link between them and have been combined before. As an example, an activity theory analysis can be used to improve boundary objects (Loughland & Nguyen, 2018). Researchers also used these theories to analyze and improve disaster management practices (Bharosa et al., 2012). Nevertheless, these examples are fundamentally different from what this research intends to research.

Secondly, analyzing contract management supported by information systems through a boundary object and activity theory perspective has not been explored before. Little research has been done on contract management in the construction sector in general. Contract management has been identified as a big contributing factor to cost overruns (Azhar et al., 2008). As a consequence, the influence of contract management on the performance of projects (Mutua et al., 2014) is already known. This research aims to supplement this knowledge base on contract management by providing new knowledge by using the perspectives derived from activity theory and boundary objects.

Another relevant aspect of this research concerns the recommendations and implementation strategy. In this contract management context of information systems, no previous research is available. Some material is available on activity theory used to analyze the use, implementation, and improvement of building information systems in operation and maintenance phases (Lu et al., 2018; Miettinen et al., 2012; Nørkjaer Gade et al., 2019). Nevertheless, this research takes a slightly different angle. In this case, the focus lies on improving contract management through better use of information systems. This perspective is yet to be explored.

Therefore, the complete combination of how activity theory and boundary objects are used to improve contract management through an information system is what creates the scientific relevance of this research project.

1.2.3 Project relevance

A general rise in scale and complexity of projects in the construction sector increases the need for proper and effective contract management. This research project aims to provide a strategy to improve these contract management practices through the implementation of a supporting information system. By taking an unbiased view of contract management and including perspectives from various sectors within the construction industry, improvements are proposed that benefit all complex construction projects. For example, fewer conflicts or litigation concerning specification documents and requirements decreases the likelihood of delays. In the same fashion, reaching a common interpretation of requirements early on in the process could decrease the need for contractual changes and, consequently, cost increases. An improvement in these main project delivery KPI's (cost and planning) lead to better project performance in general. These positive influences consequently prove the project relevance of this research.

1.3 Research strategy and method

Proper scientific research is structured according to a strategy and a method. This section discusses the research strategy first, followed by a thorough explanation of the research method.

1.3.1 Research strategy

Every proper research project is based on a solid research strategy. The strategy for this research was designed according to the book designing a research project (Verschuren et al., 2010). Five different research strategies are discussed. These are as follows:

- *Survey*
- *Experiment*
- *Case study*
- *Grounded theory approach*
- *Desk research*

Next to the strategies, the book discusses a blend of three key decisions that represent the five strategies. These decisions that are to be made are shown and discussed below with an answer in the context of this research project.

Breadth versus depth

Breadth versus depth is an important consideration in this research with respect to contract management. Contract management can be analyzed in-depth by looking at certain activities or broadly by including as many activities as possible. The role of contract management in the construction sector can be considered quite new. It started to gain traction about two decades ago. This research aims to improve contract management all over the board. Hence, it is decided to take a broad approach. It is believed that contract management will benefit more from broadly applicable results than very specific results at this point of its development. This results in a complete analysis of the contract management activities from both an employer's and a contractor's perspective.

Quantitative versus qualitative research

This research will have a mainly qualitative nature. Contract management and soft factors are very hard to capture in a quantitative way. This research has a focus on analyzing perspectives and identifying contradictions between parties trying to mitigate these contradictions. These aspects lend themselves for a qualitative analysis using qualitative methods.

Empirical versus desk research

Because of the explorative nature of this research into contract management, both of these approaches will be applied. First of all, the theoretical concepts will be explored by desk research. Contract management itself will be explored using desk research through scientific literature. Consequently, it will be analyzed using theoretical concepts from desk research, complemented by a case study to provide practice-oriented empirical information as a basis for the analysis. An empirical element is also included when the experiment is conducted where recommendations are operationalized in an information system.

1.3.2 Research method and gathering data

To execute the strategy that was chosen and explained above, some extra considerations have to be made. The methods of data collection and analysis that are combined with the research strategy are explained next. This research method follows the hourglass logic from general to detail and then back to general (Chan, 2020). A step by step approach is used to ensure the reproducibility of the research. These steps are shown in Figure 1: Research set-up.

Exploration of contract management & information systems

Contract management in the construction sector can be regarded as a very complex and intensive activity. Next to this, no consensus exists in practice what contract management actually is. This makes it important to explore what contract management is and what activities and complexities are involved in contract management. Secondly, this information is important to get a grip on what functionality the supporting information systems need to provide. This will be done by conducting secondary research with data from scientific literature and guidelines from accredited organizations involved in contract management. Examples of sources of guidelines are The World Bank and CIPS. At the same time, to make solid recommendations, it is necessary to get to know the inner working of contract management processes. In the same fashion, the role and challenges of contract management information systems are to be explored in the following chapter.

Theoretical underpinnings of the analysis

This part of the research is aimed at exploring the theoretical background of the scientific concepts in the context of this research. In this section, the underpinnings of the analysis, activity theory, boundary objects, be researched and explained using desk research. The variant of desk research that is to be used is secondary research. Here the researcher rearranges, analyses, and interprets from the perspective of the research (Verschuren et al., 2010). The data will be supplied in the form of scientific literature concerning the concepts. Examples of the main sources for the literature study are Springer, Taylor and Francis, and the TU Delft Repository.

Analyses of information system implementation & recommendations

The results of the previous chapters are used as the basis for the analysis of this research. A comparative case study is used to provide the basis for the empirical analysis. By analyzing the information system implementation process as activity systems and boundary objects developments and decisions can be analyzed. Consequently, the results of this analysis are the foundations of the recommendations for improvement that are to be created.

The case study that is performed is a bit special in the field of construction management. The definition and practices of contract management are different for every project. Therefore, the cases in this research are experiences from contract managers instead of specific projects. This research knows a constraint in time. Hence, the biggest amount of information on contract management can be derived from including all experiences of contract managers instead of focusing on single projects. The data for the case-study will be provided through semi-structured interviews. During these interviews, different perspectives on contract management from both the contractor's and employer's side are to be uncovered. These experiences and perspectives are compared and analyzed from an activity theory and boundary objects lens.

Operationalization & validation of the recommendations

The recommendations that are made are to be operationalized in a realistic and feasible information system implementation approach. In this part, the theory on boundary objects will also play a role in making sure that when boundaries are crossed using the information system, this is done in the best possible way. This consequently makes sure that the recommendations have the best chance of succeeding within the information system.

Testing and validation of the information system will be done in the following manner. The validation method will be an expert validation session. During these sessions, the expertise, experience, and knowledge of a group of contract management experts will be used to check aspects of the implementation strategy. Results from this method serve two functions. Firstly, they provide a feedback link to improve the information system. Secondly, the methods help in proving the validity of the information system.

Conclusion and discussion

The final section of this research will focus on discussing the implications of the research results. This is done by bringing the level of focus back to the initial level of the research set-up. In this way, the results are discussed in the context they were initially intended.

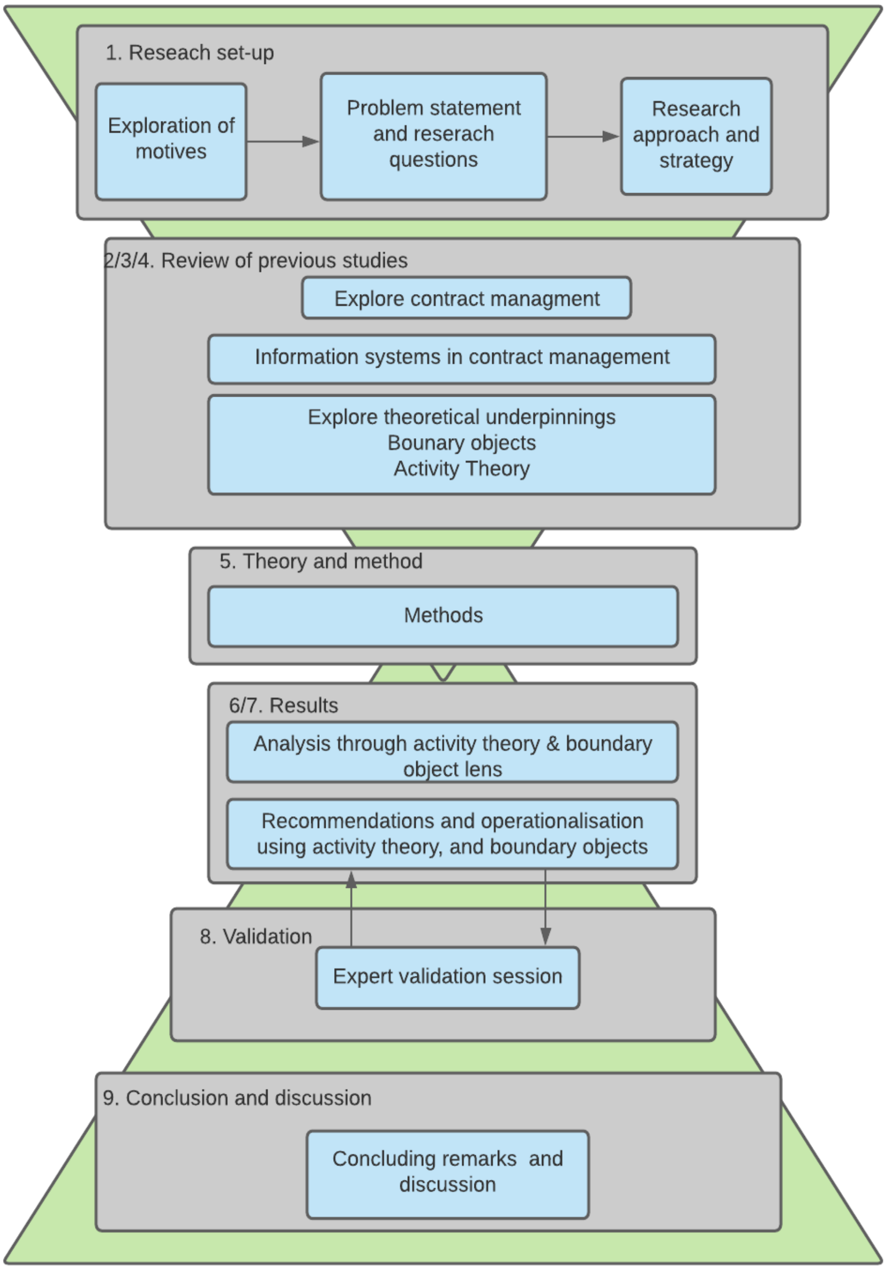

Figure 1: Research set-up

1 - Research set-up

1.3.3 Validity

Another important consideration in scientific research is the validity of the results. The validity of this research is explained by discussing the internal and external validity.

Firstly, the internal validity is secured through the secondary literature review. By carefully selecting literature on contract management, activity theory, boundary objects, and information systems, an internally valid representation of the subjects is created. The literature originates from dependable and peer-reviewed sources or sources that are generally accepted within the industry.

The external validity of this research will be improved by conducting an expert review session of the implementation strategy. A test of the information system with a panel of experienced contract managers should provide insights on the external validity of the results. Consequently, these insights will be used in a feedback loop to improve the results of this research. Nevertheless, more reviews and experiments of the results would improve the validity. But, with the limitation of time, this is the most complete internal and external validation possible.

2 - Contract Management

Over the last decade, the interest in construction contracts, and consequently, contract management, has increased in the Dutch construction sector. The main focus of this section is to discuss the complexities and define contract management within the context of this research. This chapter therefore argues, what contract management actually is, where the complexities are located, and what challenges are perceived.

2.1 Definitions, activities, and complexities

Firstly, contract management can be approached differently from sector to sector and can be seen differently in every organization. Hence it is important to establish a clear definition of contract management and its activities in the construction sector. Therefore, this chapter provides and discusses the view of contract management that will be applied in this research. This will be done by researching the correct definition, showing which activities are involved, discussing the involvement of the employer and contractor and, respectively, different specialists. Similarly, this section is used to argue where the complexities of contract management are located.

2.1.1 A definition of contract management

As indicated above, contract management as a role or activity is perceived differently depending on which organization or sector is reviewed. Where one organization views contract management as a purely administrative activity (The World Bank, 2018) the other sees it as an integral activity that already starts while compiling the business case of a project (CIPS, 2007). This part covers some of these definitions and presents the definition that is applied in this research.

The first definition of contract management is provided by the world bank. The world bank published procurement guidance to support contract management practices by discussing the main aspects and issues.

Contract management is the process of actively managing contract implementation to ensure the efficient and effective delivery of the contracted outputs and/or outcomes (The World Bank, 2018,p4).

It becomes clear that this definition of contract management is focused on only administrating the contract after it has been created. This definition indicates that the phases before a contract comes into being and becomes an official, lawful contract are disregarded and not part of contract management. This research aims to provide a broad and complete picture. Therefore, this definition is not the best fit for this research.

The second reviewed definition is provided by CIPS, the Chartered Institute for Procurement and Supply. In their procurement guide, they provide a fitting, and very important, a complete definition of contract management.

Contract life cycle management is the process of systematically and efficiently managing contract creation, execution, and analysis for maximizing operational and financial performance and minimizing risk (CIPS, 2007, p1).

This definition is a good fit for this research. It is complete and broad, which checks the necessary boxes for this research project. Nevertheless, it is considered to be slightly too abstract. This definition could be stretched very far, creating an unclear scope for this research due to a lack of detail in the description.

Finally, the last definition that is reviewed is taken from Rijkswaterstaat (RWS), the Dutch agency responsible for public works. They generally apply the IPM model in their project, which has a separate department for contract management. This IPM model will be discussed more extensively in section 2.1.4.

"Contract management is responsible for controlling and setting the procurement needs, creating the procurement strategy, contract preparation, the tender, and management of the contract within the set boundaries of time, money quality and risk "(Rijkswaterstaat, 2017, p5).

This definition provided by RWS already gives a complete overview of what activities are part of contract management. It also contains sufficient detail, which clearly bounds the scope of contract management within this research.

These differences in perspectives on contract management make it hard to decide on a fitting definition. Nevertheless, for this research, the RWS definition is applied. There are three main arguments for this decision. First of all, the creation and setting up of the contract and its requirements are a main activity of contract management (Jallow et al., 2014). No complete and effective contract management is possible if you are only involved in the realization part of a project, just as in design, the front-end-development is hugely important in contracting. This part is left out in the first definition, making that option incomplete. Secondly, the CIPS definition is considered to be too general and not detailed enough. This lack of detail would introduce a risk of scope creep during further analyses. For this reason, this CIPS definition is excluded from this research. Finally, the RWS definition is based on the IPM model, which is frequently applied in Dutch construction projects. This model is likely to become more important during later analyses. Therefore using a definition from this IPM model brings some extra structure to this research.

2.1.2 Main contract management activities

In search of the complexities of contract management, the next step is to analyze which activities are considered to be part of contract management and what these activities entail. Like the definitions, different perspectives exist on what activities are part of contract management. A full list of what activities can be placed under contract management is included in Appendix A.

Some of the activities that the guidelines consider to be part of contract management are too comprehensive for the scope of this research. Thus, for the purpose of this research, the activities that are included are limited to the main activities that contract managers are involved with according to the book: fundamentals of building contract management (Uher & Davenport, 2009). This means that, for example, the assembling of a project team and relationship management is outside of the scope of this research. The requirement process, testing, the change process, risk management, and subsequent document management are the main activities where contract managers are involved in. These activities will be briefly discussed next.

The requirements process starts with an analysis of the stakeholders involved in a project. These stakeholders can be internal or external. When all stakeholders are identified, their wishes are gathered. These wishes form the basis for later requirements. Then, an analysis is made which wishes will be included (Jallow et al., 2014) in the contract. This is consequently communicated with the stakeholders. After this is done, the clients' wishes are structured and rewritten into contractual requirements that will be placed into the final contract. This activity involved the inputs of many specialists such as stakeholder managers, technical specialists, and process specialists. A combination of these specialisms is necessary for the creation of all necessary contractual requirements.

Two procedures that follow the requirements process are the testing of the fulfilment of the requirements and requirement changes. The validation and testing process is discussed next based on a general validation process (Hamann & Oort, 2001). The first step of the testing procedure is the gathering of all requirements that are covered by the contract. Consequently, a testing method needs to be assigned to these requirements. When that part of the activity is finished, a full testing plan is set up by compiling all requirements, respective testing methods, and creating a test planning. Finally, the test plan is executed, the tests are conducted, and the results are administrated. Testing requires the involvement of technical specialists to specify the right testing procedures.

Another activity close to requirement management is the change process. After the requirements are included in a contract, and a contractor is found to realize the intended works, things can change. When these changes take place, they are likely to impact the requirements. Therefore, if this is the case, the requirements need to change as well. A change process starts with an application for a change by either the employer or the contractor. This application generally contains a short description of the reason for the intended change, a description of the change, a cost estimation, and the expected impact on time and planning. The next step is to review this change application. When the application is rejected, this is the end of the change process. On the other hand, when the application is accepted, a more detailed application is required. Hence, during the next step, the detailed change application is prepared. When this detailed application is finished, it will be reviewed for the final go or no go decision. If the application is accepted, the necessary contractual requirements will be adjusted according to the change. If the application is not accepted, the process will end, or more detailed information will be requested, and the last step will be repeated.

Risk management is a crucial part of contract management. Contractual risks are various and can have big impacts. Therefore, it is the next activity to be discussed. Risk management often follows the RISMAN method. This method applies a cyclical approach to risk management. This cycle starts with a risk analysis to identify potential risks. The following step of the cycle is to analyze these risks and thereby allocate them, quantify them, and create mitigation measures. The next step is to perform these mitigation measures. Consequently, the performance of these measures needs to be evaluated. And the final part of the cycle is to, after the initial risk analysis, update this risk analysis.

Figure 2: The RISMAN risk analysis cycle

The final process which plays a big part in contract management is document management. Contract management and the corresponding processes discussed above involves a variety of documents. These documents need to be created, stored, distributed, checked, and retrieved for analysis. First of all, a document needs to be created. When the right version is finished, this document can be stored using the document management system. This system consequently takes care of the distribution of the documents and makes sure it is available for and reaches the appropriate specialists (Ahmad et al., 2017). This cycle repeats when new versions of these documents are created.

This discussion of the most important activities in contract management provides an example of the interrelatedness of those activities. As shown below, a diagram was made containing the information discussed above. This shows that all main activities relate to each other in many different ways.

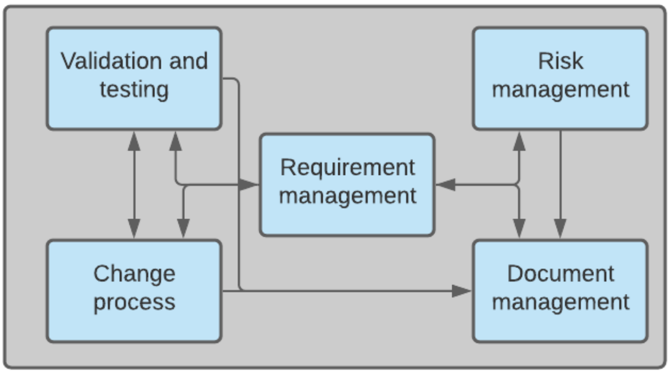

Figure 3: Interrelations between activities

2.1.3 Employer and contractor involvement

Next to the complexity contained in the activities, complexity can also originate in the involvement of different specialists. Therefore, it is important to analyze which parties and specialists are involved at what point and in which activity. This is analyzed on two levels. The first level is a short analysis of the highest level of involvement. On this highest level, the role of the employer and contractor are analyzed. The second level is focused on uncovering which areas of expertise are involved in contract management. This second, more detailed level will be discussed in section 2.1.4.

First of all, the creation of the contract is often seen as an employer only activity. This is not the case in all projects. Early contractor involvement has proven its worth over time. There are multiple ways to involve contractors in the contract strategy and tender preparation phase, but the main examples are market consultations and dialogue sessions with contractors. The involvement of parties during the phase when they are using the contract is more fixed in its nature. During this phase, the contract has been created and signed by both the contractor and the employer. This means that they have committed together to the task of realizing the contents of the contract. From this point on, they will both focus on fulfilling the requirements in a way both parties are satisfied with the results. This involvement of both the employer and contractor is shown in figure 4.

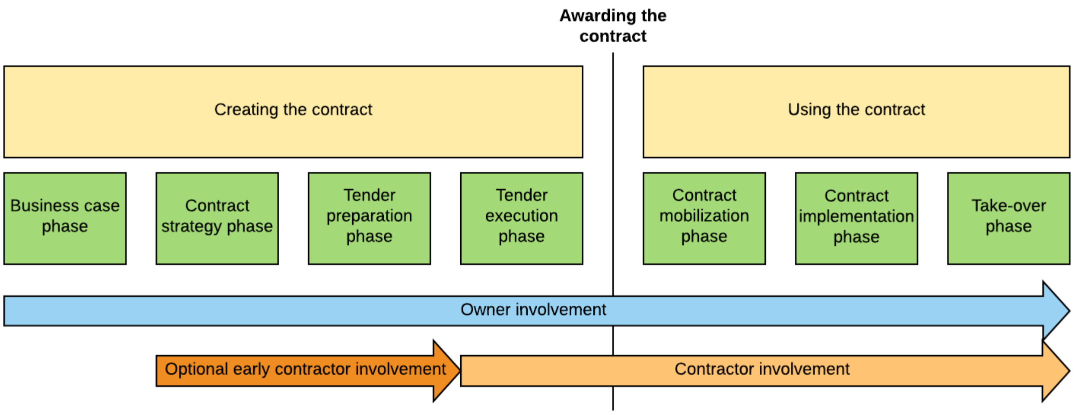

Figure 4: Employer and contractor involvement in contract management

2.1.4 The IPM model

Contract management is an activity that is tied to all specializations within a project team. Requirements, for example, need input from all different specialists to form a complete contract. If you take a deeper look at who is involved in contract management and how projects are regularly organized, the IPM model is a showcase for Dutch practice. The IPM model recognized five different roles in a construction project. These five roles are all involved in contract management activities. Therefore these roles are discussed next (RWS, 2019).

A project management team takes care of quality control, project support, and project control. This *project manager* is responsible for creating the best results on time and value of the project within the set boundary conditions. The project manager supports internal interfaces in the team and is the spider in the web of the employer's organization. He or she is responsible for the internal and organizational communication, and lastly, during bottlenecks, the project manager has the final decision on the options that are on the table. His supporting team consists of various specialists. Project management relies on contract management to stay within the set boundary conditions.

The technical team is responsible for the technical and project-specific context of the project. The technical scope, as functional requirements, is formulated under the responsibility of the technical team. The *technical manager* also provides technical input for validation or testing procedures. In the same way, technical specialists contribute to risk management. The technical specialists closely cooperate with the stakeholder management and contract management teams. The technical manager is responsible for the technical contribution to processes involved in contract management, stakeholder management, and process management. The technical manager manages his supporting team consisting of tender managers, cost estimators, tender coordinator, asset managers, planners, and other technical specialists.

The process management department is aimed at integrally controlling all risks and procedural aspects of the project. This contains project-wide management of scope, time, risks, information flows, documentation, and reporting. This is closely tied to document management, which is a key contract management activity. Thorough process management secures control on time, money, and quality during the project. The *process manager* is responsible for all process-related risks. The process management team consists of specialists such as systems engineering experts, information managers, testing specialists, project planners, risk management advisors, and interface coordinators.

The contract management team is responsible for controlling the processes related to procurement, contract preparation, and contract management within the conditions of time, money, quality, and risk. The final responsibility for the whole contracting process of contract preparation, tendering and realization, is placed with the IPM role of the contract manager. The *contract manager* keeps the contracts up to date and, when necessary, negotiates with market parties. Next to this, this role is also responsible for managing contracting related risks.

The *stakeholder manager* carries responsibility for the relationship with the environment and stakeholders of the project. Consequently, the stakeholder manager is responsible for the societal acceptance of a project. This role is the link between the project team and the stakeholders. This relationship needs to be actively balanced and managed during all project phases. Similarly, requirements and agreements made with the stakeholders are provided to technical management by the stakeholder management department. They are also responsible for the communication with the stakeholders and environment to realize the project within the judicial context. A good stakeholder manager aims to create support and trust with the environment and is able to identify important signals from the environment proactively. The supporting team consists of environmental managers, permit advisors, permit coordinator, communication advisors, and other specialists. In the context of contract management, the stakeholder makes sure wishes from the stakeholders are included in the requirements process.

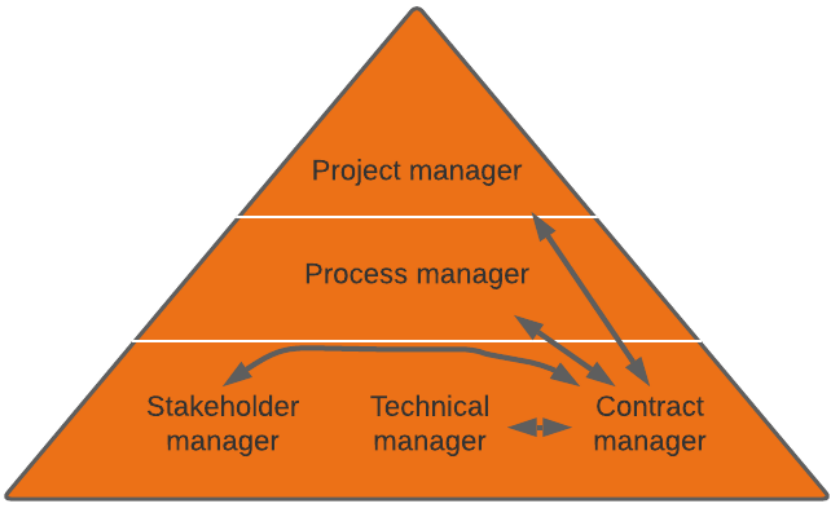

Figure 5: Interrelatedness between specialists in the IPM model

This part argues the interrelatedness of specialists that are involved in contract management. The previous section showed the interrelatedness of contract management activities. Consequently, this is supplemented with the interrelatedness of specialists as clarified with the IPM model above. Together they show the complexity that seems to be problematic in contact management practice.

2.2 Contract management practice

As stated before, proper contract management is crucial for realizing some competitive advantages for construction companies. First of all, it can support the lowering of risks and uncertainty for businesses and customers (Passera & Haapio, 2013). Secondly, it is the basis for financial optimizations of construction organizations. This protects them from unwanted costs. And finally, operational efficiency can only be realized if proper contract management is applied for better outcomes (Muhammad et al., 2019). Therefore it can be stated that proper contract management should lead to:

“success for the procurement as it ensures the performance of contractor as per the defined schedule, time, specification of the contract and specification, defined in the contract” (Muhammad et al., 2019, p-1290)

On the other hand, contract management failures are widely known. Many governmental institutions all over the world have lost significant amounts of money due to bad or weak contract management practices (Muhammad et al., 2019).

These failures have incentivized research into what the challenges concerning contract management actually are. R. Surajbali (2016) researched these challenges of contract management. Consequently, he produced an oversight containing the main challenges that are identified in contract management practices. These challenges are presented below:

- a lack of capacity
- lack of knowledge and skills of the officials involved in contract management activities
- poor communication and relationship management
- a lack of staff
- absence of a contract management unit;
- a lack of policies and procedures
- a lack of monitoring
- and a lack of training

Looking closer at these challenges makes some aggregation possible. A lack of capacity is similar to a lack of staff. In the same way, a lack of training can be combined with a lack of knowledge and skills of the officials involved in contract management activities. These factors are based on inexperienced officials. This can be summarized in five main categories of problems, a lack of efficiency, the use of inexperienced officials, poor communication and relationship management, a lack of policies and procedures, and a lack of monitoring. These problems lay at the basis of the search for improvement of contract management. One of the possible solutions for these problems, the application of supporting information systems, will be discussed in the next chapter.

2.3 Conclusions

This chapter was written to get a grip on what contract management is and what is involved during contract management. Consequently, the first sub-question of this research is answered by this chapter.

Question 1 – Which complexities and challenges are involved in contract management?

First of all, complexity in contract management was found in two main areas. The first type of Complexity can be attributed to the interrelatedness of contract management activities. A good example of this complexity is the requirements process. The requirements process spans many phases, it already begins when composing the contract strategy, and it only ends when the requirements are fully tested and validated just before the take-over. At the same time, during this requirement process, risk management plays a vital role because mitigation measures might need to be included in contractual requirements. Similarly, procedural controls need to be in place to stay in control of the project. All these activities need to be administrated by conducting proper document management. This short example illustrates the complexity of the interrelatedness of contract management activities.

The second area of complexity can be attributed to the involvement of specialists in the previously discussed activities. Contract management activities rely on the inputs of many different specialists. Contractual requirements can include, for example, technical specifications, stakeholder wishes, procedural agreements, or boundary conditions from project management. At the same time, during the realization phase of a project, these specialists are both located in the employee's and contractor's organization, making the collaboration even more complex. This example indicates the complexity due to the interrelatedness of different specialists in different organizations.

Secondly, the following challenges were identified in contract management in practice:

- a lack of efficiency,
- the use of inexperienced officials,
- poor communication and relationship management,
- a lack of policies and procedures,
- a lack of monitoring.

These challenges and complexities are the underpinnings for the efforts that are currently undertaken to improve contract management. The next chapter provides a more detailed focus on what these efforts might be.

3 - Information Systems in Contract Management

In order to control the complexities and mitigate the challenges of contract management that were introduced in the previous chapter, supporting information systems are regularly proposed as a solution (Olatunji, 2014). Similarly, the general need for automation of processes and procedures in order to improve efficiency is growing (Surajbali, 2016). This growing interest indicates that, recently, this movement of using information systems to improve contract management is gaining traction. Due to this interest, this chapter focuses on explaining the role of information systems in solving contract management challenges and problems. This is done by first addressing the benefits of information systems in relation to the challenges. Then, the chapter is continued by discussing some characteristics of the systems that are used in current contract management practice. Next, problems that are experienced with these systems are discussed. Finally, the conclusions of this section are presented.

3.1 The case for information systems

Information systems aim to improve coordination and collaboration between companies in construction projects. Improving these factors should lead to some of the following benefits (Nitithamyong & Skibniewski, 2004).

- Improved communication practices
- Increase in document quality
- Increased speed of work
- Better financial control
- Simpler and faster access to common data
- A decrease in documentation errors

These benefits tie in perfectly with the problems that were identified in the previous chapter. These benefits show that communication practices can be improved. Similarly, efficiency can be improved with more speed of work and simpler and faster access to data, and a decrease in documentation errors. In the same way, information systems in the construction sector have been shown to be able to improve monitoring practices (Piette et al., 2001). Next to this, information systems in contract management appear to be able to mitigate a lack of procedures. This is indicated by the following quote:

> *"the utilization of contract management tools and systems assist in improving the ability of organizations and individuals to apply contract management processes"* (Surajbali, 2016, p-130).

Similarly, significant potential for improvement of efficiency and a decrease of complexity was attributed to the use of information systems in the construction sector (Ramaji & Memari, 2015). Therefore, it seems that the identified complexities in the activities and involvement of different specialists in contact management can be managed with the introduction of information systems.

A final important remark is that the risk exists that due to a lack of a supporting information system, contract management will become a reactionary process instead of being proactive (Surajbali, 2016).

These arguments above indicate that the evidence supporting the implementation of information systems in contract management is available in scientific literature. Therefore the case in support of information systems in the construction sector in general and contract management in specific is, in fact, a strong and valid one.

3.2 Examples of contract management information systems

Due to this focus on information systems in contract management, this research benefits from a short exploration of the types of information systems that are available in the field of construction contract management. Therefore, this section will discuss the main types of information systems that are relevant for contract management.

As discussed in section 2.1.2, some very important elements in contract management are requirement management, change management, and document management. These are also the main areas of focus where the IT sector has provided software packages that are used within contract management. Therefore, this section can later be used as a reference for the systems that are present in the analysis part of this research.

The remaining part of this section will discuss two different types of Information systems. These are document management systems and requirement management systems. Consequently, some examples will be provided and discussed per type category that is presented. From these examples of software packages, some characteristics, advantages, and disadvantages will be discussed.

3.2.1 Document management systems

The first category of information systems to be discussed is document management systems. The need for a document management system or DMS is a result of the growth in the number of documents that are generated during construction projects. Traditional manual methods of filing documents are not workable in current projects. They are decreasingly effective due to the growing amount of information that is processed during projects. Secondly, they require previous knowledge and understanding of the documents, which is time-consuming for seekers. Digital document management systems are able to decrease the costs of the handling of these documents and increase the efficiency of this process. Organizations have claimed time savings increased profitability, productivity, coordination, and collaboration among end-users due to these systems (Ahmad et al., 2017).

A document management system refers to the repository where documents are stored and through which users are able to retrieve the information they are looking for. In this way, a DMS coordinates the flow of electronic documents in an efficient and safe process. Processes that can be included under this type of digital document management systems, systems are storing, archiving, and retrieval of these documents for interactions (Ahmad et al., 2017).

VISI

The first example of a document management system is VISI. According to their website, VISI is an online communication platform designed for the distribution, registration, and analysis of information according to predetermined messages and processes. VISI aims to create real-time insight into time, money, and quality. It is based on the prescribed VISI-standard for construction process management (Bakker&Spees, 2020). VISI is delivered as a turnkey solution. This means it does not have to be customized for the user's needs. On the other hand, changes to the system are only possible through the providing company itself. Users themselves are not able to customize the system to their needs.

VISI	
Advantage	**Disadvantage**
Clear UAVGC based processes	Hard to customize
Turnkey system	Bakker en Spees retains control on changes
Easy to use	

Table 1: Characteristics of VISI

Microsoft SharePoint

The second example of a document management system that is regularly applied in the construction sector is Microsoft SharePoint. SharePoint provides a platform for shared access to documents. By creating team sites for every project, team documents and sources are shared and accessible for all team members. This site can be customized to fit the needs of different teams. The functionality of SharePoint is fixed and cannot be changed. On the other hand, the user layout is customizable to a limited extend.

Microsoft SharePoint	
Advantage	**Disadvantage**
Known windows environment	Very limited support
Easy to set-up	Limited functionality
Easy to change	Limited customization

Table 2: Characteristics of Microsoft SharePoint

3.2.2 Requirement management systems

Within contract management and construction projects, requirement management is one of the most important tasks. Requirements have to be managed during the whole project lifecycle. In this activity, the focus is put on elicitation, analysis, specification, and validation of requirements. In other words, requirements need to be written down, gathered, analyzed and validated, or tested. These complex processes make requirement management a very complex undertaking. Mechanisms for documentation, storage, and access, distribution of requirements information between stakeholders and across project phase, and traceability management of requirements and changes are major factors influencing the complexity of this activity (Jallow et al., 2014).

Requirement management systems aim to control this complexity with the use of software and relational databases. Requirement management systems aim to integrate requirement analysis, allocation, and allocation of verification methods (Hamann & Oort, 2001). The IT sector responded with two commonly knows solutions, Spirra and in the Dutch practice, Relatics.

Relatics

Software that is widely known in Dutch practice which is used for requirement management is the relatics software package. Relatics provides an application that serves to structure and store information. Using a semantic database and relational information, a requirement system can be created by the users themselves. Requirements, objects, activities, and verifications can be managed in a coherent system. Relatics is provided as an empty shell. The users themselves are responsible for the creation of the models and modules.

Relatics	
Advantage	**Disadvantage**
Flexible applications	Old interface
Good knowledge base on system elements	No turnkey solutions
	Limited support on application
	Complex to learn

Table 3: Characteristics of Relatics

Spirra

Spirra is another example of a software package to support requirement management. Spirra aims to provide full support for the requirement process, including testing. Spirra facilitates this process, firstly, by capturing the requirements in a shared environment. Once they are captured, a hierarchical structure can be added. Subsequently, the software provides possibilities to prioritize them, estimate them, and link them to a relevant object. Spirra provides a turnkey solution with some small customization. Nevertheless, functionality cannot be changed by the end-users.

Spirra	
Advantage	**Disadvantage**
Easy to use	Very limited support on application
Easy to configure	Limited functionality
	More aimed at software requirements

Table 4: Characteristics of Spirra

3.3 Application of the systems

The systems that are discussed above should be able to provide improvements in project performance. Nevertheless, the application of these information systems regularly seems to be related to the occurrence of new problems. This section further elaborates on these problems.

Research has indicated that the evidence of the benefits on cost and project performance the systems are supposed to create still seems very thin (Zhai et al., 2009). Similarly, contemporary information systems have often failed to realize their intended benefits (Mutschler et al., 2008). Another paper indicated that efforts from 20 global companies that suffered from excessive IT growth reported mainly disadvantages rather than gaining economies of scale. Therefore it is argued that instead of gaining efficiency, professionals indicate that they are all having a hard time managing the complexity that the newly introduced information systems brought with them. The supposed economies of scale have turned into diseconomies of complexity (Benbya & McKelvey, 2006). In contact management practice, similar sounds are heard. This is acknowledged by research that shows that contract management supported by information systems fail to deliver its intended improvements (Olatunji, 2014). Therefore, it can be concluded that although considerable steps have been made in getting a grip on information systems' design and development, the systems by themselves and their results remain to disappoint (Benbya & McKelvey, 2006).

However, why these information systems are not able to deliver on their promises in the context of contract management remains to be researched. The next chapter of this research will argue why a focus on human-system interaction will be beneficial.

3.4 Conclusions

This chapter was written with the aim to provide answers to the second research question.

Question 2 – Why are information systems implemented, with which functionality do they provide to support contract management, and what challenges do they create?

First of all, there is a strong case supporting the implementation of contract management information systems. Many of the supposed benefits of information systems tie in directly to problems that are experienced in practice.

Next, an analysis of examples of information systems showed that a variety of systems is currently used in Dutch practice. The characteristics of these systems are very different. VISI and Spirra deliver a turnkey software product that is not meant to be changed, while relatics focuses on supplying a collection of elements that need to be transformed into a system by the end-user. Similarly, functionality is different from system to system. For example, relatics can be adapted to suit the whole requirement process specified for construction projects, while Spirra uses a standard process based on software development, which cannot be changed. Similarly, user support of the systems is shown to be very limited in almost all cases.

Consequently, many challenges concerning these information systems were identified. Generally, information systems seemed unable to deliver on their promises. Many companies showed the results of increased complexity and increasing costs instead of benefits from the information systems. This was also confirmed within contract management practice where information systems failed to deliver on their promises. However, why these problems occur and how they can be overcome remains to be researched. They might be related to characteristics of these systems, but the remainder of this research will show if this is actually the case.

4 - Theoretical Underpinnings

The previous chapter introduced the case in support of the use of information systems in contract management. On the other hand, it continued to show that these systems, although they are promising, do not deliver their intended results. In order to continue setting the scene for this research, more light has to be shed on which aspect of this problem has remained in the shadows. This chapter argues the direction of this research towards human-system interaction and the crossing of knowledge boundaries.

4.1 A new focus

Literature shows many reasons for the failure of information systems in general. Poor performance is often attributed to human errors (Beynon-Davies, 1999) or increased IT complexity (Benbya & McKelvey, 2006). Similarly, more specific reasons are put forward, such as defective analyses of performance, organizational cultures that reject information systems, and rash management decisions negatively impacting the systems (Bartis & Mitev, 2008).

Nevertheless, research on these failures in the context of construction contract management is rare. Some papers show the problems are related to the legal framework surrounding the implementation, or a poor link between the new virtual contract management approach and the existing approaches (Olatunji, 2014). Subsequently, more information on these problems seems to be lacking, and further research into these reasons for information system failure in contract management is necessary.

The introduction of information systems in contract management can be viewed as a timely process taking weeks, months, or years in some cases. During this process, many changes and developments take place. Activity theory helps to holistically capture the dynamics that are involved in this change process (Robinson et al., 2016). Previous research has applied activity theory as a conceptual framework for modeling and analyzing human activity in relation to issues of information systems in building Operation & Maintenance (Lu et al., 2018). This research has led to promising results and recommendations in this area O&M. This indicates the possibility to apply this analytical tool in the case of contract management information systems in order to analyze and improve current practices.

Similarly, in this area of information systems, the concept of knowledge transfer is key. Information systems are mainly means to transfer information from one party to another. Challenges concerning this transfer of knowledge can also be a reason for the absence of information system benefits (Levina & Vaast, 2005). This indicates the importance of the concept of boundary objects in this research. Boundary objects facilitate this transfer of knowledge between specialists. Boundary objects are very likely present in the use of information systems. When they are handled incorrectly, they can lead to problems that might block the benefits of information systems. If this is the case in contract management information systems remains to be researched. Research in this area was also able to provide useful recommendations to improve the use of boundary objects in practice (Styhre & Gluch, 2010). Therefore including this perspective is also likely to provide a basis for improvements.

The remainder of this chapter will focus on explaining the relevance and background of activity theory and boundary objects. This should provide the needed understanding of these concepts in the context of this research.

4.2 Activity theory

Activity theory is a theoretical framework for the analysis and understanding of human interaction combined with their tools and artifacts (Hashim & Jones, 2007). Activity theory, therefore, provides a very useful analytical framework to examine activities and artifacts (Bharosa et al., 2012) involved in contract management supported by information systems while taking the human context into account. This provides the new sociotechnical lens that this research is looking for. Thus, in this research, activity theory will be used as an analytical framework in order to analyze the implementation and use of contract management information systems.

This section will start with an explanation of the origins and development of activity theory. Next, the analytical framework behind an activity system will be explained by discussing its five main principles and activity systems in general. Finally, the concept and use of mediation and contradictions in activity theory are discussed.

4.2.1 Development of activity theory

Activity theory has seen three generations of research in its development. It all started with the Russian psychologist Lev Vygotsky. In the 1920s and 1930s, he laid the foundations for activity theory. Vygotsky founded the idea of mediation. This focused on the idea that actions or activities are started through a stimulus and mediated through artifacts (Engeström, 2001). This relationship has consequently been reformulated in the triangle between subject, object, and mediating artifact (figure 6).

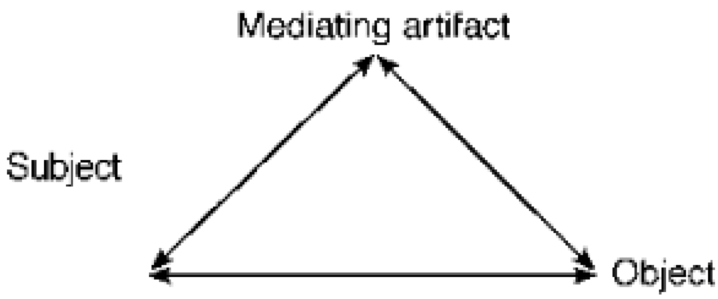

Figure 6: The first generation activity theory (Engeström, 2001, p-134)

This first generation did know its limitations. The analysis of an activity was only focused on an individual level. Therefore, Leont'ev expanded the concept by introducing the difference between an individual action and a collective action. Leont'ev never included this in the triangular structure created for the first generation of activity theory. Nevertheless, others included this idea by creating a collective activity system. In this approach, the first triangle is expanded with a layer that consists of rules, community, and division of labor (figure 7). The relations with this extra layer introduce the collective activity into the individual system. A full explanation of these elements will be provided in section 4.2.3 which discusses activity systems.

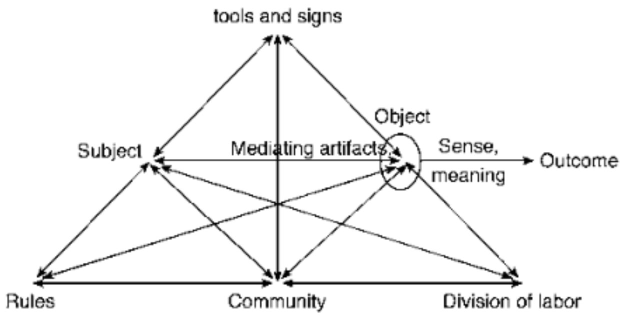

Figure 7: The second generation of activity theory (Engeström, 2015)

However, when activity theory took off in the west in the 1980s and 1990s, some new challenges were identified. This third-generation needed to adapt to the idea of multiple perspectives and networks of interacting activity systems. This led to the creation of the model of two interacting activity systems (Figure 8). This model shows that collective actions also depend on and are influenced by other actions that exist in or around the activity system.

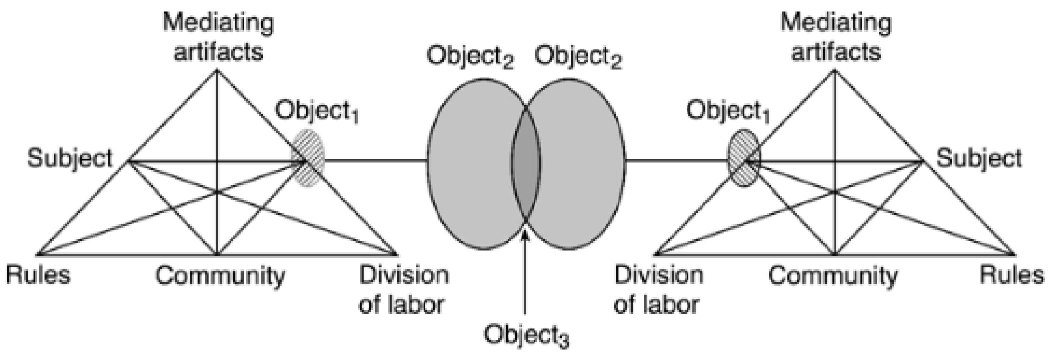

Figure 8: The third generation of activity theory (Engeström, 2001, p-136)

4.2.2 The five principles of activity theory

In its current form, activity theory is commonly summarized and analyzed based on the following five principles (Engeström, 2001; Lu et al., 2018).

According to the first principle, an activity is the prime unity of analysis. This means that the activity cannot be seen separate from the collective activity, artifacts, objects, and other activity systems connected through network relations.

The second principle shows that an activity system is always a community of multiple perspectives, traditions, and interests. These perspectives are shown by the division of labor, which creates different positions for the members of the community.

The third principle is about historical context. Activity systems and their issues and capabilities cannot be separated from the historical developments that took place in that system. This is shown by the fact that human activities are reformed through historical development. An activity system becomes unstable due to these reformations, which leads to new adjustments. These *disturbances* describe problems at the surface, and they are key in analyzing hidden causes for disturbances.

The fourth principle is about *contradictions*. Contradictions in activity systems are the sources of change and developments. They are identified as structural tensions within elements, between elements, between different activities, and between different phases of activity systems that have built up over time. Each of these contradictions indicates a misfit in the activity system or between the systems. This principle is key to this research. Therefore it will be discussed more elaborately in the next paragraph.

Finally, the fifth principle considers the expansive transformation of activity systems. This principle acknowledges that activity systems change over time due to systemic issues or contradictions. When contradictions arise, individuals within the system can be triggered to change their behavior, which can change the system. This is called *evolution* of the system. These changes do not only arise from individuals taking action. It can also be the result of concentrated and deliberate effort to realize the change. This principle is also at the foundation of the recommendations that will be made later in this research.

4.2.3 Activity systems

The basis for an analysis of an activity is an activity system. This is the framework the analyses will of contract management will be built upon. An activity system contains the *following elements* (Lu et al., 2018), and will be explained using an easily recognizable example of the activity the *formation of an assignment in university* (Allen et al., 2013).

Object – The object of an activity is the immediate goal of that activity. It is also important to note that this object also has an outcome. These are the long-term results of executing the activity. It is important to keep in mind that this object and outcome are different things. In the example of the formation of an assignment, the object would be a completed assignment.

Subject - The subject is the organization or group that performs the activity that is the focus of the analysis. A group of students would be the subject from the example.

Community – The community is everyone who has the same stakes, goals, interests, and knowledge to accomplish the activity. University students, lecturers, teaching assistants, tutors are all part of the community in the example.

Rules – Rules are all customs, norms, laws, and conventions that community members adhere to while performing the activity. The rules from the examples are a grading policy, plagiarism policy, attendance hours.

Division of labor – How the work needed for an activity is spread over its community. A teacher grades the assignment, students research the subject, others might write the assignment, which are all parts of completing the object of a completed assignment

Instruments/tools – Tools are physical or conceptual things that are used by the subject to execute the activity. It is possible that various tools are used for a single activity. Instruments in the formation of an assignment are computers, communication devices, meeting spaces, but also experience, writing skills, and research skills.

4.2.4 Mediation and Contradictions

Next to the elements of an activity system, two other crucial parts of an activity theory analysis are the concepts of mediation and contradictions. Therefore this section will provide an elaborate overview of what these concepts are and why they are important.

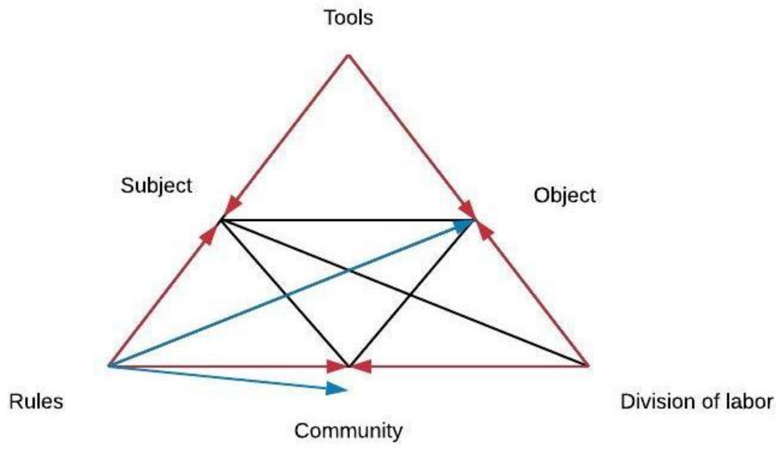

Figure 9: Primary and secondary mediating relationships

Mediation was introduced in the previous section. Mediation is the idea that actions are mediated by tools, rules, and division of labor. The three primary mediating relationships (red in figure 9) in the framework are (Lu et al., 2018): the interaction between a subject and the activity object is mediated by tools, the relation between subject and community is mediated by rules, and finally, the relationship between the community and the object of the activity is mediated by the Division of labor. These three relationships are examples of primary mediation. Secondary mediation is also possible. An example of this would be rules that mediate between the community and object (blue in figure 9).

As a result of the first three principles that were discussed at the start of this chapter, tensions can accumulate over time in an activity system. Due to the different perceptions and influences in an activity system, these tensions build up between different elements or activities of the same activity system (Lu et al., 2018). On the one hand, these contradictions are the basis for disturbances and conflicts in the system, but at the same time, they can lead to innovation attempts to change and improve the activity (Engeström, 2001) in search of the stable state of the system.

Contractions are split into four categories (Yoon et al., 2016). These are, primary contradictions that indicate a misfit within an element. Primary contradictions can act as a driver to make specific elements adapt to the changes in the activity system and to return to the stable states again (Foot & Groleau, 2011). Secondary contradictions, which indicate a misfit between two elements. Tertiary contradictions show a misfit between phases of development of an activity and, finally, quaternary contradictions that indicate a misfit between concurrent activities. The tensions derived from these contradictions drive new elements to be introduced in the activity system. Consequently, the activity system is reconfigured and rebalanced to return to a stable state (Lu et al., 2018).

Next, some examples of contradictions are discussed to give a more practical picture of what contradictions are in practice. Lu et al., (2018) analyzed the implementation of BIM in operations and maintenance (O&M) and first response by using activity theory. The second example from Foot et al, (2011) is used to show contradictions in the healthcare sector in the United States.

First, a primary contradiction is discussed. As explained, a primary contradiction is tension within an element of an activity system. The following example shows a primary contradiction within the tools of an activity system of information system implementation in operations and maintenance. In this case, a primary contradiction is found in the transformation from the old tools to the new BIM assisted tools.

FM professionals, the subject, use different tools to perform preventive, corrective, and predictive maintenance of the targeted buildings. The new tools require new and better expected performance, the convenience of use, the integrity of stored data, and specialization of information needs in different phases. These requirements accelerate the regeneration of tools within the activity system. That regeneration creates tension between the tools that do not develop at the same speed and therefore start conflicting with each other (Lu et al., 2018). Another example from the healthcare sector in the US shows a primary contradiction within the object of doctors. Their object is to provide treatment to their patients with the goal to heal them. At the same time, the treatment is also a source of income for these medical specialists. They try their best to relieve pain and heal ill people. Nevertheless, the treatment is part of a socioeconomic system where these services are exchanged for financial compensation. Therefore, the object of a medical specialist is always dual, healing people and increasing revenue (Foot & Groleau, 2011).

In case an activity system adopts a newly introduced element from the outside of the system, such as a new tool or object, it often results in an aggravated secondary contradiction where an older element, such as rules or division of labor, collides with a new one (Engeström, 2001). An example of a secondary contradiction between rules and tools is as follows.

When BIM was implemented in operations and maintenance, a contradiction between tools and rules was identified. The regulations that specify information exchanges for special/local situations, these rules block the generalization of BIM in a more global context. This mismatch forces the rules to be adjusted even though they are newly created to support the use of BIM in O&M. At the same time, the tools should be made to fit the local needs and rules instead of just the needs in a global context (Lu et al., 2018). In the case of medical specialists in the US, a secondary contradiction is uncovered between rules and the object of an activity. Us practice shows rules that allow doctors to spend a maximum of 15 minutes per patient, which impairs the object to heal people to the best of their abilities. This indicates a problem between the rule of a maximum of 15 minutes per patient and the goal to heal this patient. Without the 15 minute rule, a doctor would be in a better position to heal the patient (Foot & Groleau, 2011).

Shortly summarized, contradictions like those discussed above are very likely to lead to disturbances and friction, which in turn can create an attempt to evolve the activity system (Engeström, 2001; Lu et al., 2018). This evolution of activity systems aims to relieve the tensions created by contradictions (Georg et al., 2015) and results in a changed (and sometimes improved) status of the activity system.

4.3 Boundary objects

Like previously introduced, boundary objects might provide an interesting addition to the activity theory analysis of contract management information systems. The background and application of this theory will be discussed next.

As shown in chapter 2, specialization and fragmentation are key aspects of contract management complexity. Boundary objects are of interest because they are responsible for transferring knowledge between specialists. It is possible that the boundary objects that are involved in contract management information systems are handled badly. As a result, these boundary objects might be part of the problem why benefits of information systems are not realized in contract management practice. In order to understand boundary objects better, the following section will discuss what boundaries and boundary objects are, where they originate, which boundary types exist, and how boundary objects can be used optimally.

4.3.1 The concept of boundaries and boundary objects

Boundary objects find their origin in education research and psychology. Within teaching and educational research, transferring knowledge across boundaries takes on a very important role. At the same time, transferring this knowledge in an effective way can be a competitive advantage for an organization (Carlile, 2002).

Because of this interest, boundaries have been subject to research over the past decades. As a reaction to the identification of these boundaries, research has focused on how stable relations over boundaries can be established despite differences in specialists (Akkerman & Bakker, 2011). Hence, to avoid the fragmentation induced by boundaries and specialization, scholars have been in search of ways to cross these borders between practices (Hermans & Hermans-Konopka, 2010).

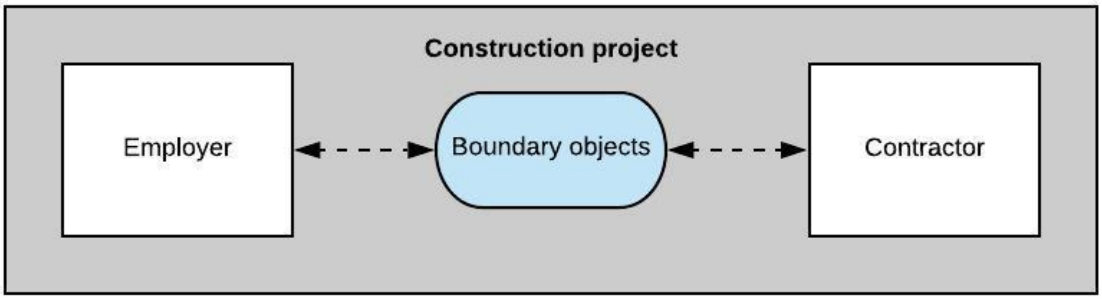

Figure 10: Boundary objects in the employer contractor relationship

Star and Griesemer (1989) were the first to coin the concept of boundary objects. While developing a natural history museum, they noticed that this required the collaboration of many different actors. They attributed the success of this project to the establishment of a few boundary objects like date records and lists of species for collecting and describing insects. This research led them to introduce the now generally accepted definition of boundary objects:

Boundary objects both inhabit several intersecting worlds and satisfy the informational requirements of each of them. ... [They are] both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use and become strongly structured in individual site use (Star & Griesemer, 1989).

4.3.2 Discussing a boundary object

A boundary object can be a hard concept to grasp. Therefore this section discusses the characteristics of a boundary object and provides a more specific example of a boundary object.

To become a boundary object, the following conditions have to be met (Star, 1989):

- Boundary objects are artifacts that reside in the interfaces between organizations. Thus it exists between organizations.
- It satisfies the informational needs of all of these organizations.
- They contain sufficient detail to be understandable by both parties or specialists using the object, although neither of them may understand the full context of use by the other.

An example from Carlile's research into product development serves as an example for a more detailed example of the concept. Below, assembly drawings as a boundary object are discussed:

"For Vaughn, the assembly drawing represented critical tolerances and functional specifications. For Mick, the assembly drawing provided a more three-dimensional representation of the orientation of parts and critical issues for assembly and testing" (Carlile, 2002, p-451).

This shows that the assembly drawing exists between two parties, has multiple meanings for the different parties or specialists and serves their informational needs, but both parties do not know what the assembly drawing represents for the other.

Other examples of boundary objects may be physical product prototypes, design drawings, shared IT applications, standard business form, or more abstract concepts like product yield (Bharosa et al., 2012). In the context of this research, one could think of examples of boundary objects as requirements or risks contained in the information system.

4.3.3 Pragmatic application of boundary objects theory

The previous section describes what boundary objects are in general. But the question how these boundary objects relate to this research remains to be answered. This section aims to provide this answer.

Because information systems in contract management are challenged with the transfer of knowledge, they seem to fail in their function as a boundary object. At the same time, theories on how to improve boundary objects are available. Sadly, this knowledge base on boundary objects in contact management information systems seems to be not fully exploited in practice. These theories can be applied in order to improve the boundary objects that are involved in contract management information systems. Consequently, this might improve contract management information systems performance in general through the optimization of these boundary objects.

In order to improve a boundary object, some further information needs to be provided. Firstly, the types of boundaries where the boundary objects reside in need to be discussed. This way, boundary objects can be categorized according to what boundary they need to cross. Next, when these boundary types are known, information on how to improve boundary objects at these boundaries is available. These two aspects of boundaries and boundary objects are discussed next.

Types of boundaries

A first step in analyzing boundary objects is analyzing and categorizing at what type of boundary they are located. In 2002 Paul R. Carlisle helped by categorizing these boundaries. He identified three different types of boundaries. These three boundaries are based on product development cases. In these cases, many different specializations are important in the development process, think of sales and marketing, design engineering, and production. The case of construction contract management is actually quite similar, where a contract manager relies on inputs from many different specialists in the IPM model and vice versa (as discussed in section 2.1.4). Each type, step by step, shows a more complex and challenging boundary.

Syntactic or information processing boundaries

The first type of boundary is a *syntactic boundary*. At a syntactic boundary, the problem is "matching differences", the information is not matched through a shared syntax or language. Therefore the message will not be transferred correctly. A shared and stable syntax ensures that communication between senders and receivers will solve many challenging communication problems and ensure a quality information exchange.

Semantic or interpretive boundaries

The next type of boundary is a *semantic boundary*. This approach recognizes that even when a shared language or syntax is present, interpretations can still be different. This results in difficult communication and collaboration. In a semantic boundary, problems shift from the processing of information to identifying semantic differences. The process of identifying and solving semantic differences is the creation of “mutual understanding”.

Pragmatic boundaries

The final type is a *pragmatic boundary*. This type recognizes that when things (or knowledge) are different and also depend on each other, problems arise. Knowledge is used to solve a particular problem that has different informational needs per party. Thus these parties are committed and invested in their knowledge. Therefore the challenge becomes, next to difficult communication, that individuals need to alter their own knowledge and also be able to influence or transform the knowledge from another party. This situation creates a need for an overall process for transforming knowledge to deal with these problems.

Creating effective boundary objects

When the boundary type is known, the next piece of theory can be applied. Carlisle (2002) also described the functions of *effective* boundary objects. These characteristics are of interest because they describe what functionality the boundary object should provide and what examples of this functionality are. Consequently, when problematic boundary objects are identified in contract management information systems, this theory will support recommendations for their improvement.

Transfer

The first characteristic of an effective boundary object is the *establishment of a shared syntax or language to represent knowledge*. Having a shared language when dealing with boundaries is of fundamental importance. This characteristic is required for dealing with any type of knowledge boundary. In all these types, some kind of shared syntax is necessary to make a boundary object effective. In this boundary type, the general boundary object will be a repository. When using a repository, some shared language interpretation is needed for the words that are used to search and store knowledge. If this is absent, the repository will become useless.

Translate

The second characteristic is derived when a semantic boundary is targeted. In this case, a boundary object at a semantic boundary needs to *provide a concrete means for individuals to specify and learn about their differences and dependencies across a given boundary*. In this boundary, the creation of mutual understanding is the problem. This is done through interactions between individuals where they make tacit knowledge explicit across a boundary. A specific process helps parties specify what they know as concretely as possible matched to the problem they are trying to solve. This characteristic is, for example, found in standardized forms and methods but also objects models and maps.

Transform

Finally, when a pragmatic boundary is encountered, an effective boundary object *facilitates a process where individuals can jointly transform their knowledge.* When a problem is encountered and one of the parties cannot transform the current approach to a problem to an approach spanning the functions involved, their knowledge will have a limited effect in solving the problem. This shows the need for a process that helps in transforming knowledge in a way that other specialists can understand its meaning. Transforming is the process where current knowledge is altered, new knowledge is created and validated within each function and over all functions.

4.4 Conclusions

This chapter has been written in order to provide the theoretical basis for the continuation of this research. Activity theory and boundary objects were discussed extensively. The following conclusions can be derived to summarize this chapter.

Both activity theory and boundary objects are likely to be able to identify problems in current approaches to contract management information systems. This perspective has not been used before in the context of contract management information systems. On the other hand, both theories have been applied successfully in other contexts (Lu et al., 2018; Styhre & Gluch, 2010). Therefore, it is likely that applying this perspective will lead to new discoveries concerning problematic practices in contract management information systems.

In order to use activity theory in this research, some extra information needs to be provided. Therefore, some history of activity theory was discussed, the five principles it is based on were explained, and the concepts of activity systems, mediation, and contradiction were described. These three elements will be an essential part of the analysis that will take place in chapter 5.

Similarly, the theory on boundary objects needed some explanation to be used in this research. First, the concept of boundary objects was discussed. Next, specific examples of boundary objects were provided. And finally, in order to show their use in this research, how boundary objects can be categorized and optimized was discussed.

When the analysis of current practices using activity theory and boundary objects uncovers the reasons for problems, solving these problems is likely to lead to unlocking the benefits of information systems in contract management. The method that will be used to perform this analysis is discussed in the following chapter.

5 – Methods

This chapter contains the methods behind the analysis of the implementation of information systems within construction contract management. It will explain the whole process, from the gathering of the data that serves as a basis for the analysis, to the analysis itself. These two steps of gathering data and consequently analyzing the produced data are broken down and discussed in more detail in the remainder of this chapter.

5.1 The analytical process

In order to fully present the used methods, a general description of what steps were undertaken is discussed in this section.

This first phase of the research starts with gathering the data that will be analyzed. The data will be derived from interviews with experts in contract management that have experienced the introduction and use of information systems.

This process of gathering data is initiated by creating an interview protocol (as included in full in appendix B-1). This interview protocol discusses the purpose, the methodology, how the questions have been constructed, the selection of interviewees, the interview process, and how the data is to be analyzed.

Next, the protocol is followed, and the interviews take place. These interviews result in an audio file, and these files were consequently translated into a series of transcripts of all the interviews that were conducted.

When these transcripts of the interviews have been written, the data is complete, and the analysis can proceed. This starts with inductive coding. During this phase, the full transcripts are analyzed and structured according to the data. This results in a codebook containing all important events that were identified in the transcripts. After this first part of the analysis, the inductive coding is finished the next step can be started. Inductive coding is a complex task. Therefore the coding approach will be discussed in more detail during section 5.2.

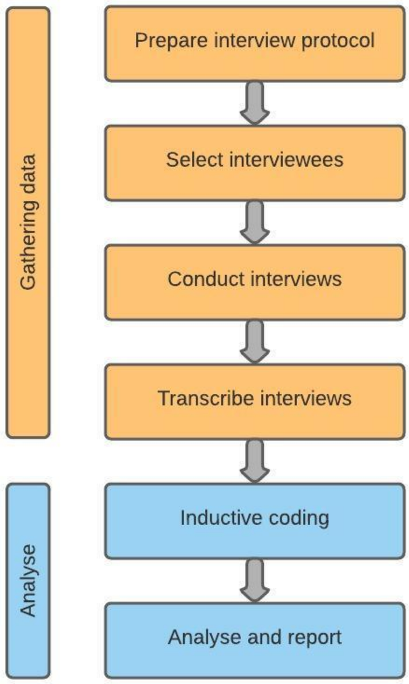

Figure 11: The analysis process

This last part of the analysis focuses on analyzing the data as it is gathered and structured with the coding. Consequently, a timeline is constructed to create an overview of when and how the events described in the codebook occur. Next, activity theory is used to analyze this timeline containing the events from the codebook. These results will be presented per main section of the timeline. Similarly, after the analyses using activity theory are presented, the theory on boundary objects is used to analyze the structured data. The results of this boundary objects analysis will be presented at the end of the analysis section. These methods of the analysis will be discussed in section 5.3.

5.2 Coding

The main source of data for this research is the interviews that were conducted. To transform these interviews from mere transcripts to useful data, a method needs to be used that is able to reliably retrieve information from the interviews. “Codebooks are essential to analyzing qualitative research because they provide a formalized operationalization of the codes” (Macqueen et al., 1998, p-138). A codebook provides researchers with the means for data reduction and simplification (DeCuir-Gunby et al., 2011). Therefore, coding and codebooks are recognized as a valid way of analyzing interviews. As discussed previously, this research will also make use of a codebook in order to analyze the results in the form of the transcripts from the interviews.

5.2.1 What is a codebook

The coding of data is the process that relies on detailed reading of data in order to capture, among others, assumptions, insights, and complex motivations (Mihas, 2019). This method focuses on using codes to represent many condensed topics that are included in the data that is gathered during a research project. This coding is done based on the use of various sentences, paragraphs, or textual sections from the transcripts based on the recordings of the various interviews.

Different sources cite different structures for codebooks. For example, Macqueen et al. (1998) suggest that a codebook should contain the following six elements: a code name or label, a brief definition, a brief definition, inclusion criteria, exclusion criteria, and an example. On the other hand, DeCuir-Gunby et al. (2011) only use three: a code name, full definition, and an example.

This research uses this last thee element approach. This will result in a codebook consisting of examples of events that are identified using the transcripts. These examples are represented with quotes from the transcripts and are used to show the link between the raw data and the constructs (Pas & Lauche, 2019). Next, a second-order construct is created to show the lowest level of generalization. Finally, these second-order constructs are aggregated one more time to create the most general level of the codebook, the third-order constructs.

5.2.2 Coding and coding methods

Coding can be inductive or deductive (Mihas, 2019). Deductive coding is done in advance, and inductive coding is done based on the review of data. According to scientific literature on coding, there are multiple ways to develop a codebook. Nevertheless, three main ways are prevalent, theory-driven codes and data-driven codes (DeCuir-Gunby et al., 2011). The first is a deductive theory-driven codebook. In this case, codes are developed in advance of the data collection using existing theories or concepts. The second approach, the inductive, data-driven coding method, emerges from the analysis of raw data. The third and final widely recognized approach is the structural approach. In this case, the coding grows from a specific research goal and questions and is often both deductive and inductive.

This research will use a data-driven, inductive approach. This decision is based on the following reasoning. Firstly, this research is grounded on an absence of information on how well information systems perform in the world of construction contract management. Therefore, theory-driven codes are likely to provide less useful information. Secondly, the research also has an explorative character with a few specific research questions that are to be answered. Finally, this research is based on interviews with specialists as raw data. Inductive coding supports the use of this type of data in three more ways (Thomas, 2003). This approach helps to condense extensive and varied raw text into a brief summary format, in this case, this is a summary with drivers, problems, and coping mechanisms during the implementation of information systems in contract management, as will be discussed in the next section. Therefore, it also helps to create clear links between objectives and findings from the raw data and to ensure these links are both transparent and defensible. Finally, inductive coding supports the development of a model or theory on the underlying experiences or processes which are presented through the text. This also fits well with the third principle of activity theory as presented in 4.2.2 The five principles of activity theory. All the arguments above support the use of an inductive coding approach for this research.

To construct data-driven codes, the following steps are to be undertaken (DeCuir-Gunby et al., 2011). The first step is to reduce the raw information. This step focuses on transforming the wholesome transcripts into interview summaries. This action structures the data that is available within the transcripts. This is done by analyzing the transcripts by looking for interesting events in the change process. Next, the interview summaries categorized according to the themes are analyzed and compared as a whole. During this phase, the most detailed categories are created from the transcript summaries. These categories are called second-order constructs. These constructs are checked and adjusted by comparing them across the other data. This step was repeated to create a set of more general categories. This is subsequently called a third-order construct. The development of the codebook is known to be an iterative process. Therefore the steps between the transcript summary and the establishing reliability can be recurring. Normally, when multiple coders are used, the fifth and final step is to determine the reliability of their coding work. Considering this research is performed single headedly, the final step of establishing reliability is left out.

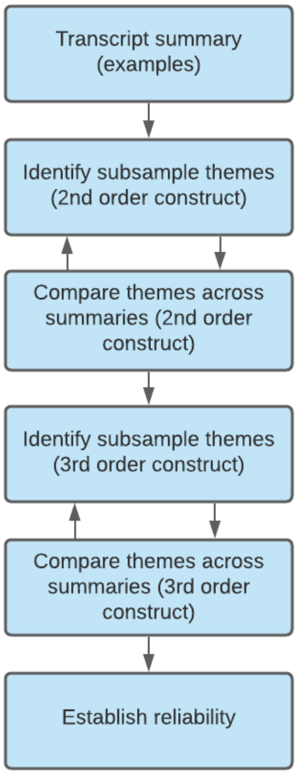

Figure 12 Steps for data-driven coding adapted from DeCuir-Gunby et al., 2011, p-142.

5.3 Analysis methods

After the inductive coding is done, the data that is necessary for this research has been gathered and structured. Next, the analyses using activity theory and boundary objects are to be conducted. The steps involved in this process are discussed next. Starting with the activity theory analysis.

The previous step ended with a list of categorized events that occur during the change process. The next objective is to apply the sociotechnical lens obtained from activity theory. In order to conduct this analysis, the change process needs to be structured chronologically. The codebook contains important events but no relation to when in the change process they occur. Therefore, to provide context to the events, it becomes necessary to create a chronological timeline describing the change process.

The timeline will consist of phases, but these phases are still too general to be analyzed using activity theory. Because of this high abstraction, the phases are split up into two or three more detailed chronological steps. Combined with the codebook events, these steps contain sufficient detail to be analyzed as activity systems. Next, all of these steps and their respective events are observed and analyzed using activity theory. This approach will provide the required results concerning the analysis of the change process.

Boundary objects are analyzed in a more separate way. When events concerning boundary objects are encountered in the codebook, they are to be flagged. Next, when the boundary objects have been identified, they have to be analyzed further. This further analysis will focus on presenting at what boundary they are located and how they are currently handled.

6 - Results

This chapter is focused on discussing the results of the previously described steps. It covers the data that has been generated and how this data is analyzed. First, an explanation is given for how the results will be structured. Next, the results will be discussed extensively by explaining the created codebook. Next, the results of the continued analysis of the data using activity theory and boundary objects are presented. Finally, the last section of this chapter will focus on discussing the conclusions derived from the results.

6.1 Structuring the results

In order to present the results of this research in a clear way, the following structure is applied to this chapter. First of all, a timeline is presented which is the main guideline of the analysis. This timeline covers all phases of the implementation of contract management information systems as they were identified in the interviews. Next, the codebook is discussed which contains detailed descriptions of situations that occur in specific sections of the timeline. This codebook contains an extensive overview of what can happen during the change process. Finally, the timeline, codebook, activity theory, and boundary objects are combined. This last section presents a detailed analysis of sections of the timeline using activity theory and boundary objects. In this section, the developments as described with sections of the codebook and the timeline are presented with the use of activity systems. Next, boundary objects within the activities are discussed. Finally the conclusions of this chapter are presented.

6.2 Timeline

To present the results of this analysis in a clear and structured way, a timeline was created. This timeline provides an overview of what steps are involved in the change process of implementing a contract management information system. The timeline has been constructed by analyzing the transcripts from the interviews. Combining the stories that were obtained in the interviews provides a complete picture of what the change process looks like.

Secondly, this timeline also supports the five main principles of activity theory (section 4.2.2) that were introduced by Engeström (2001). One of the main principles of activity theory is historicity, an activity system, and its issues and capabilities cannot be separated from historical developments. By analyzing the introduction in chronological steps, the third principle of the historical context of an activity is taken into account. Another important principle with supports the use of this timeline is the expansive transformation of activity systems. This timeline provides a basis to trace the events or actions that lead to changes in the activity systems and therefore facilitate the principle of expansive transformation. Consequently, this timeline provides a structured baseline to investigate the implementation and use of information systems in contract management.

The timeline consists of the following evolutions of the activity system. First of all, the implementation has to be driven by some kind of development. This change is the beginning of the process. Therefore, status 1 covers the development of why an information system is implemented. Next, the system is implemented, and users start experiencing work with the new information system. Very often, this stage was characterized by resistance from the users. A new system is often not directly accepted, and a lot of effort has to be spent to create support for the information system. These developments are covered by the second stage. Consequently, the next stage, growing pains, is characterized by users that are no longer undermining the use of the system. They are accepting the fact that the system is beneficial instead of a limitation. During this stage, users cooperate more, but new problems concerning coordination are discovered. When this stage is finished, status 4 is reached. During this status, users support the system and are open and able to use it. Similarly, coordination and supporting mechanisms are often better than at the start of the process. This phase is categorized by problems that occur due to the information system itself.

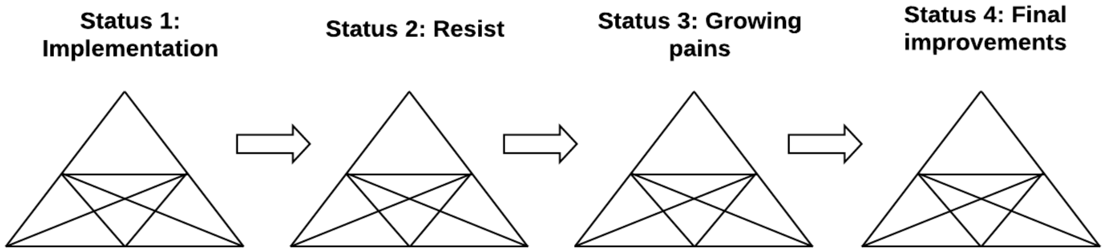

Figure 13: Timeline of the change process according to the interviews

It is important to note that not every case has to follow these steps in the same order. This timeline is a generalized representation of what can happen during the implementation of a contract management information system. In some cases, steps are skipped, or the order can be different.

6.3 The codebook

The timeline that was discussed in the previous section guides the results. Nevertheless, they remain an empty shell. The phases cover all stages of the change process, but what happens in all these stages is still unknown. Therefore, this section provides a complete overview of what events occurred during the stages. The codebook is a summary that structures and categorizes the information that resulted from the interviews.

The basis of the codebook consists of three main elements that are based on a common problem exploration, this starts with a cause, is followed by a problem, and finally, the problem is solved. These phases are slightly adjusted to describe the development of the implementation of an information system in contract management. Consequently, the first step is the identification of the drivers that are the reason for the introduction of an information system in contract management. These changes create tensions in the activity system that often resulted in problems. These problems are the second part of the timeline. Finally, these problems lead to solutions. These events can be considered as coping mechanisms for the problems that were related to the introduction of the information system. The next section will present the full codebook in detail.

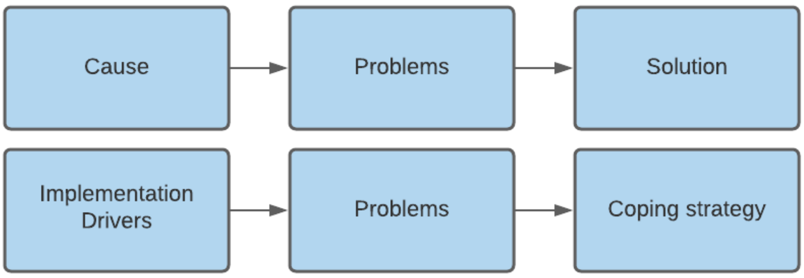

Figure 14: Codebook Structure

6.3.1 Introduction drivers

Reasons for the introduction of the systems were regularly mentioned during the interviews and are therefore captured within the transcripts. In order to identify these drivers in detail and to bring structure to the analysis, inductive coding of the interview transcripts was used, as is discussed previously. This resulted in the following codebook section describing introduction events.

First of all, ***Coercive tactics*** were identified. These drivers of the use of information systems were focused on putting pressure on team members to ensure the use of the information system. This pressure was created through different actions such as hierarchical expectations or formal enforceable rules in a contract.

The first sub-category of these coercive tactics is the ***use of rules*** to ensure the use of the information system. The interviews showed a few examples of this second-order construct. The first example was of a contract manager who stated:

"Everyone we work with (contractors, sub-contractors, and our own staff) is simply obliged to use the system" (Interview 9).

This shows that rules exist to force the use an information system. Another example identified where these rules were written down explicitly*:*

"I am obliged to use the system, therefore I will do this. Especially the fact that I have to conform to the contract is extra important for me as a contract manager. We have agreed that I will use the system, in that case, you will do it, you just have to" (Interview 8).

In this sub-category, the rules are explicitly written down in the contract, which in turn makes them enforceable. Consequently, the enforceability of these rules creates the pressure and basis for potential penalties when they are not followed.

The second sub-category is ***management driven***. This second-order construct focuses on the pressure that is resulting from upper management stating the expectation that the system is to be used by project members. This category does not show a specific written rule but a more informal expectation from line managers that is enforced by pressure related to the hierarchical structure of a company or project. The first example of this category was showed as follows:

"*You just lose the big picture with a system. I am old fashioned, I just want everything on paper. I only use this system because I have to satisfy the interests of my process manager. It improves nothing in the project or communication." (Interview 1).*

This contract manager stated that he only used the information system to satisfy the interests of the process manager of his project. This was the only reason he identified for using the system. This category also appeared in another variant:

"It (the introduction of a system) was supported by a necessity of senior management themselves. They identified a need for the system that we did not have up till that point in time." (Interview 9)

This example shows that the driver of the introduction of the system clearly came from upper management lines in a hierarchical organization.

Illustrative text fragments from interview transcripts	2^{nd} order construct	3^{rd} order construct
"I have always tried to block the introduction of think project. But I was forced to use it, so because of that, I will. Especially because I am a contract manager, I have to follow the regulations, we agreed on this, so then you simply have to use the system." (Interview 8)	***Rule driven:*** *the introduction of the system is driven by explicit rules.*	***Coercive tactics:*** *the use of information systems is driven by coercive factors like rules or expectations from upper management, which are based on the force of penalties.*
"You just lose the big picture with a system. I am old fashioned, I just want everything on paper. I only use this system because I have to satisfy the interests of my process manager. It improves nothing in the project or communication." (Interview 1)	***Management driven:*** *when upper management is responsible for the use of the systems by setting expectations.*	

Table 5: Coercive tactics

The second main category of drivers of the introduction of information systems in contract management that were uncovered is ***intrinsic project drivers.*** These drivers are not focused on force and punishment, and they find their basis in intrinsic motivations from the project team. The motivations of the project team appeared to be related to improving their own efficiency and performance.

The first sub-category of this construct is the need for ***accessible and structured information.*** This category showed that project teams felt the tasks included in contract management were growing beyond their capabilities. Information flows and requirements are examples of numbers that became bigger and bigger up to a point unstructured methods would not cut it any longer. This need for structure, prevention of the loss of information creates the need for an information system to provide clearly structured and accessible information.

The first example from the interviews showed that employers used to work in an unstructured manner and that this was a reason for the introduction of a supporting system:

"Employers were not structured very well, and they did not manage their affairs properly…. (after the introduction of a system) We were able to retrace what we did and why. This helped us a lot" (Interview 7)

This need for structure in requirement management was also identified in the following example:

"We used to use spreadsheets (for our requirement management), this makes it very difficult to find the structure that these documents (the contract) are intended to have. This took up a lot of our time." (Interview 7)

Another example of this construct relates this need for accessible and clear information to interfaces and people leaving and entering the project teams:

"Especially these interfaces between project phases were various specialists work on, are an element where a lot of information gets lost when people leave that were involved in previous project phases." (Interview 5)

Without a system, information gets lost when people leave a project. When this information is stored in an information system, this situation can be easily prevented.

The second sub-category is ***Added complexity.*** This construct shows that the introduction of an information system is driven by a general increase in complexity in construction projects or by the addition of new tasks for project teams. That this general increase of complexity is one of the drivers of information systems is shown in the following quote:

"We have made things more complex without showing the need of it. A system is presented as an easy solution to control this self-made complexity." (interview 4)

New tasks for the project team also increase complexity for project teams. Project teams used to have very similar tasks in every project. Nowadays, different forms of collaboration are becoming more common. These new ways of collaboration create different roles and project teams in every project. Because of these different project teams, companies have to be able to adapt to this complexity of changing roles, and the corresponding new information flows that need to be controlled. This is illustrated best with the next example:

"we moved to more complex projects where, apart from the design, we also had to do stakeholder management and were responsible for all permits… due to all these new actions we lost oversight of the consequences of our work." (Interview 3)

Illustrative text fragments from interview transcripts	2nd order construct	3rd order construct
"Employers were not structured very well, and they did not manage their affairs properly…. We were able to retrace what we did and why. This helped us a lot" (Interview 7)	***Need for accessible and structured information:*** *the use is driven by a need for better structured and accessible project data.*	***Intrinsic project drivers:*** *the use of information systems is driven by an internal need for more efficiency and better performance in project teams.*
"There is more information available than what needs to be taken care of with the contract, client wisher, permit requirements, and many other promises that are made and not presented clearly. These agreements might not be of great importance for the project, but they are important for those people that they are made for" (Interview 5)		
"We have made things more complex without showing the need of it. A system is presented as an easy solution to control this self-made complexity." (interview 4)	***Added complexity:*** new and more complex tasks for project teams drive the need for improvement in projects.	
"we moved to more complex projects where, apart from the design, we also had to do stakeholder management and were responsible for all permits… due to all these new actions we lost oversight of the consequences of our work." (Interview 3)		

Table 6: Intrinsic project drivers

6.3.2 Problems

Three different main categories of problems were identified while coding the interviews. These main categories were problems related to the user community, problems related to the guidance in using the system, and finally, problems related to the structure of the system. These categories are all related and can sometimes seem similar. Therefore, the interactions between the users, the information system, and guidance on the use of the system (as presented in figures 15, 16, and 17) are used to show the difference in the constructs from the codebook.

Figure 15: Focus of unprepared user community

The first category to be discussed is the third-order construct of an ***unprepared user community***. This construct relates to problems that originate in the user community itself. The user community is a collection of different specializations, knowledge fields, impressions, and perceptions. These differences in the user community can create problems that are separate from the information system and the guidance that is provided.

The first sub-category of an unprepared user community is problems that are related to the ***specialized knowledge*** of information systems. Knowledge of IT and information systems is a very specialized type of knowledge. Secondly, the introduction of an information system creates the need to accommodate additional roles in a project team. This need for specialized knowledge and the supporting roles for the information system creates various problems. These are described with the following examples.

In projects, you can often observe that information systems in contract management are introduced as a wholly separate entity in a construction project. This creates islands of knowledge which hampers the integration of an information system in a project team. A system specialist is not a contract specialist, and a contract specialist is no system specialist. The problem of this separation is exemplified with the following quote:

"The complexity of the system causes a situation where only one person is familiar with the system, only he feels at home in this context. But he does not know anything about contracts. We really have a Thinkproject geek. But he is absolutely useless" (Interview 8)

This problem of needing different specialties to implement and use an information system consequently leads to a lack of structure in roles and responsibilities regarding the system. This was identified in another interview where the interviewee mentioned that someone in the project team should take responsibility for the system:

"at some point, so many things will be added to the system that, as a contract manager, you will lose your mind. Combining too many functions without someone taking charge is a huge pitfall of the systems. This deserves more attention." (Interview 6)

Another example from the interviews shows the lacking similarities between the IT specialists and the other members of a construction project:

"apparently, the IT world does not listen to the real needs. Actually, management systems are limited by people who serve the IT sector's agenda" (Interview 9)

The second-order construct ***Individual characteristics*** shows problems that are related to individual project team members. Every individual has his or her own perception and opinion of his or her way of working. When a system is introduced that changes this approach, they can feel threatened, which causes them to oppose the system in different ways. These situations make the implementation of new information systems more problematics as shown by the next quotes:

"You don't have to look far before you find someone who hates the system. They are not able and don't want to adapt. Some groups are just not going to start using it." (Interview 5)

This first quote is an example of an individual who strongly opposes the system, which appeared to be very common in projects. The following example shows another more detailed individual decision that can block the effectiveness of an information system.

"because of that, people don't see the system as useful, and they are only going to oppose the system use. This is not about the quality of the system, but they are looking for excuses to not use the system" (interview 3)

A final example is provided to show how a lack of transparency of individuals can block proper implementation of an information system:

"You depend so much on the transparency of managers in the sharing of information. When things start to go wrong, people rarely feel comfortable saying they need help. Systems that can predict these types of trends are often suppressed by individuals in the top of the organization." (Interview 9)

Illustrative text fragments from interview transcripts	**2nd order construct**	**3rd order construct**
"The complexity of the system causes a situation where only one person is familiar with the system, only he feels at home in this context. But he does not know anything about contracts. We really have a Thinkproject geek. But he is absolutely useless" (Interview 3)	***Specialized knowledge:*** *this category of problems is based on the fact that knowledge about the IS is specialized and separated.*	***Unprepared user community****: the problems that arise are caused by a user community that individually and in a team, context is not prepared to use an information system.*
"people don't share enough, which decreases transparency. Consequently, the efficiency gains of the systems become hard to bring across" (Interview 4)	***Individual characteristics:*** *the problems that are identified in this category relate to decisions and opinions from individual team members.*	
"You don't have to look far before you find someone who hates the system. They are not able and don't want to adapt. Some groups are just not going to start using it." (Interview 5)		

Table 7: Unprepared user community

The second third-order construct that was created in the codebook is ***poor system design***. This construct can be directly related to the information system itself. Problems that were covered by this category are caused by a system that is badly designed.

Figure 16: Focus of poor system design

The first second-order construct of this poor system design considers problems that relate to the information ***system's interface***. The system interface covers a few subjects, such as the ease of use of the system, the way data is represented, and how data is to be retrieved from the system.

The first problem with a bad system interface that was identified relates to bad ease of use. If a system has a very unintuitive interface, team members have a very hard time working with the system. If it is not easy enough, they are more likely to make mistakes in using the system. This is shown with the next example:

"you have to use the system daily or weekly to get the hang of it. If you don't, you don't know where to look for data. …. Ease of use of the system is very important." (Interview 2)

This is confirmed by another quote that shows that complex programs are more a nuisance than a supporting tool for a project team. It also shows that the knowledge threshold for users should be kept as low as possible:

"systems were more of a burden than the value they created. They required more work to enter data and to use the software than the revenues compared to a simple excel sheet…. When you need a course to learn a system, the threshold as a user is too high. This makes it (the system) not useable for the whole team." (Interview 3)

The representation of data can be arranged in different ways in modern information systems. This representation used to be thought out very clearly because computer power was limited. Nowadays, computing power is no longer a limitation. Nevertheless, the representation of data has not changed for the better. A few interviewees named the new approach "the big bucket principle" all data is gathered in a single table, which is structured by adding lots of metadata. This is shown in the next example:

"The big bucket principle, put everything in a single table. This used to be impossible due to hardware limitations. If all data is in one table, you need to provide lots of metadata with a file. This is bound to go wrong." (Interview 9)

The other sub-category of poor system design is bad ***system architecture***. Problems in this category are resulting from the architecture or background of the software that is used. This includes the use of wrong or incomplete processes in an information system and the possibility of trying to over organize information.

"Another thing that often occurs the use of incomplete processes. … These processes are elaborated based on the requirements but are not totally finished. Where is the flow chart, which forms do we need and which data element is used? When you want to finish this, they tell you, we will complete it together in the future. My experience in system development shows this never happens. The data only arrives when you have defined how it needs to be delivered." (Interview 9)

This lack of proper processes, in turn, creates new problems. If a process is not designed correctly, information is not optimally used. These consequences of a bad process are explained with the next example:

"If I would only enter risks into the system, I would not see them return later in the process. What happens with all this data? It only ends up in a monthly report, and nobody sees that. This misses the mark, this information could be used more effectively" (Interview 5)

Information systems provide a lot of freedom and possibilities in their functionality and architecture, but this freedom can also become problematic. Too much freedom can lead to the wish to relate as many things as possible in an information system. But simply creating more relations does not lead to a better system, as is illustrated in the following quote:

"The pitfall is that you will start over organizing because of the freedom that the system provides. But not everything can be related to each other… I have seen this occur from time to time." (Interview 6)

Illustrative text fragments from interview transcripts	**2nd order construct**	**3rd order construct**
"you have to use the system daily or weekly to get the hang of it. If you don't, you don't know where to look for data. …. Ease of use of the system is very important." (Interview 2)	***System interface:*** *this category contains problems that are caused by bad interface design, such as low ease of use and the inability to retrace documents.*	***Poor system design:*** *the identified problems can be traced back to poor design decisions in the development of the information system.*
"We have many lists in excel, it is horrible, they think they can cover everything with the file explorer. If I move changes to the final folder and wait for too long, it ends up in another subfolder. Then it is just gone for me." (Interview 2)		
"Another thing that often occurs the use of incomplete processes. … These processes are elaborated based on the requirements but are not totally finished. Where is the flow chart, which forms do we need and which data element is used? When you want to finish this, they tell you, we will complete it together in the future. My experience in system development shows this never happens. The data only arrives when you have defined how it needs to be delivered." (Interview 9)	***System architecture:*** *problems with the system itself are related to the use of incomplete or bad processes or using wrong relations between elements.*	

Table 8: Poor system design

The final third-order construct of the problems is ***Coordination insufficiency.*** Coordination insufficiency is about problems due to the interaction between the system, users and how this is influenced through the means of providing guidance on the system. Therefore it is different from the previously discussed constructs. This coordination is crucial in making sure the system is used correctly. The problems a lack of coordination can bring are part of this construct.

Figure 17: Focus of coordination insufficiency

The first sub-category of coordination insufficiency is a ***lack of guidance*** on how to use the system. This guidance can be training sessions, manuals, and formal or informal rules on how to perform processes in the system. An introductory training session is generally provided, but that is the only training users often receive. No follow-up sessions are held to keep users updated on the system's functions. Similarly, manuals and rules on the use of a system are rarely set up clearly in projects. This statement was confirmed by one of the contract managers with the following quote:

"informal agreements would be very helpful. To discuss this during the project start-up would help immensely. Then we agree on behavioral and use rules. This is absolutely necessary but happens rarely." (Interview 5)

Consequently, in case these rules or manuals are set up early in the project, they need to be written down and made visible somewhere for the users of the system. Nevertheless, the following example indicates that this is forgotten regularly, and therefore limits the benefits of the information system.

"I would expect those rules (on the use of the system) are written down somewhere, in the management plan or whatever. But in most cases, this is not the case. This is also often the reason that effects (of the system) are limited" (Interview 8)

Unintended use is the second sub-category of problems related to a lack of coordination. Unintended use arises when users are given the freedom to develop their own way of using the system due to a lack of coordination. Information systems have a lot of different functionalities. Without proper guidance, these functionalities can be abused. An initial example of this abuse of functionality is that the information system is used as a communication system. When the system is used as a communication tool, people who feel comfortable in the system are more likely to use it to shirk responsibilities. This is confirmed with the following statement from the interviews:

"You should be wary that the system does not become a communication tool. This is a big risk of systems, especially the people who are experienced users. People are just bouncing tasks and curling with responsibilities. On a Friday, they wipe their side of the street until they are back on Monday" (Interview 5)

Another form of unintended use is the creation of problematic workarounds. When users are not comfortable with the use of the information system, they are likely to create workarounds themselves. This is illustrated in the next example:

"(When they don't understand the process) the documents are downloaded so many times that everyone has a different local copy. You can bet on it that everyone will be working in a different version." (Interview 8)

The next second-order construct is ***different interpretations.*** A lack of proper coordination of the system use can provide room for conflicting interpretations to arise. When, for example, the purpose of the information system is not discussed clearly between users, users can create conflicting ideas on what and how the system should perform. These different ideas are likely to incite conflicts between the users, as is shown next.

"Sometimes the way of thought is, I just enter a change into the system, and that solves everything. This change needs to be solved in practice and not in the system. New generations grow up with these systems, and they have to be reminded that the system is just a tool." (Interview 2)

These interpretation problems can also arise at the data level. Some types of data, like requirements or risks, are very much open to interpretation. Similarly, data in the system consists of textual semantic information. This use of specific terminology and definitions of data elements can therefore also be the basis for the creation of opposing interpretations. On this level, interpretation problems of the data contained in the system can lead to bad decision making, as is illustrated next:

"The part about risks also applies here. We have collected about 200 risks in the system, and they have all been mitigated. But we are still in the phase before the investment decision. Thus, the worst is yet to come. That is why this risk register gives a wrong impression of the risk management part of the project" (Interview 5)

The final second-order construct of this category is ***bad input***. When the system use is not coordinated correctly, it is likely that at some point, bad input will be entered into the system. This input can be data but also other elements like the use rules. The use of copied or useless requirements is a prime example of this bad input:

"Another problem is the fact that in some cases you need to think why certain requirements are set. Some of the requirements are already fulfilled with the use of the system. … It is useless to record these requirements another time." (Interview 3)

Bad input leads to bad output. Similarly, entering bad data into the system limits the benefits of the information system. This is confirmed by the statement that these bad inputs require lots of additional time to correct, as is described in the next example:

"We are cleaning up the risk register. We need to read and analyze rule by rule what is actually Witten down, what do they intend to say with this text? This is very time consuming, but it increases the benefits. A good system with a good theory but with but inputs is what you are left with. Bad input in a good system does still not deliver the desired benefits (of the system)." (Interview 5)

Illustrative text fragments from interview transcripts	2nd order construct	3rd order construct
"informal agreements would be very helpful. To discuss this during the project start-up would help immensely. Then we agree on behavioral and use rules. This is absolutely necessary but happens rarely." (Interview 5)	***Lacking guidance:*** *a shortage in clear guidance on the use of the information system such as manuals or training sessions*	***Coordination insufficiency:*** *the problems that arise are related to a lack of coordination on how to use the information system correctly*
"You should be wary that the system does not become a communication tool. This is a big risk of systems, especially the people who are experienced users. People are just bouncing tasks and curling with responsibilities. On a Friday, they wipe their side of the street until they are back on Monday" (Interview 5)	***Unintended use:*** *due to a lack of coordination, extra uses or workarounds for the system arise that block proper use of the system*	
"Sometimes the way of thought is, I just enter a change into the system, and that solves everything. This change needs to be solved in practice and not in the system. New generations grow up with these systems, and they have to be reminded that the system is just a tool." (Interview 2)	***Different interpretations:*** *problems created by different interpretations of system elements or data*	
"What creates a lot of problems is the fact that people copy requirements from one project to the other project." (Interview 7)	***Bad input:*** *problems related to the input of bad data into the information system*	

Table 9: Coordination insufficiency

6.3.3 Coping mechanisms

The final section of the codebook that needs to be discussed is the part of the coping mechanisms that arose due to the problems that were identified previously. These coping mechanisms aimed to mitigate problems related to the introduction of information systems in contract management.

The coping mechanisms that were identified were split into three third-order constructs, ***correct, force, and discuss.*** The first category ***correct*** covers mitigation measures where elements involved in the use and implementation of information systems are actively changed. The coping mechanism ***discuss*** tries to mitigate problems by creating support for the system by discussing functionality and elements together. The final strategy ***force*** is aimed at using pressure to incentive a better implementation of information systems.

The first strategy to be discussed extensively is ***correct.*** When this strategy is applied, changes are made to the working processes, communication lines, the system itself, or the project team to mitigate problems with the use of the information system.

Improve informal communication is the first sub-category of active changes to the use of information systems. Informal communication is all communication between team members that are not formalized like meetings are. Walking over to someone to discuss something or giving a call is considered informal communication. An information system is regularly seen and used as a communication tool between project members. Communication outside of the system is useful to decrease these types of problems. Therefore, informal communication is seen as very helpful to support information systems. This measure aims to keep reminding project member to communicate with each other outside the system, as exemplified in the next example:

" the use of the system needs to come from both sides, you have to make sure you will keep talking to each other. … I want people to talk to each other to prevent surprises." (Interview 1)

Another way to approach the issues with communication is to internalize these processes into the information system. Nevertheless, it is not advisable to include these processes in the information system. One of the experts stated that it is smarter to simply keep communicating outside of the system.

"If you talk to each other, this (communication problem) would not have occurred. In a system, this has to be included in a process. It is better to keep this outside of the system and to keep communicating with each other." (Interview 3)

The last example of the need for better informal communication is showed by the following quote that confirms that informal communication helps to implement an information system.

"To implement this system, we had a lot of human interaction and communication. This has led to a functioning system" (Interview 4)

The second sub-category of coping mechanisms under correct is to ***change the task allocation*** in the project team. This measure is about changing tasks and responsibilities within the project team. The first example of this is appointing a responsible person for the system or element of the system. One example of this is that this person becomes responsible for preventing the system from growing out of control:

*"You need someone who makes prevents the system from growing out of control in elements and inputs."(*Interview 1)

Another example of this can be that this person is responsible for the quality of data that is entered in his module of the system.

In my opinion, every part of the system should have some kind of owner who is responsible for the quality. … Make sure in the front-end that new information has value and is not already in there" (Interview 6)

Finally, not only responsibility for the system needs to be arranged. When building the information system, the right sets of knowledge need to be present. Knowledge from both the system and contract management processes are required to build a good system:

"The people with experience (in contract management) are the ones who think of good processes. These need to be implemented in the system. This remains crucial and requires the biggest amount of effort." (Interview 7)

The third second-order construct covers the use of an ***external informal process***. A process outside of the information system is considered to be an external process. Some processes in contract management can become very complex, almost to an unworkable level. In this case, an external informal process is seen as less problematic to the system use, and it can even be beneficial. Next, an example from the interviews is provided which shows this approach in relation to the process of contract changes:

"Think of contract changes. If you would follow all the process steps, you will never finish a change in time. You will get stuck in the process approach, which takes an unrealistic amount of time. You need an informal line. You need to be able to change quickly. If you can fall back on the system in these cases, which shows you where you are at, you will be ahead of the curve" (Interview 7)

This example shows that discussing changes outside of the system before they are entered into the process does not take away its functionality in the change process. Including this full process in the system would only make it more complex and less practically usable.

The last sub-category to be discussed is the creation of an ***alternative system structure.*** This measure aims to use adjustments to the system itself to improve the use. Making the processes or forms within the system less complex is an example of this approach:

"at first, we used a table with 36 columns. Nobody knew where all these columns were used for or why they were relevant. After we researched the reason for the table, we found out that of the 36 columns, 29 were irrelevant. After this point, we removed the irrelevant columns, and the remaining 7 were used correctly" (Interview 3)

Illustrative text fragments from interview transcripts	**2nd order construct**	**3rd order construct**
"Communication is two-directional, and you will have to make sure you keep talking to each other, but this does not happen when you use an information system. This way, you feed the inward focus of engineers. I want people to talk to each other to prevent surprises" (Interview 1)	***Improve informal communication:*** *this approach uses the creation of informal communication lines to decrease problems with the information system.*	***Correct:*** *this strategy uses active changes to processes, the system, or the workforce to improve the use of the IS.*
"The people with experience in the field are the people who create good processes. These processes will end up being the basis for the system. This work is crucial and requires the most amount of time" (Interview 7)	***Change task allocation:*** *in this case, the allocation of tasks within the project team is changed to improve the use of the system.*	
"Think of contract changes. If you would follow all the process steps, you will never finish a change in time. You will get stuck in the process approach, which takes an unrealistic amount of time. You need an informal line. You need to be able to change quickly. If you can fall back on the system in these cases, which shows you where	***External Informal process:*** *an external informal process is used to avoid the use of the (inefficient) system.*	

you are at, you will be ahead of the curve"(Interview 7)		
"at first, we used a table with 36 columns. Nobody knew where all these columns were used for or why they were relevant. After we researched the reason for the table, we found out that of the 36 columns, 29 were irrelevant. After this point, we removed the irrelevant columns, and the remaining 7 were used correctly" (Interview 3)	***Alternative system structure:*** Changes are made to the system itself to improve its use.	

Table 10: Correcting practices

The next main category of the coping mechanisms is ***discuss.*** This approach is about trying to find common ground on the use of the system and its elements. Similarly, it covers the creation of support for the system by showing the value for its users.

The first second-order construct of this category is ***show value.*** This approach is meant to generate more support for the system under project members. This support is created by, for example, discussing tangible gains of the system like time savings:

"it (the system) has to stay a tool which increases productivity compared to other tools. It may cost some effort to enter in the system, but it should become clear what the gains are, it saves time, this has to be very tangible." (Interview 3)

When discussing problems using the information in the system, the added value can also become visible. One of the contract managers named the next situation as an example of this statement:

*"especially in works with many problems, these problems are solved way quicker. Interfaces with cables and piping with different owners are a good example. If you coordinate this well through exchange portals, you will keep everyone up to date. What I consequently notice is that this added transparency and the facilitating of the discussion on contractual problems that occur, lead to gains in efficiency." (*Interview 4)

Create common interpretations is the next sub-category to be explained. As discussed in the previous section, interpretation problems are quite common in the implementation and use of information systems. Therefore, the creation of common interpretations is aimed at the discussion of viewpoints of all parties involved. The goal of this measure is to create a common interpretation where the perspectives of the people involved are aligned, which should prevent problems in a later stage. How common interpretations are created on the level of a requirement is explained using the next quote:

"We ask the contractor to create a list of requirements that, in his opinion, can become critical at a later stage, those where he thinks disagreements will be based on. We will do the same thing. These requirements will be discussed and reformulated together to create a common interpretation." (Interview 7)

<table>
<tr><th>Illustrative text fragments from interview transcripts</th><th>2nd order construct</th><th>3rd order construct</th></tr>
<tr><td>“especially in works with many problems, these problems are solved way quicker. Interfaces with cables and piping with different owners are a good example. If you coordinate this well through exchange portals, you will keep everyone up to date. What I consequently notice is that this added transparency and the facilitating of the discussion on problems that occur, lead to gains in efficiency.” (Interview 4)</td><td>Show value: Discuss and show how the information system provides added value to the project and all team members</td><td rowspan="2">Discuss: a strategy to create support and improve the use of the information system by discussing the value and the use of the system together</td></tr>
<tr><td>“We ask the contractor to create a list of requirements that, in his opinion, can become critical at a later stage, those where he thinks disagreements will be based on. We will do the same thing. These requirements will be discussed and reformulated together to create a common interpretation.” (Interview 7)</td><td>Create common interpretations: by discussing viewpoints of all parties involved in common interpretations of the system or data elements are created.</td></tr>
</table>

Table 11: Discuss practices

The last third-order construct to be discussed is the strategy ***force.*** When force is used, pressure and the threat punishments are used to incentivize better use of the information system. This can be done in various ways such as, the introduction of new rules or putting pressure on a project member. It is important to note that deregulating the use of the information system is also part of this category.

The first second-order construct is ***Pressure.*** This measure uses, for example, peer pressure to incentivize better use of the information system:

> *“show them that the others that need the information they possess. If you do not want to do it for your own good at least do it to help and support some else in the team.”* (Interview 5)

Next to pressure, the addition of new rules can also be used to force project members to use the system. Therefore ***regulate*** is the next sub-category. These added regulations do not have to be formal rules. Procedural agreements are proposed as a better way in the next segment:

> *“It is of utmost importance to have good agreement on the use of a system in place. You will have to do this together. You should not fix this with formal requirements, but you do have to make process agreements on how you collaborate”* (Interview 3)

Finally, adding rules should not be seen as a simple fix. It is very important to keep the negative side effects of putting pressure on team members in the back of your mind. Therefore, ***deregulating*** has also been proposed to improve the use of information systems in contract management. An example of the side effects of regulating is shown below:

"Contract managers like to capture things in new requirements. But when you start to fix the use of a system in requirements, you will over-regulate something. This will lead to a decrease in transparency." (Interview 6)

Illustrative text fragments from interview transcripts	**2nd order construct**	**3rd order construct**
"show them that the others that need the information they possess. If you do not want to do it for your own good at least do it to help and support some else in the team." (Interview 5)	***Pressure:*** *when peer pressure is applied on team members that are not using the information system*	***Force:*** *strategies concerning the use of force and punishment to improve the implementation of information systems.*
"Contract managers like to capture things in new requirements. But when you start to fix the use of a system in requirements, you will over-regulate something. This will lead to a decrease in transparency." (Interview 6)	***De-regulate:*** *when a decrease in the number of rules regulating the use of the system is identified*	
"It is of utmost importance to have good agreement on the use of a system in place. You will have to do this together. You should not fix this with formal requirements, but you do have to make process agreements on how you collaborate" (Interview 3)	***Regulate:*** *When an increase in rules regulating the use of the information system is used to motivate the use of the information system*	

Table 12: Force practices

6.4 At theory analysis

This next section combines the previously discussed timeline, codebook sections, and activity theory. All respective statuses of the timeline are to be discussed in detail. Zooming in on what happens during the phases of the timeline provides a basis for the analysis. Important sections from the codebook are placed in perspective by linking them to a specific status. Consequently, the sections from the codebook that happen during a specific phase are discussed and analyzed by presenting the developments in the activity system during these phases. In order to present clearly structured results, this analysis contains one aggregate storyline based on all the interviews. Not all elements of the codebook were used because this would make the storyline too complex and hard to follow.

6.4.1 The introduction drivers

The first section of the timeline describing the change process to be discussed in detail is stage 1: the implementation drive. This stage covers the reason why a supporting information system is introduced and next what is done to introduce the system and the response to this introduction. These steps are represented with activity system 1A, 1B, and 1C in figure 18.

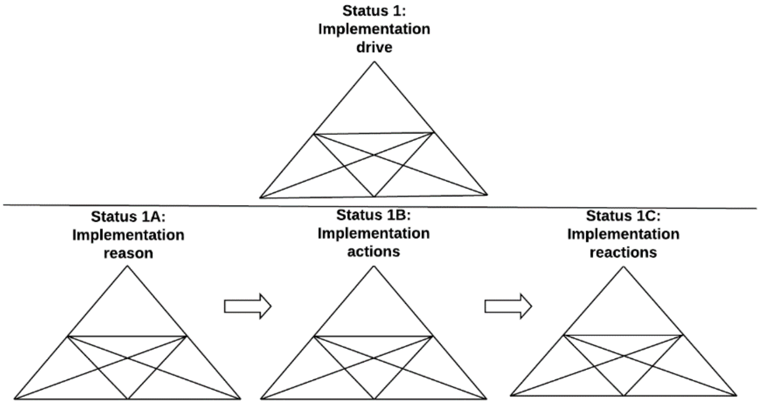

Figure 18: Sub-systems of status 1 - Implementation drive

The reason why an information system is introduced can be traced back to a new desired outcome. Apparently, somewhere in the organization, a need for more efficiency was discovered. In order to fulfill this new desired outcome, information systems are introduced. This introduction led to implementation actions. These two steps are discussed in more detail next.

System 1A shows the changed desired outcome. This change is contained in the codebook sections of ***Intrinsic project drivers*** and ***management driven*** implementation. These sections indicate a change in the desired outcome of the activity system. This new desired outcome leads to a changed object. The object becomes: to efficiently realize what is agreed in the contract. In turn, this changed object creates a contradiction with the current tools that are not able to realize the new object. Current tools such as word, excel, and emails are deemed not to be efficient enough. Therefore, this secondary contradiction between the object and tools of the activity has arisen. The solution for this is the implementation of a supporting contract management information system, which is discussed in the next activity system.

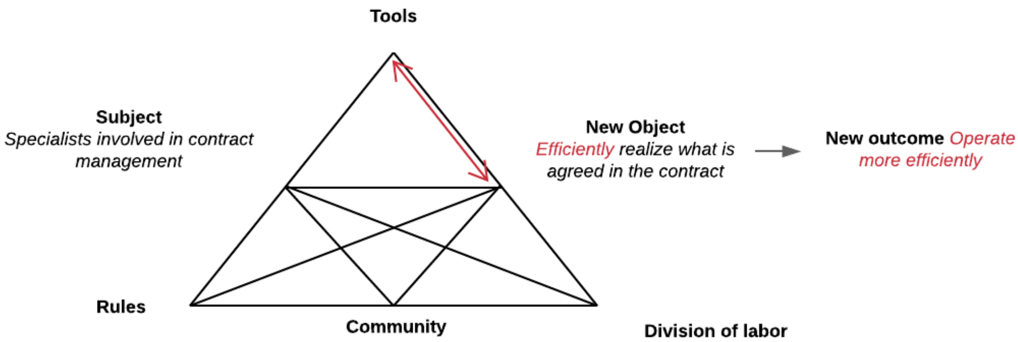

Figure 19: Sub-system 1A - Implementation reason

System 1B is a response to the developments that took place in sub-system 1A. In order to cope with the previously identified contradiction, a new *tool*, the information system, is procured. This tool is generally obtained from an external organization. This organization is responsible for providing and managing the tool. This leads to the introduction of an information system developer who is responsible for building and managing the information system. Consequently, this developer is added to the community and division of labor.

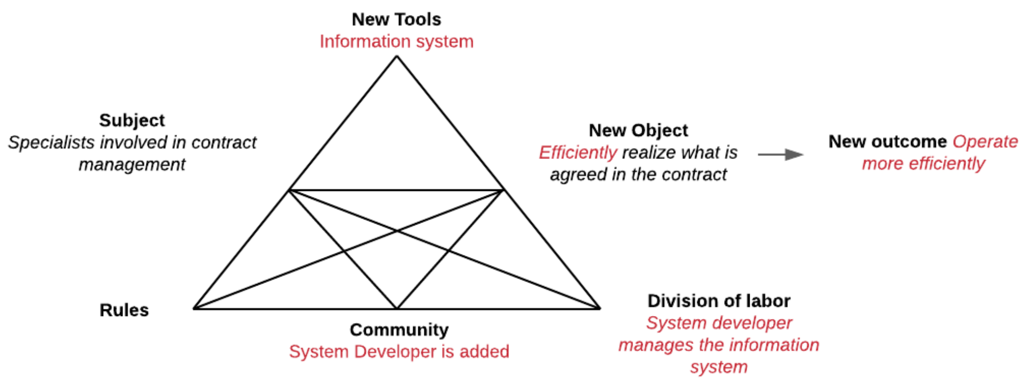

Figure 20: Sub-system 1B - Implementation actions

The sole introduction of the new information system as a *tool* leads to a new contradiction. This is shown in the reactions to the introduction in status 1C. The tool is not immediately usable by the subjects because they lack the proper knowledge to use the information system. This indicates a secondary contradiction between the tool and subjects because the subjects are unable to properly use the tool. In order to fill this knowledge gap, training sessions were introduced as a new tool. Nevertheless, these training sessions rarely provided enough knowledge for the users. Therefore, the contradiction between the subjects and tools remained to exist. In a similar way, manuals, work flows, and rules to support the subject in using the information system are often introduced. But, these supporting elements were often not created or hard to find. Therefore this action also often fails to solve the tool-subject contradiction and can even create a new subject-rules contradiction. These two are examples of ***Coordination insufficiency*** with an example of ***lack of guidance*** as mentioned in the codebook.

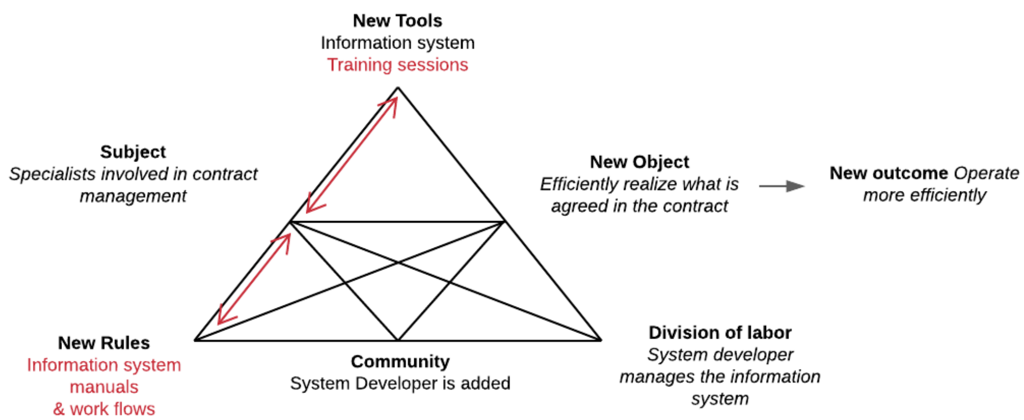

Figure 21: Sub-system 1C - Implementation reaction

6.4.2 Resist

The previous stage of the development of the change processes left some contradictions unsolved. Therefore, the next section shows the reaction of the users to these contradictions. The first sub-system of the timeline was characterized by users that oppose the implementation of the system and resist its introduction. The other sub-systems cover what measures were taken to mitigate these problems and how successful they were.

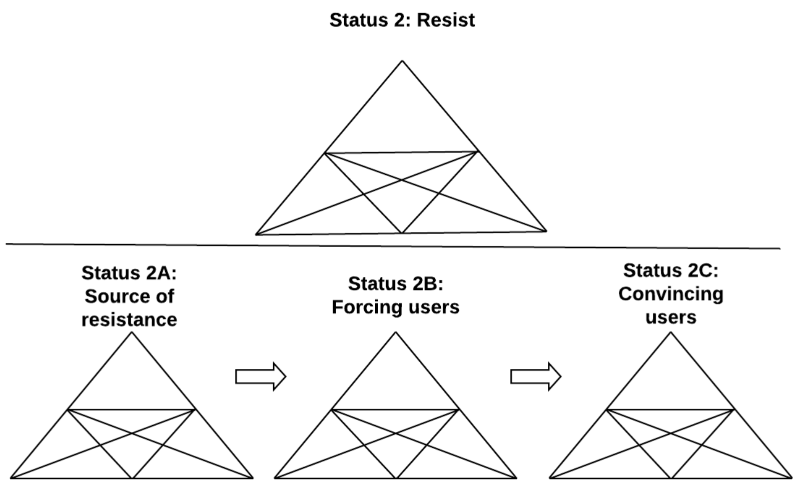

Figure 22: Sub-systems of status 2

Status 2A is a consequence of the unsatisfied subjects due to the contradictions between the subject and tools and subject and rules. This is specifically mentioned in the codebook section of ***Individual characteristics*** under the category ***unprepared user community***. Due to the existence of these problems, users started to reject the system and refused to use it. This indicates a second subject-tool secondary contradiction. Because the new tool, the information system, is essential to realize the changed object, another secondary contradiction occurred between the subjects and object.

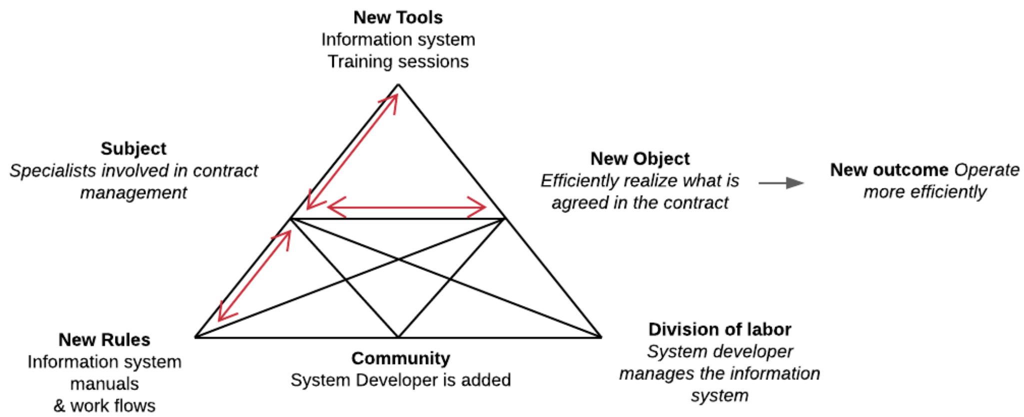

Figure 23: Sub-system 2A - Source of resistance

During the second stage, status 2B, the remaining contradictions of status 2A led to a few measures that needed to be taken. Due to the contradiction between the subject and object, the goal of the activity is compromised. Therefore, the project managers felt the necessity to intervene. This intervention consisted of a few measures. At this moment during the change process, the coping mechanism ***force*** was applied. ***Pressure*** was put on team members, and ***regulations*** were added to stimulate the use of the information system. This had the goal to solve the contradiction between the subjects and the object. Putting (peer) pressure on team members indicates the addition of an informal rule. This seemed to convince a few of the individuals that were rejecting the information system. Nevertheless, resistance remained with other team members. Next, this group was approached with an attempt to incentivize information system use by adding formal regulations in the form of contractual agreements. This action seemed to fail completely. Team members indicated that these additional regulations only increased resistance to the system.

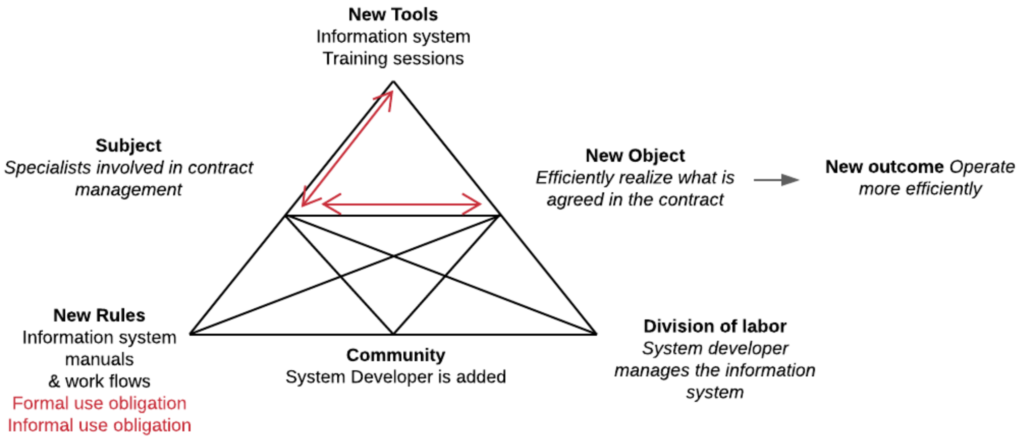

Figure 24: Sub-system 2B - Forcing users

Status 2C describes a change of the approach of project management. As a reaction to the new resistance and the tool-subject contradiction that remained to cause problems, ***deregulation*** took place. This turned back the newly introduced formal agreements. The final measure that was taken by management was to discuss the functionality of the system with the remaining opposing team members. This was described in the codebook with the section on coping mechanisms ***discuss.*** More specifically, by ***showing the value*** of the information system, the managers tried to solve the subject-tool contradiction. This appeared to work. A lot of project members were convinced using this approach. These actions resulted in a minimization of the individual resistance to the contract management information system. Therefore the respective contractions were mitigated as well.

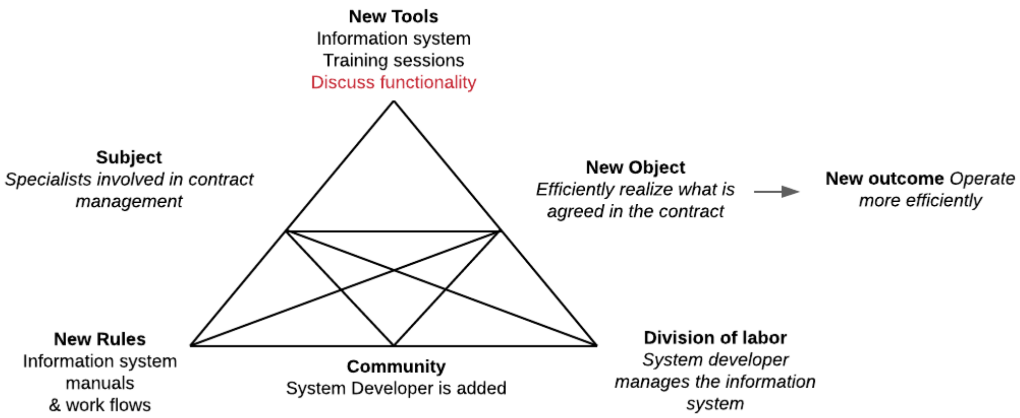

Figure 25: Sub-System 2C - Convincing users

6.4.3 Growing pains

When the individual objections to the system were taken removed, users started accepting the system. This introduces a new status of the system, status 3: accepting. This status was characterized by users that are willing to cooperate and use the information system, which brought a new group of problems to light. These problems led to the identification of deeper rooted problems, which were finally (partly) solved with new coping mechanisms.

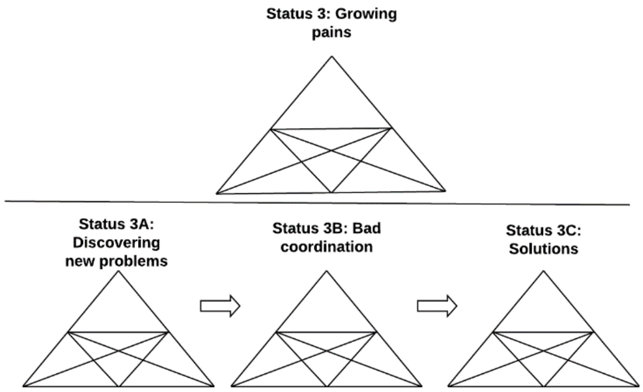

Figure 26: Sub-systems of status 3

The first sub-system, status 3A, starts with users that are starting to really use the information system in bigger numbers. Although subjects became willing to use the system, they still lacked all proper user knowledge. The subject-tool contradiction from status 1B still existed. As a consequence of this contradiction and more users, new problems and, therefore, contradictions appeared. Examples of these problems are ***unintended use, bad input,*** as described in the codebook. These problems decreased the effectiveness of the tools. Therefore it can be stated that the remaining subject-tool contradiction led to new tool-object contradictions.

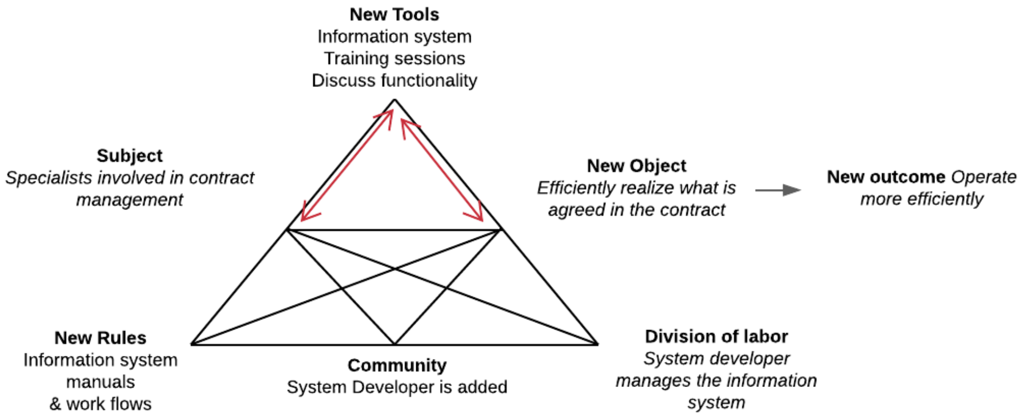

Figure 27: Sub-system 3A - Discovering new problems

In the next status, these remaining contradictions led to initiatives to solve the problems. Users of the system identified that problems were starting to arise. As a reaction, they tried to obtain knowledge on how to properly use the system. But they discovered responsibilities for the guidance of the system were not defined clearly. As a consequence, they did not know whom to approach for guidance. The knowledge required for properly using the information is located with the information system developer, who is separated from the rest of the organization. This is described in the codebook as ***specialized knowledge*** and can be categorized as a secondary contradiction between the subjects and the division of labor.

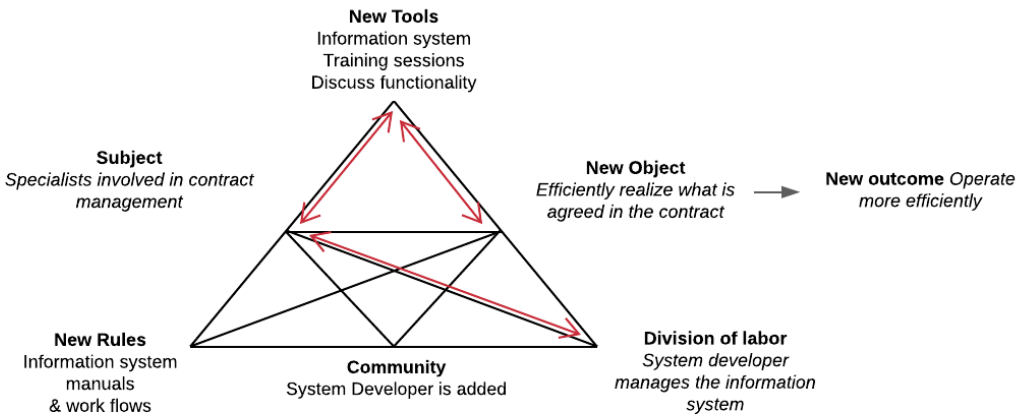

Figure 28: Sub-system 3B - Bad coordination

In status 3C, solutions were created for the previously identified contradictions. In order to bring the information system knowledge to the users, two changes were often made. First of all, the emphasis was put on the use of informal communication. This ***improvement of informal communication*** was intended to make the system developer more accessible for the users, as described in the codebook. This change can be described as the addition of an extra tool and informal rule. Secondly, the responsibility for the guidance of the information system was clearly allocated to the system developer. This is described in the codebook by a ***change of task allocation.*** In the activity system, this is shown by a change in the division of labor. These approaches seemed to help, but still, some of the problems remained, and not all users were satisfied with the support.

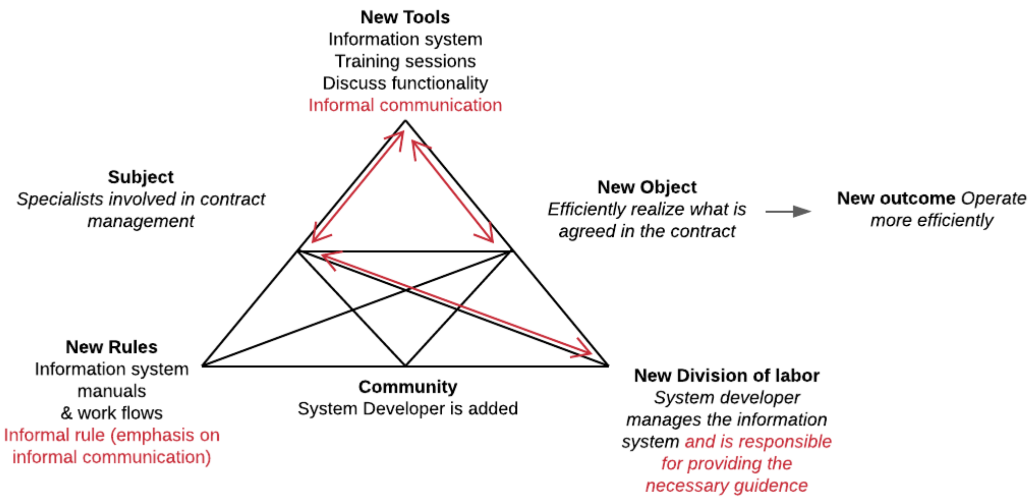

Figure 29: Sub-system 3C - Solutions

6.4.4 Final improvements

Finally, the last section of the timeline, status 4, will be discussed. This status is characterized by users that want to use the system, and coordination was improved. During this phase, users started to mention other problems that focused on the information system itself.

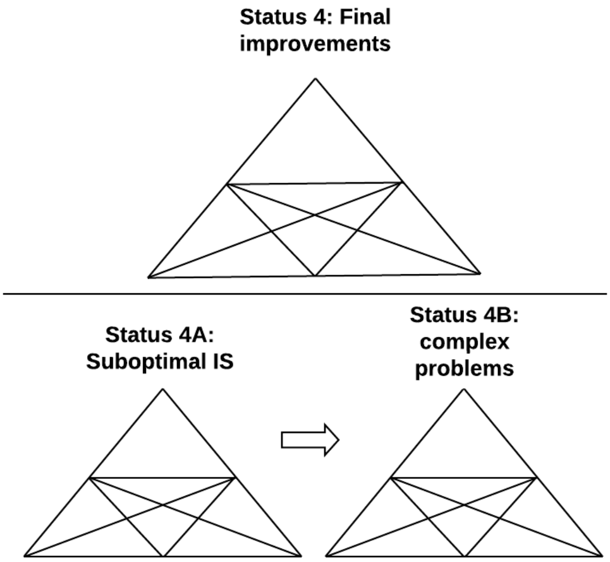

Figure 30: Sub-systems of status 4

During the first sub-system, problems with the information system were identified by users. Because system use was coordinated in a better way, they started to find new problems. These problems were mentioned in the codebook under ***Poor system design.*** This category was split into two main categories of problems, poor ***system interface*** and poor ***system architecture***. A decrease of the subject-tool contradiction, therefore, led to a new tool-object contradiction. In order to improve this situation, the system developer started to make changes to the information system itself. These types of actions were described in de codebook with the section ***alternative system structure.*** This action changes the information system itself. Hence, it can be shown as a change to the *tools* in the activity system. These changes were often able to solve problems related to a poor system interface. The problems related to the system structure appeared to be more complex and were often not successfully solved by the system developer. The next section describes why these problems are more complex.

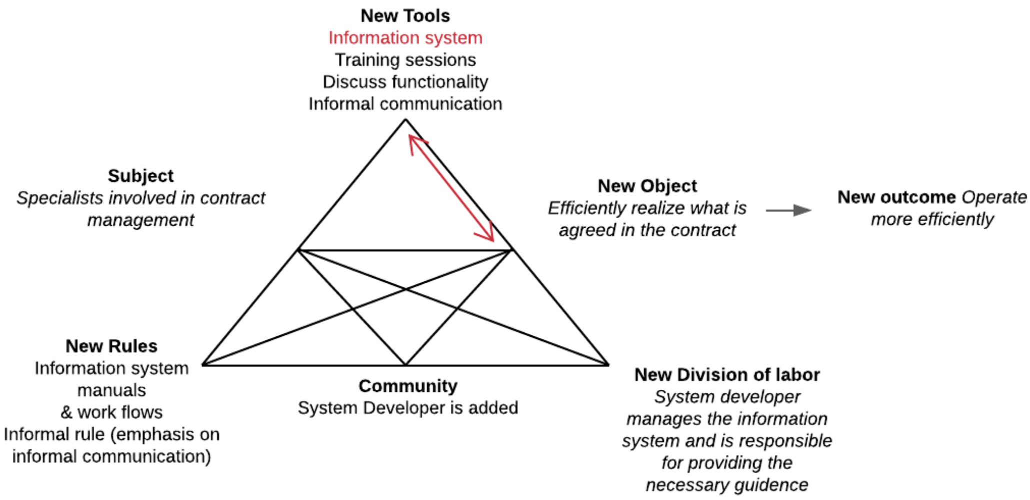

Figure 31: Sub-system 4A – Suboptimal information system

Sub-system 4B shows what happened when actions were taken to solve the remaining tool-object contradiction. While solving problems related to the system architecture, the system developer encountered that he did not have the right knowledge to properly make changes to the system. The system developer lacked knowledge of the contract management processes. This indicates that the ***specialized knowledge*** problem appeared once again as a secondary contradiction between the division of labor and tools. ***Changes in task allocation*** were introduced once again. The system developer was asked to gather input from the required specialists by himself. Nevertheless, these problems were never fully solved. The continued existence of this problem eventually led to project workers creating workarounds for the system as described by ***external informal processes*** in the codebook. These external processes can be viewed as the introduction of a new tool. The use of this new tool decreased the effectiveness of the information system. Hence, it introduced a new tool-object contradiction that was never solved.

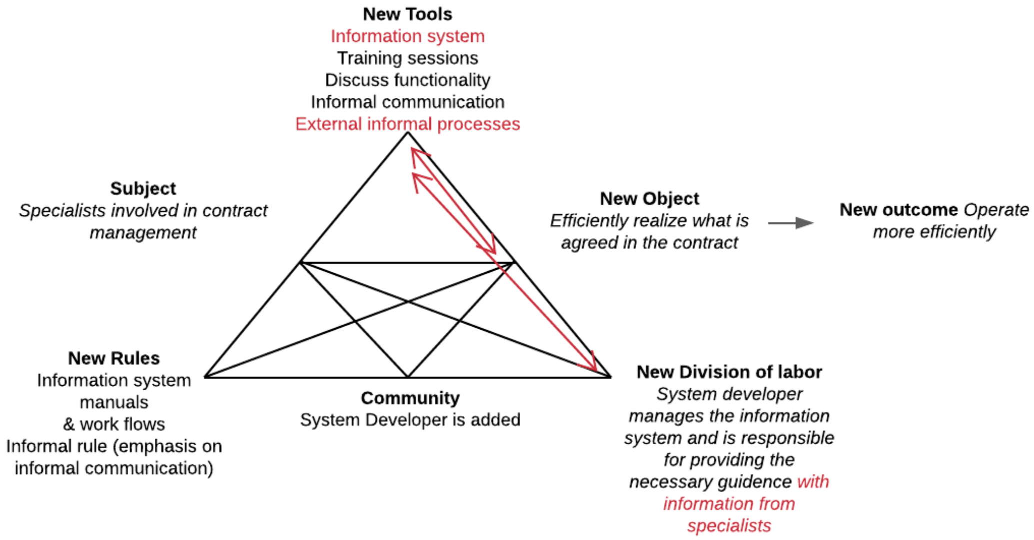

Figure 32: Sub-system 4B - Complex problems

6.5 Interpretation problems & boundary objects

As was shown in the codebook of the interview data, a lot of problems were based on different interpretations. These interpretation problems can be explained with the use of the theory on boundary objects, as discussed in Section 4.3 of this research. This section presents the boundary objects that were identified. In order to complete the analysis of these boundary objects, it also shows at what type of boundary the boundary objects are located.

6.5.1 Identified boundary objects and boundaries

During the previous analysis, interpretation problems were identified regularly in the codebook. These interpretative problems can clearly be related to the crossing of knowledge boundaries. Consequently, four main boundary objects were identified. These boundary objects and their characteristics will be discussed next.

First of all, risks were identified as a boundary object. Within a contract management information system, risks are written down in a risk management module. This module is accessible for many users. The example in table 13 shows multiple perspectives on risks. In this case, a risk manager can look at the risk register and realize that only a few of the initial risks are mitigated. A lot of important risks can still be ahead later in the project. But another project member, with a more technical approach to risk management, is likely to look at this and think that all risks are managed and that everything is going smoothly. These different interpretations can lead to conflicts when to project team needs to take decisions concerning risk management. The problem lies in the creation of different interpretations of the contents of the boundary object. The quote of the different interpretations of risks is a prime example of *an interpretive/semantic boundary.* Even if a common syntax or language is present, interpretations are often different, which makes communication and collaboration difficult. Translation of knowledge is the process that is described to cross this interpretive semantic boundary (section 4.3.3). A more detailed way of improving boundary objects will be discussed in the next section.

Boundary object	**Boundary**	**Example**
Risks contained in the information system	Interpretive/ semantic boundary	*"The part about risks also applies here. We have collected about 200 risks in the system, and they have all been mitigated. But we are still in the phase before the investment decision. Thus, the worst is yet to come. That is why this risk register gives a wrong impression of the risk management part of the project" (Interview 5).*

Table 13: Risks as a boundary object

Contractual requirements are a crucial part of contract management. To properly administrate and manage these requirements, they are also are written down as text and stored in the contract management information system. In table 14, an example of requirements as a boundary object is provided. An employer can create a risk with a specific reason and result in mind. On the other hand, a contractor can have a completely different interpretation from their point of view. These different interpretations can become very problematic during the realization of the project. Similar to risks, this boundary object creates different interpretations of the data. Therefore, it is also located at an *interpretive semantic boundary.*

Boundary object	**Boundary**	**Example**
Requirements contained in the information system	Interpretive/ semantic boundary	*"When you complete a tender, you also buy an interpretation of the contract. … Simply explained, when we prescribe a red door, we want a dark red door. The contractor interprets this as a Bordeaux-red door which he can procure cheaply." (Interview 7)*

Table 14: Requirements as a boundary object

Next to these specific data elements, the information system also contains other data elements that are written down. All these elements can also be considered to be a boundary object. Projects in Dutch practice often contain both English and Dutch-speaking project members. This creates a language barrier that is also experienced in the data contained in information systems. It is obvious that this language barrier can create problems during the use of the contract management information system. It is also clear that this boundary object is located at a syntactic language boundary. Theory has shown that these boundaries require a common syntax or language to be crossed. More on this common language will be discussed during chapter 7.

Boundary object	Boundary	Example
Other written data contained in the information system	Syntactic language boundary	*“there are many things in the system that I simply do not understand. They are Dutch or English words in a row, but what do they say, or what do they mean? You lack context to create a good understanding of what they say. This mainly relates to language barriers.” (Interview 5)*

Table 15: Other written data as a boundary object

Interestingly, the functionality of what tasks a contract management information system should perform can also become a discussion point when both perspectives in this example are discussed. These “new generations” see the system as an overarching tool in which problems can be solved through the use of processes. On the other hand, “the older generation” views the system as a tool where information is stored and that problems need to be solved in other ways. These opposing views are likely to create problems concerning the functionality of the information system later on. Just like risks and requirements, this boundary object is based at an *interpretive semantic boundary.*

Boundary object	Boundary	Example
Functionality of the information system	Interpretive/ semantic boundary	*“Sometimes the way of thought is, I just enter a change into the system, and that solves everything. This change needs to be solved in practice and not in the system. New generations grow up with these systems, and they have to be reminded that the system is just a tool.” (Interview 2)*

Table 16: System functionality as a boundary object

6.5.2 Handling of boundary objects

Although the examples seem to indicate that all boundary objects are handled in a similar way, this view appeared to be wrong. The boundary objects language use, system functionality, and risks were largely neglected. No further action was taken to address these problems. This created many (avoidable) interpretation errors, which could lead to long-lasting arguments. On the other hand, the codebook has shown that in the case of requirements, a very effective process was created. This specific process is discussed next.

The previous section of this chapter has shown that requirements are a perfect example of a boundary object. Many different specialists are involved with requirements, and all these specialists are likely to have another interpretation of what the requirement means for their practice. This was the basis for many conflicts concerning the interpretation of requirements. Nevertheless, contract management specialists have created a process to solve this problem. Contract managers asked the contractors to create a list of requirements that could become problematic in their eyes. They did the same thing from the perspective. Consequently, in a meeting, these interpretations were compared, discussed and a common interpretation was created. This was also mentioned in the codebook under the ***creation of common interpretations***. This approach appeared to be very successful in preventing conflicts based on different interpretations.

This small process is depicted in the figure below. It is also interesting that this little process is a perfect example of the translation process of knowledge, as discussed in section 4.3.3. Literature in chapter 4 has also proven that this translation process is crucial to cross an *interpretive semantic boundary*. This translation of knowledge has naturally occurred for the boundary object requirement. A similar approach to the other boundary objects located at an interpretive boundary is likely to be useful.

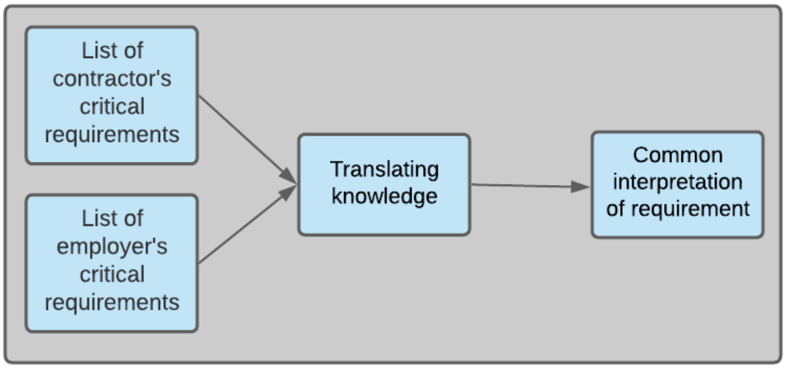

Figure 33: The translation process of requirements

6.6 Conclusions

This extensive analysis was aimed to provide an answer to the third sub-question of this research:

What new information concerning the implementation of information systems in contract management can be identified using an activity theory and boundary object lens?

This has led to some important observations. These observations are discussed next.

The analysis of the first status showed that the reason for the introduction could be found in the change to a new desired outcome, which focused on realizing more efficient operations. The new information system was introduced to reach this changed goal. The results indicate that support was lacking during the introduction, training was lacking, and rules were unclear during the implementation. These supporting structures were rarely improved.

The lacking coordination led to users that resisted the implementation of the system. This problem was initially handled poorly. Forcing users did not improve the situation and showed to be the wrong approach. Next, management turned back the rules and tried to convince users of the importance of the system to incentivize the use. This approach decreased the resistance significantly.

Next, because of the growth in the number of users, new problems were identified. These problems were causes of decreased effectiveness of the information system. The first initiatives from users to solve these problems failed in most cases. The responsibilities for coordination of the system were unclear, and users did not know where to ask their questions in search of solutions for their problems. Actions were undertaken to fix the allocation of responsibility and the accessibility of the right knowledge. But again, these problems were never successfully solved. Therefore, this section indicates the main problem of unclear responsibilities and incorrect accessibility of knowledge.

Finally, a new set of problems concerning the information system itself. These problems showed the need for changes to the information system. The first attempts to solve these problems seemed successful. But a specific type of problems kept appearing. Therefore, this approach was still insufficient. The separation of contract management and information system knowledge seemed to be responsible for the continued occurrence of problems, but this problem was never solved. Hence, this result showed that the wrong information systems were being used or built due to the separation of knowledge types. This also shows that information systems are regularly changed, which indicates that turnkey solutions are rarely beneficial. Therefore, the use of the turnkey systems identified in chapter 3 should be discouraged.

The main conclusions from this section are that the initial information system was not fit for the goal of creating efficiency, or the users were not able to use the system correctly due to individual characteristics, knowledge specialization, or lacking coordination of the system use. In activity theoretical terms, these points can be described as:

- Information systems (*tools)* that are used are not well enough aligned with the project goals or users.
  - The *tool object* and *subject tool* secondary contradictions that were identified indicate a tool that was not fit for purpose
- *Rules and tools* to support the system are lacking on many occasions.
  - Rules, manuals, and training are insufficient to support the subjects and community. Therefore unwanted practices like unintended use, bad input, and conflicts over opposing interpretations arise
  - Subject miss knowledge to understand and work with the system
- The *community* and *division of labor* are not well adjusted for the creation and support of an information system.
  - Creation is problematic due to the absence of contract management process knowledge at a system developer
  - Responsibility for the system generally rests at one specialist who knows to work the system.

Similarly, boundaries and boundary objects have been shown to play a big role in contract management information systems. Interpretation errors can be related to difficulty in crossing knowledge borders using boundary objects. Therefore, four boundary objects have been identified in the analysis. They can be summarized in two main categories. The first one is the functionality of the information system itself, and the second one is the data that is contained in the information system, such as requirements and risks. Next, the type of boundaries where these boundary objects were located was identified. These boundaries are created by different responsibilities and knowledge of members of the community. Consequently, to mitigate these problems, translation of knowledge and the creation of a common language will be key. A process of translating knowledge has already been created for requirements. Creating common interpretations decreased the number of interpretation problems. Thus, this approach might also be useful for other similar boundary objects.

Finally, some concluding remarks can be made on the analysis as a whole. During the full analysis of the implementation process**,** no structured approach was identified in current practice. Current approaches can be described as ad hoc and reactive. A system that is turnkey or custom made is generally provided by a separated specialist or group of specialists. The turnkey systems seem to be the least effective. Together with providing the system, these people are tasked with providing guidance on the use of the system. They have to perform these tasks without the correct knowledge and supporting organization. This consequently leads to an insufficient trial and error approach. Therefore, the current approach needs to be transformed to a more structured way of implementing information systems in contract management. It seems that providers/developers of the information systems should aim for delivering a service of more efficient information control instead of just a functioning system. Creating the right roles, getting the right knowledge with the right people, improving the supporting tools, and consequently creating and supporting a system that is aligned with its goals and users will be key in improving the current approach. The following chapter contains recommendations that elaborate further on how to improve this current approach.

7 - Recommendations

The previous section of this research has revealed which problems occur during the change process when contract management information systems are introduced. Consequently, these developments have been analyzed using activity theory and boundary objects. This has resulted in an objective overview of problems during the implementation process. This showed that, although all phases of the introduction were covered, not all problems or contradictions were solved, and not all coping mechanisms are good ways of coping. On top of that, the way of coping with problems was very ad hoc and not structured. The next step is to use these results to optimize the implementation process. This is done by first setting some general goals. These are discussed in the next section. Then, detailed recommendations are made on how these goals are to be realized. Finally, the last part of this chapter discusses the integration of the recommendations into a complete implementation roadmap.

7.1 General goals

An activity system functions best if it is stable. Therefore the goal of the recommendations is to reach this stable state as early as possible. The subject and object can be considered as fixed. The subjects will be the users of the information system, and the objects of information system supported contract management is still to efficiently realize what has been agreed in the contract. What also is known is the introduction of the new information system this activity system. Hence, other tools, the rules, the community, and the DOL need to be aligned for the use of this information system by the subject to reach the desired object.

Consequently, a few general conditions that are currently not met, should be realized as early as possible in future change processes:

- The tool needs to be fit to support the object
- The tool needs to be usable for the subjects
- The division of labor needs to accommodate responsibilities for the creation and support of information system
- The community needs to include the right roles to support developers in building the system and the subjects in using the system
- The subjects need to have the right tools and rules that support the use of the information system

From these conditions, it can be stated that the activity system of contract management supported by information systems needs two main things, the *right information system,* and the *right supporting infrastructure.* The conclusions in section 6.6 of the previous chapter showed that these aspects are currently not facilitated well enough. How these aspects are to be realized in the future is discussed next.

7.2 The right information system

This section is aimed at providing the right context to facilitate the building of a contract management information system. The first condition to be met in this respect is the building of an information system that fits in the activity system with the object efficiently realizing what has been agreed in the contract. As discussed above, this means that the information system should fit the goal of the activity and that it should be aligned with the subjects that are supposed to use it.

7.2.1 The development team

To create a tool that fits the object, it is necessary to bring the specialist knowledge of a system developer and the knowledge of contract management processes together. Section 6.4.3 and 6.4.4 showed that these problems have big results. In practice, they were solved by changing task allocations. But, problems remained, so this task allocation has to be changed more effectively. Hence, creating the ability to design a tool that fits the object is the process that is discussed next.

Combining this knowledge requires some changes to the current approach. It is possible to search for a specialist who is knowledgeable in all important areas of expertise. Nevertheless, these specialists are likely to be hard to find. For bigger projects with bigger information systems and contract management needs, a single person responsible for the system design would not suffice. Therefore this approach is not feasible. Another way to cross this knowledge barrier is by building the system with a development team of different specialists. In those cases, the creation of a team that carries responsibility for the system design together would pose a solution. This team can be viewed as an additional team to the IPM model. This system development team should consist of **specialists** in all fields involved in contract management (the IPM roles) and the **system developer**. The system developer does not have to be a single person, and this role can be scaled according to the size of the project. Combined with their shared responsibility for the system, this system development team should be able to create a fit for purpose system. Thus, the change in the division of labor and community seem to be able to align the tool with the object.

This proposed development team has to realize a complex system. Some coordination for this team could prove very helpful. Therefore a coordinating role is added to this team. The **system coordinator** bears responsibility for planning, monitoring progress, and coordination of activities included in building the information system. This role does not carry responsibility for the result. It is merely meant to support help coordinate the development team.

When the approach described above is applied, the division of labor, tools, and community facilitate the building of a tool that tool is aligned with the subjects and the object of the activity.

7.2.2 Development tools

To create this fit for purpose information system, some other important observations were made based on the analysis of the codebook. The following recommendations will also support the design of a fit for purpose tool.

The analysis shows that contract management processes can become very complex. Literally translating this complexity into the information system leads to workarounds for the system use, which rarely benefit its gains, as shown in the codebook section on external informal processes. Therefore, the processes in the system's architecture should be kept as simple as possible but should retain their intended functionality.

The use of a specification meeting can be a very useful tool to create the right system. The results of the analysis showed that turnkey information systems are not a good path to follow. Consequently, the use of custom-made systems is preferred. But, some basic information about the intended functionality is required to be able to build these custom-made systems. During a specification meeting, this necessary information can be gathered. This information relates to what contract management processes need to be included, which functionality is desired, or which type of specialist knowledge is involved in the respective processes. This meeting should take place as soon as possible after the decision to procure a contract management information system, and it should be attended by specialists of contract management processes, the end-users, and the system developers. The use of this tool ensures that the right information is available for the development team in the community to start creating the right information system.

The other condition to be met for an information system to become the right system for the activity is to align the tool with the subjects. In current practice, this is often not the case, as shown by the tool subject secondary contradictions in the results. The subjects all have different needs and specialisms, as is visible in the community. Therefore the information system needs to fit a lot of different needs. A possibility to do this is by the introduction of an extra tool. For example, a test run session of the system with representatives from the whole community. In this session, representatives can use the system to check whether it fits their needs or if improvements still need to be made. This feedback loop aims to ensure that the tool fits the needs of the community and that the right information system for the community is created.

When these additional rules are also followed, the resulting information system is more likely to be fit for purpose.

7.3 The right supporting infrastructure

The second condition to be met is to create the right supporting elements for the information system. Current practices are experiencing a lot of problems related to these supporting structures. The right knowledge was not spread to the right people due to lacking training, unclear responsibilities, and a general shortage of guidance, as shown with the contradictions identified in sections 6.4.2, 6.4.3, and 6.4.4. Providing proper support requires fitting rules, proper training, the right people in the community, and a corresponding distribution of responsibilities. These elements can be split into two categories: the supporting organizational elements, which explain necessary roles, and supporting tools that show which tools need to be used and how.

7.3.1 The support team

The first aspect of the supporting infrastructure to be discussed is the supporting organizational elements. This part covers the roles and responsibilities that need to be introduced and allocated to ensure optimal support of an information system. Currently, these roles and responsibilities are not defined clearly enough (section 6.4.3). Although measures like changing role allocations were taken, problems related to these responsibilities continued to exist. Therefore this section aims to provide the needed clarity for these roles and responsibilities. An information system support team is to be created containing the necessary roles and responsibilities in a clearly structured way. Similar to the development team, this team can also be seen as an addition to the IPM departments. This support team can be viewed as the evolution of the development team after they have finished their tasks. The teams do not exist at the same time. First, the existing role of the system developer will be briefly explained. Next, the introduction of three new roles will be discussed. These are the system ambassador, the system trainer, and the system coordinator.

System developer

The role of the system developer remains unchanged but necessary. Therefore this role is only briefly summarized. This person is responsible for the information system itself. The system developer is the person who eventually was the end-responsible for building the information system. Key knowledge for this role is IT system knowledge. This developer is expected to cooperate with specialists to construct the right information system. During the use phase, this developer is responsible for maintenance and changes to the system. At this time, he or she is expected to collaborate with the system ambassadors, trainers, and owners to make sure the physical system is up to date. As stated before, this role does not have to be a single person, and it should be scaled according to the needs of the project.

This role and its responsibility in the division of labor keeps the tool (the information system itself) aligned with the wishes of the community.

System ambassador

The biggest and most important measure to be taken is the introduction of the new role of system ambassador. Due to the segregation of specialized knowledge required for contract management supported by an information system, this new role is necessary. The results of the analysis showed that responsibility for providing help to the information system users was not allocated clearly. As a consequence, users did not know where to go with their questions.

The system ambassador is intended to be the spider in the web between the users and the system developers. Every team section involved in contract management (in this research, all the IPM teams) gets allocated a system ambassador. A system ambassador possesses the necessary knowledge to use the system combined with his or her own specialist knowledge from their project team. And, just as important, is a supporter of the use of the information system. The system ambassador should be a very clear and visible role. Team members can approach this person when they have questions about the functionality and use of the information system. The system ambassador should be able to answer these questions, and if not, they can be forwarded to the system developer. From this role, the system ambassador is able to propagate support for the system to other team members, which is key for effective use of the system (Barki et al., 2007). When this support is created, the resistance of individuals, as shown in section 6.4.2, will be decreased earlier and more efficiently. This system ambassador will have to bear a few responsibilities. The system ambassador will be responsible for monitoring system use. To be able to stay up to date on system use and to evaluate it properly, someone needs to monitor the use of the system by the project members. The system ambassador is the right person to do this due to his or her extensive knowledge of the system and position within the teams of users. Similarly, the rules and agreements for the use of the system need someone to enforce them. For the same reasons as the monitoring responsibility, this task will be placed at the system ambassador.

These elements ensure the system ambassador is up to date on the users and use of the information system in his respective department. This information from all departments is very useful to monitor the system use. It can be combined and analyzed to improve the performance of the system. More on this will be discussed under the evaluation meetings. Adding this role to the community with the necessary changes to the division of labor supports the distribution of supporting tools (in this case, user knowledge of the information system) in order to support the subject in the use of the tool.

System trainer

Another specialist role to be added to the system is the role of system trainer. Training is a very useful tool for the successful implementation of information systems (Sharma & Yetton, 2007). Currently, the training approach and the responsibility for providing the training was unclear. Hence, a system trainer should be responsible for transferring the necessary user knowledge to the subjects. This trainer should be able to and responsible for explaining the functionality of the system and, consequently, provide proper training and instruction for all types of users. More on what the training should look like will be discussed later in this section. This role can, for example, be shared with the system developer role. The system developer creates the initial system, but after the system has been set up, this role is tasked with maintenance and changes of the system. It is likely that during this implementation and use phase, the developer can also be deployed as a trainer. The necessary knowledge of the system and its modules functioning are present with the developer. Therefore, in some cases, these roles can be combined.

Similar to the system ambassador, including the system trainer in the community and division of labor, increases the effectiveness of the supporting tool that is training, to support the subjects in the use of the information system (tool).

System coordinator

General coordination of the change process appeared to be lacking (section 6.6). Next, to that, these newly introduced organizational elements need to be managed and coordinated by someone to ensure proper implementation and use of the information system (Melin & Axelsson, 2005). Therefore, the final role to be added is the role of the **system coordinator.** This role is similar to the system coordinator in the development team. The system coordinator is responsible for planning, monitoring progress, and coordination of activities concerning the support of the information system. This is just a coordinating role, and it does not include end responsibility for the functioning and use of the system. The aim of this new role is to make sure the new supporting tools and organization don't grow out of control and lose sight of the goal of the activity.

In activity theoretical terms, this addition to the community and division of labor should ensure the added supporting structures are coordinated and do not lose sight of the object of the activity, which is to create more efficient contract management.

7.3.2 Supporting tools

The second element of providing the right supporting infrastructure is the creation of the right supporting tools. The results have shown that the supporting tools were not applied very effectively in current practice. Consequently, the intended results were not realized. The use of training was generally limited to introductory training, and rules and manuals were often missing or hard to find. This led to contradictions that were still remaining in the final activity systems. Therefore this section has the goal to improve these supporting tools and consequently solve the remaining contractions. This will focus on the tools training, rules, common interpretations, and system meetings.

Two-stage training

The first supporting tool that is to be optimized is the training of users. Training has shown to be a very successful tool to support and improve information system use (Sharma & Yetton, 2007) based on scientific literature and previously discussed results. Yet, in current approaches, structured use of this tool is missing. This active way of transferring knowledge to users is meant to provide the required user knowledge to users. In current approaches, training is used as a supporting tool. Nevertheless, the benefits of this tool are not fully optimized. Interviewees indicated that training sessions are generally only provided at the beginning of the system use phase to provide users with basic user knowledge of the system. These are often the only training sessions. The following set of recommendations aim to optimize the use of training in support of the information system.

First of all the level of training needs to be set. As discussed during the validation sessions, it is not possible, nor necessary to provide users with full background knowledge of the working of information systems. Users want and need to know what the process in the system is aimed to realize, and not how this works in the system (Validation section 8.3). Therefore the level of knowledge transfer during the training sessions should be limited to the use of the information system and the process that is followed within the information system. This is also a great moment to show users examples of unintended use and to discuss why and how this can be prevented.

Secondly, the current training strategy can be improved. Training can be done in various ways, from group sessions to individual sessions, from interactive to passive. A combination of these approaches will be the fit for purpose approach. The first step of the training strategy should be to provide a general training session for all intended users. During these sessions, all users should be given the basic knowledge that is necessary to work with the system. The following step should be providing more detailed training sessions. These sessions should be aimed at providing individuals or small groups from the same teams with detailed knowledge of their role in the process within the system. These sessions should be interactive to make the users more familiar and comfortable with the use of the system. Finally, this two-stage approach should also be followed when new people join the project team.

With this training approach, the tool that supports the information system is aligned with the needs of the subjects.

Clear and targeted manuals and rules

Next to training as an active way of supporting knowledge transfer, a more passive way of this knowledge transfer is also provided. The following tool concerns the use of clear rules and manuals to support the use of the information system. Procedural agreements (rules) and manuals, or rather the lack thereof, posed to be a problem for users of the information system section. The results showed that these rules, procedural agreements, and manuals were not set up clearly enough, untraceable, or even not created at all (6.4.1). Nevertheless, optimizing and making these rules visible should improve the implementation of information systems in contract management (Lee & Yu, 2012).

This could consequently be done with the following approach. First of all, when system use is intended to begin, these rules need to be agreed upon. This can, for example, be done during a system start-up meeting, which will be discussed later on in this chapter. When these rules are discussed, it is important they fit the context of the project. Frequently, rules are copied and therefore no longer fit the context of the project. Therefore, the rules need to be either created as new rules or, in case they are copied, adapted to the new context. Similarly, the number of rules should be kept at a minimum to prevent over-regulating and the corresponding problems such as individual resistance (section 6.4.2). Next, when these rules are agreed upon, they need to be written down and located where all users have access to them. A manual containing the rules placed within the settings section of an information system can pose a solution for this problem. Another thing to keep in mind is that the context of the project, and therefore the required guiding rules, can change. Hence, keeping these rules up to date is a necessary activity that can be conducted during evaluation meetings. These meetings will also be discussed later on in this chapter. To create optimal results of these rules, someone needs to be responsible for their enforcement. As discussed before, this responsibility is to be placed with the system ambassador due to his or her position in the team and their system knowledge.

When these rules and manuals to contain them are created and updated regularly, they create rules that are aligned with the subject and tool of information system supported contract management.

Securing of common interpretations

The crossing of knowledge boundaries and corresponding conflicting interpretations also appeared to be problematic according to the results (section 6.5.1). Further analysis indicated that this problem was related to the incorrect handling of boundary objects. Two boundary types (semantic and syntactic) and four boundary objects were identified. The results also showed that the only boundary object that was handled correctly were the requirements. The other boundary objects, risks, information system functionality, and system data were largely neglected, leading to many problems.

Because of these problems, the crossing of boundaries should be improved in order to unlock more benefits of information systems. This is realized by transferring knowledge when *syntactic or language* boundary is encountered. This is done by creating and using a common language or syntax. Similarly, translation of knowledge is the process that is needed in case a se*mantic interpretive* boundary is encountered. Translation of knowledge is facilitated by using models or a process (Carlile, 2004) such as the one that is currently used to mitigate problematic interpretations concerning requirements (section 6.5.2). Implementing these approaches should decrease problems with conflicting interpretations in the use of contract management information systems.

The start-up meeting is the perfect moment to discuss these interpretations of the boundary objects. During these meetings, the system aspects such as functionality, the requirements module, and the risk module should be discussed, and the main language can be specified. When attention is paid to the boundary objects, possible interpretation problems can be identified early on. When these possible interpretation problems are identified, a follow-up meeting is to be planned to discuss these interpretations of the elements. This meeting should be supported by a process similar to the one that has been used with the requirement interpretation approach. A generalized form of this process, which is applicable to all boundary objects at a *semantic interpretive* boundary, is shown below. When this approach is followed, the handling of boundary objects involved in contract management information systems is optimized, and problems should be decreased.

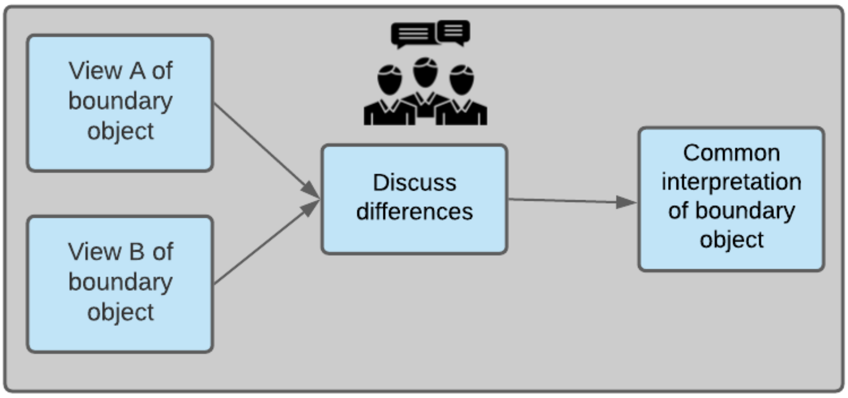

Figure 34: The general process for the translation of knowledge

System meetings

The final supporting tool to be discussed is the use of specific meetings that are necessary to facilitate the support of the contract management information system. To create a proper information system and to use it in a proper way, some decisions need to be taken, and some information needs to be gathered and analyzed. The following meeting types are an example of how to create the governance model to facilitate the change process.

The first type of meeting that is necessary is the *system start-up meeting*. When the system is ready to be used, it is important to discuss some aspects. Examples of this are showing the functionality of the system, which rules will be necessary, or the training schedule. In the same way, a start can be made with the identification of interpretation issues like discussed above. These meetings should be attended by the system ambassadors, the system developer, and the system coordinator. The system ambassadors represent their section of specialist users, and together with the system developer and owner, they can decide on how the rules, training, and interpretation sessions should look like to start the use of the information system.

The last type of meeting to be discussed is *the evaluation meeting*. These meetings are intended to evaluate the state of use of the information system. The use of the information system is not stable in any way. Therefore, some kind of reoccurring evaluation moment is necessary. By cyclically checking the status of the support base, the rules and manuals that are used, and the progress of the training, the use of the system can be monitored. When problems are identified with the use of the system, this meeting is also a good moment to decide if the system itself needs changes or added functionality. The initially created system is rarely the optimal iteration of the information system. The needs of users and the project change during the duration of a project. Therefore, instead of using lots of effort to change the users, changes to the system can present a great solution to improve the performance of the system. These changes need to be facilitated. Discussion on the necessity of these changes can take place during the evaluation meetings that will be discussed in section 7.4.2.

Like the start-up meeting, this evaluation meeting should be attended by the system ambassadors, system developer, and owner. A fitting moment for these meetings would be in the middle of a phase of a construction project to evaluate to current system performance and a few months in advance of the start of a new phase to evaluate the future performance.

These meetings create the ability to adjust the guidance when it seems necessary. Therefore the addition of these tools supports the creation and support of the information system while being aligned with the rules, community, and division of labor of the activity system.

7.4 Tool-support implementation roadmap

The previously discussed list of recommendations contains the measures that need to be taken to unlock the potential of information systems in contract management. They form the basis for information system supported contract management within construction projects. But, on the other hand, they might lack some integration and seem complex to carry out in practice. In order to make these recommendations usable in real-world practice, this part of the report has been composed. This section aims to provide a less complex and integrated summary of how the measures are intended to be used. This is done by transforming the recommendations into the practical and applicable tool-support implementation (TSI) roadmap.

The roadmap is split up into two phases. First of all, the building of the system is discussed. In this section, the conditions and steps for building a proper contract management information system are explained. The second phase to discuss is the support phase. During this phase, all conditions for proper support of the contract management information system are discussed.

7.4.1 Creating a fit for purpose information system

The first section of the roadmap is focused on building the correct physical information system. It is presented in figure 35 below. As discovered in the results, it is key to make sure the right knowledge is available with the people responsible for building the information system. The five steps that need to be undertaken to realize this are discussed next.

The first step is to assemble the right types of knowledge in the development team that will build the information system. Due to the nature of contract management, many different specialisms are involved in the use of a contract management information system. Consequently, all these specialists have different needs and requirements for the system. To include all these needs correctly, a specialist from every project department (the IPM teams in this context) needs to be included in the development team. These specialists provide the system developer with background knowledge from their specialty in order to create the right processes in the information system. Together with the system developer, they work as a team to build a correct information system. Because input from all specialists is important, they should all bear responsibility for the resulting information system. Finally, a system coordinator is added to the development team. This role is strictly a coordinating and supporting one, and it does not include responsibility for the resulting system.

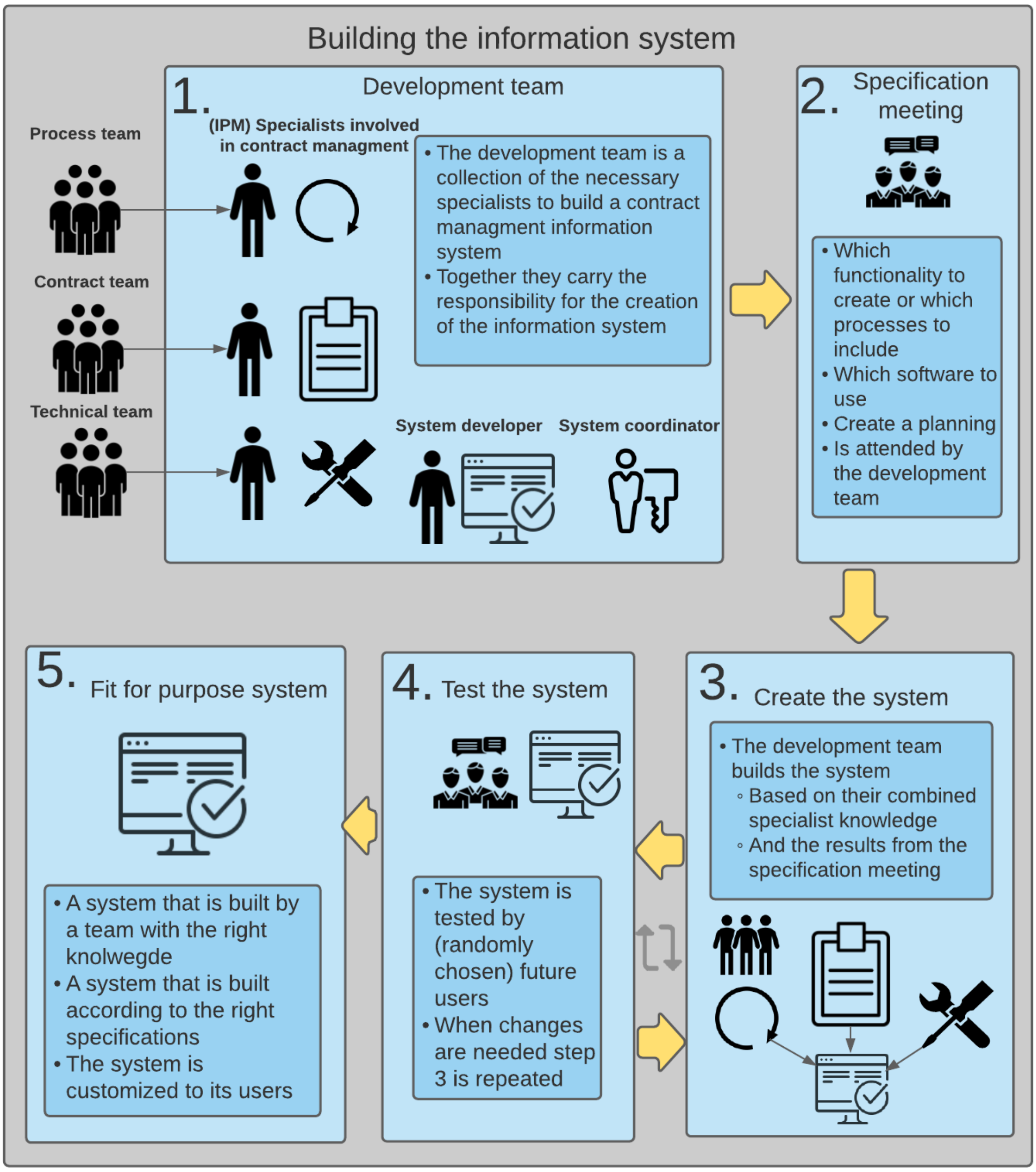

Figure 35: TSI roadmap part 1 - Building the information system

The next step is having a specification meeting. During this meeting, some additional and necessary information is created as discussed in section 7.2.2. This meeting results in a set of information system specifications. These specifications are the basis for the information system that is to be built. The specification contains some crucial pieces of information, such as which software package is to be used, which functionality needs to be created (which processes are included in the system), or a build planning can be created.

The third step is to continue and build the physical information system. The bulk of the work is done by the system developer role, but when he or she is in need of support, the other specialists in the development team can be approached for help. Consequently, the system is built on combined specialist knowledge according to proper specifications.

After the system has been built, it needs to be tested. This testing is done during the fourth step. Testing is done by the intended user community. These community members can be the specialists included in the team. But to remain unbiased, these users are a random sample from the specialist departments in the community. When the test is concluded positively, a fit for purpose system is delivered in the next step. When the tests indicate a need for adjustments, the process goes back to the third step, after which the testing should be repeated. This feedback loop ensures the system fits its user community.

When this roadmap is followed, the right information system can be built. The resulting system is a fit for purpose contract management information system. This system has been built by a team that possesses the required knowledge, and it has been built according to a specification that was set up by specialists. The system has been tested and consequently tailored to fit its intended users.

7.4.2 Supporting the information system

After the contract management information system has been built, the support phase can begin. This is discussed in the second part of the roadmap, as presented in figure 36. This part of the roadmap contains the necessary steps to support the information system in the best possible way.

The support phase starts with the creation of a few necessary roles that are combined in the (information system) support team. These are, respectively, the system ambassadors, the system developer, the system coordinator, and the system trainer. The system ambassador is a supporter of the information system and the point of contact for other users in his or her project department. They have the right user-specific system knowledge, combined with knowledge from their own specialist field. In this way, they can easily support other users in their department and also increase support for the system. They bear responsibility for the users and their behavior within and around the system. The next role to be introduced is the system developer. This IT system specialist is responsible for maintenance and changes to the physical system during this supporting phase. The second to last role is the system coordinator. This person is responsible for the coordination of the supporting mechanisms and people. The final role to be introduced is the one of system trainer. The system trainer is responsible for the training sessions that support the users of the system. This trainer should be familiar with the whole system and its functionality.

The next step, after these roles have been assigned, is to have a system start-up meeting. These meetings should be attended by the team members that were assigned to the previously created roles. During this meeting, some important information has to be distributed, and some important decisions regarding the support have to be taken. The dominant language can be selected, rules that are going to be used end enforced need to be created, and the training approach needs to be discussed. At the same time, the functionality of the system can be presented to the newly introduced roles. Similarly, the training strategy can be determined. And finally, in the presence of the system ambassadors, and while the functionality and content of the system have been discussed, possible interpretation issues can be identified early on in the process.

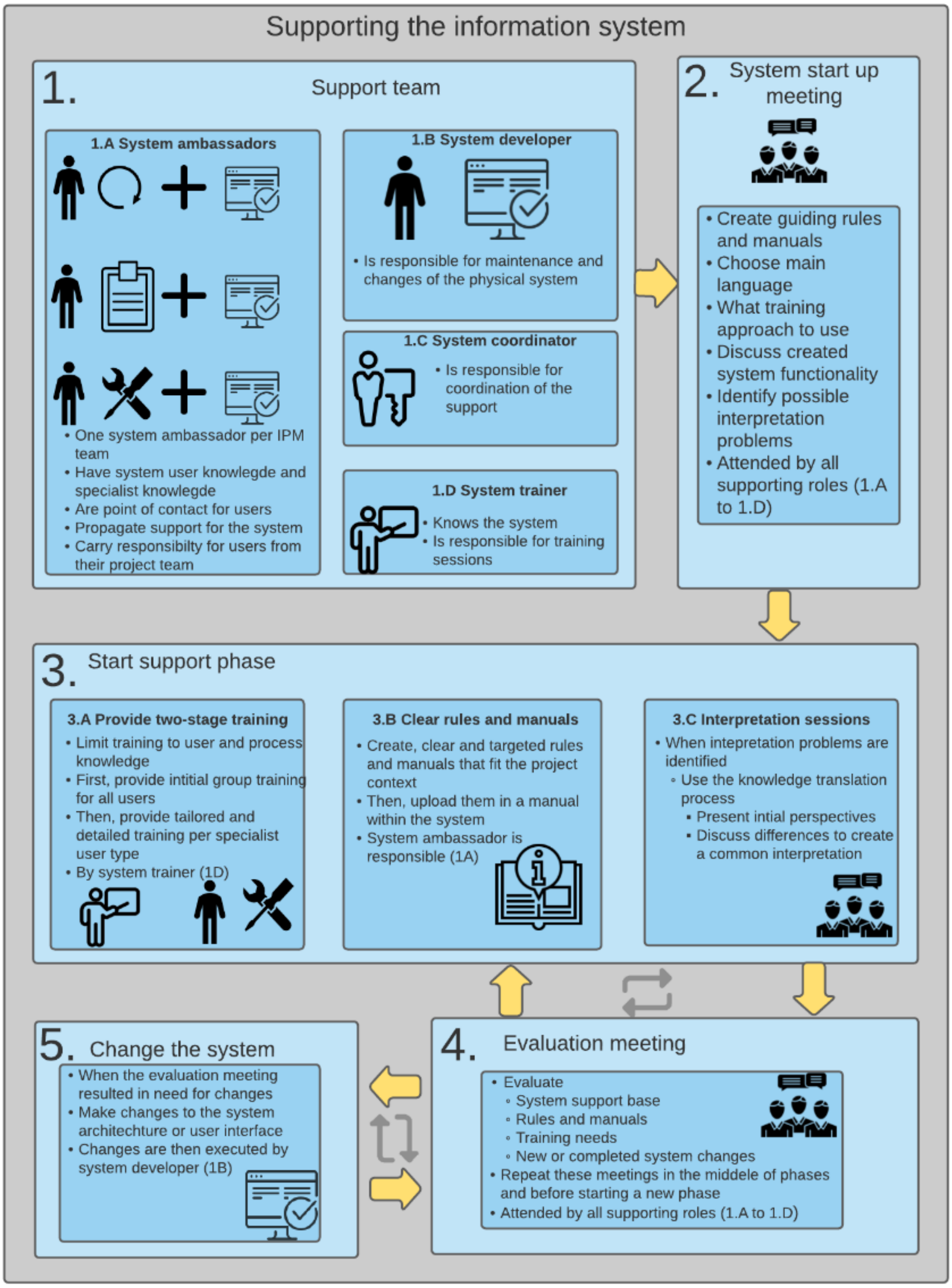

Figure 36: TSI roadmap part 2 - Supporting the information system

After this meeting, the support can phase can begin during step three. In this step, three clear actions have to be undertaken to ensure proper support. The first of these is providing the necessary training sessions. The two-stage training approach can be implemented here. First, the community should be trained in the basics of information system use. Next, after this basic information is provided, more detailed sessions should be provided. During these sessions, more detailed user knowledge is provided to the users tailored to their intended role within the information system. Another supporting mechanism is the prevention of interpretation problems in interpretation sessions. When possible interpretation problems have been identified during the system start-up meeting, they can be mitigated during the interpretation sessions. During these sessions, different interpretations concerning boundary objects are presented. Consequently, an effort is undertaken to translate knowledge by creating a common interpretation. This should prevent interpretation problems from arising due to neglected boundary objects. Apart from these forms of active support, some passive support is also provided. The rules and manuals that were based on decisions from the start-up meeting are created. After they have been created, they have to be located in a clear and findable place in the information system. This way, users can easily find the information they need to use the information system.

The second to last step in the support phase is to have evaluation meetings. These meetings are crucial to keep the support tools and the information system up to date. During these meetings, the support under users is discussed, the rules and manuals are evaluated, and the possible need for changes to the system are checked. This meeting is attended by all the new roles that have been introduced to make sure decisions can be made using the right expertise. When changes to the training, rules, and manuals, or the system are deemed necessary, they can be fed back to improve the supporting structures. Therefore, this evaluation meeting should be had at multiple moments during the support phase of the information system. Preferably, these moments are in the middle of a phase and in preparation for the starting of a new phase in the construction process.

Finally, the evaluation meetings can result in a need for a change of the information system itself. If it is decided during the evaluation meeting that one of these changes is necessary, the next step needs to be undertaken. In this step, changes to the physical system are made. Consequently, these changes need to be checked in the next evaluation meeting to ensure they have indeed solved the problem they were intended for.

7.5 Conclusions

This chapter focused on providing solutions for the problems that were identified during the analysis. The resulting recommendations and roadmap were based on activity theory and the use of boundary objects. The first section provided answers to the fourth sub-question:

How can activity theory and boundary objects help to solve the identified problems in contract management?

In order to answer this question, the first section of this chapter presents some conditions that needed to be realized to improve the implementation of contract management information systems. The search for a stable activity system derived from activity theory was the background of the creation of these conditions. Next, to realize these conditions in accordance with activity theory, the following requirements were compiled.

Firstly, steps need to be undertaken to support the ability to create the right *tool*. To build the right information system, the right development team is necessary. This team needs to consist of the right specialists with the right knowledge. By sharing responsibility over multiple specialists under the guidance of a system coordinator, the information systems can be created. Including feedback from users, keeping the system as simple as possible, and using proper specifications make sure the information system is fit for purpose and aligned with the *subjects* and the *object.*

The second set of recommendations cover the realization of the requirements for the correct supporting infrastructure of the *tool*. This consists of the introduction of a few new roles and supporting tools to align the supporting structures with the *tool* and the *subjects*. This supporting infrastructure requires the introduction of system ambassadors, a system developer, a system coordinator and trainer in the *community,* and *division of labor*. The necessary *tools* to support the system are two-stage training, system meetings, clear and targeted manuals and rules, and finally, the securing of common interpretations.

The second part of this chapter, the presentation of the tool-support implementation roadmap, was the result of answering the final sub-question:

What would these recommendations look like when they are combined into an integrated implementation strategy?

The recommendations from the first section aimed to mitigate the problems identified in the results. The tool-support implementation (TSI) roadmap was created in order to bridge the gap between this research to real-world practice. This roadmap consisted of two series of steps that are to be undertaken to create and support a contract management information system.

The first step is designed to provide the required to build the correct information system. The five steps of this part covered respectively, the creation of the development team responsible for building the information system, the meeting necessary to specify the system, the building of the system, the testing of the system, and finally, the presentation of the finalized contract management information system.

The second part of the tool-support implementation roadmap covered the creation of the supporting mechanisms for the information system. This roadmap explains the following steps: the creation of the necessary supporting roles, the system start-up meeting, the mechanisms that provide support, and the feedback loop of these support mechanisms with the evaluation meeting.

These recommendations and the TSI roadmap were improved with validation feedback from contract management experts. This validation cycle and its results are discussed in the next chapter.

8 - Validation

The recommendations from the previous chapter have been developed using a combination of scientific literature, theories, and empirical data from the contract management practice. By analyzing the empirical data with the scientific theories, the foundations of the recommendations were laid. Consequently, the results led to the recommendations to improve the implementation of information systems in contract management, as they were presented in the previous section. However, the value of these recommendations can be increased by including a validation cycle. This is done by presenting and discussing the recommendations with a selection of contract management experts and including the results in a feedback loop to the recommendations.

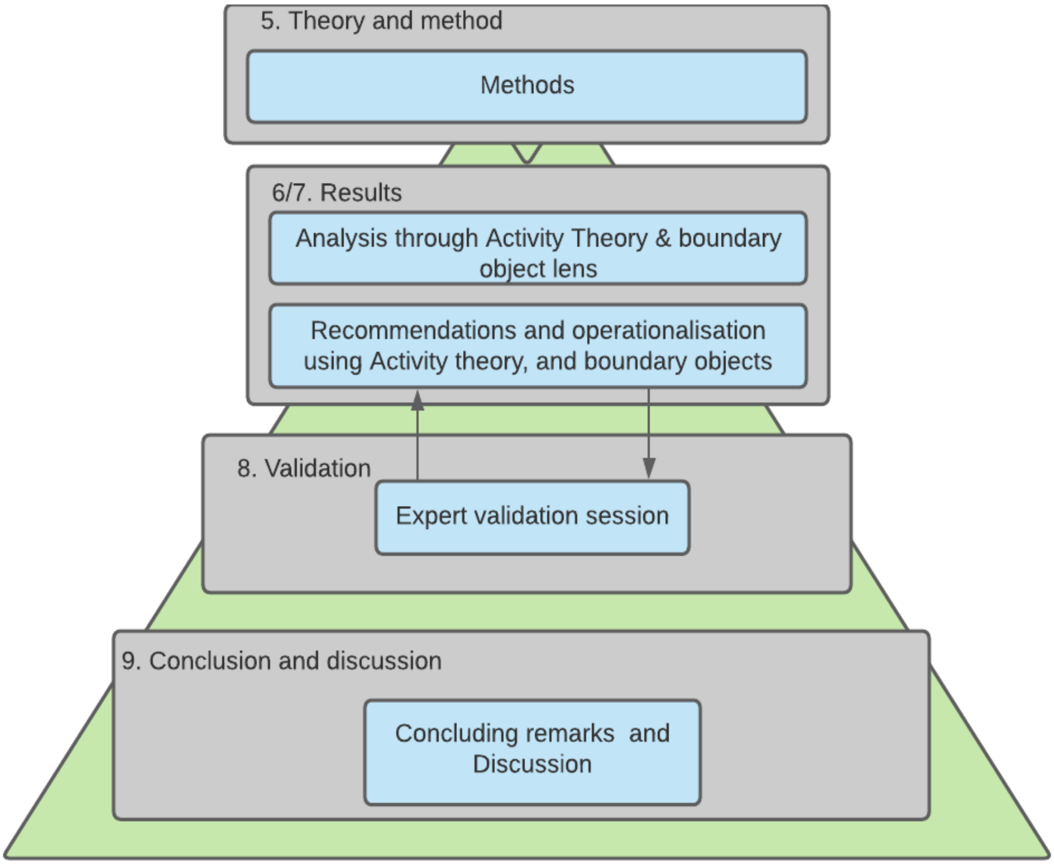

Figure 37: Positioning of validation in this research

The expert validation has been conducted with the following goals in mind:

- First of all, the validation aims to ensure if the recommendations were complete.
    - Do you have any additions to the measures?
- The second objective is to analyze if the recommendations, in fact, do improve the implementation of information systems in contract management.
    - Will the recommendations have the intended results?
- And the third and final goal is to check if the recommendations are feasible and realistic in the context of real-world practice.
    - Are the recommendations feasible in real-projects?

Next, the method that was used is discussed, the results are presented according to the goals to completeness, effectiveness, and feasibility, and finally, some conclusions from the validation are presented.

8.1 Method

Next to these objectives, it is also important to discuss the process of the validation sessions. The validation meetings were conducted individually to make sure groupthink does not influence the results and to give all experts complete freedom to share their opinions. The experts were selected from the group that was previously interviewed. From this original group, a selection was made of 5 experts that provided the most detailed information during the first interviews. After this selection was made, an appointment was scheduled with these specialists.

- During the validation sessions, firstly, the findings and recommendations of the main analyses were presented and discussed (slides are included in appendix D-1)
- The second part of a session was focused on discussing the recommendations by asking questions on the performance of the recommendations in regard to the objective
- The final part of a validation session was a discussion of possible improvements to the recommendations

8.2 Results

This section will discuss the results of the previously explained validation sessions. Therefore, the aspects completeness, effectiveness, and feasibility of the recommendations will be discussed one aspect at a time. A summary of the validation meetings can be found in Appendix D-2.

8.2.1 Completeness

The first aspect to be analyzed during the validation meetings was the completeness of the recommendations.

The first comment that was made on completeness related to the enforcing of rules. When rules are created, someone needs to monitor if they are followed (Validation 1). Therefore, this remark indicates the need for the *responsibility of enforcing rules*. This person should be responsible for a part of the system and its users. One of the experts stated that the use of SharePoint was very regulated in one of his projects, but this was not noticeable in the use of the system. Every folder or thing deviated from the rules, and people are just doing something. Some identical files were found in three different locations or folders (Validation 1). This remark of the necessity for enforcement was later elaborated with the discussion of a system ambassador (validation 2).

The introduction of a key-user such as a *system ambassador* would support the implementation of the systems in a good way. These system ambassadors are supporters of the system. They can serve as a point of contact for other users. When other users have questions, they can approach this person. This role should be very accessible (Validation 4). These key users feel part-owner of the system, which makes it easier to spread responsibility and support for the system. In another project, this role proved very effective (Validation 2).

Another remark was made concerning the updating of rules, training, and support. Using a short cyclical evaluation approach with an *evaluation meeting* was proposed to integrate this evaluation element in the implementation strategy. During this meeting, the performance of the information system can be evaluated. This meeting can also be a moment to proactively identify problems with the use of the system and to decide if *system changes* are necessary (Validation 1). If a situation is identified where more than two people indicate a new wish or requirement for the system, there is no shame in being reactive to this new need. It is incredibly hard to predict what users need in the future. Therefore being proactive is not always possible (Validation 4). At the same time, these meetings can be used to look forward to future needs concerning the information system (Validation 3). In order to stay up to date, it is necessary to repeat this process in some kind of short cyclical fashion.

The new approach to use *tailored training* was received positively. One of the experts stated that a general session for all users was also applied in one of his previous projects (Validation 2). A classroom session with a large group of users was held to get all users to a basic system knowledge level. This approach can be supplemented with a tailored, more specific training for users after this general session. Similarly, two of the experts noted that the required training type also changes during a project (Validation 3,4). Therefore the contents of the training sessions need to be updated.

8.2.2 Effectiveness

Next, the effectiveness of the recommendations was discussed. Discussing effectiveness was aimed at finding out if the recommendations would have the intended results. Some important remarks were made during the validation sessions concerning this effectiveness.

First of all, the recommendation to make the backend of the information system accessible for users was discussed. This measure is likely to be effective, but it remains to be seen if it is really necessary. The knowledge users require to properly use the system is not the same knowledge required to build a system. Therefore these two types of knowledge should be seen differently. In the case of user knowledge, understanding the background should be limited to the processes that the system follows. No technical IT knowledge is necessary for users (Validation 2). One of the experts mentioned that users generally want to be facilitated with the system. They want to use it because it is intended to make their lives easier. *They do not care about the technical details* (Validation 3).

The proposed approach to rules of the information system was received well. Creating them properly, making sure they have a fixed and known location would improve current implementation practices. Nevertheless, to stay effective, they need to be used carefully and kept to a minimum. As stated by one of the experts, people become disappointed due to an increase in rules they have to follow (Validation 2). Especially the Dutch hate doing something because they have to. They want to know why they have to do something (Validation 3). *The energy put into these rules should be in balance with the benefits of these use rules*.

The effectiveness of the evaluation meetings was also discussed. Because *the frequency of these meetings* was regarded to be very important for their effectiveness. To optimize the effectiveness of the proposed cyclical evaluation meetings, they should not occur too often, but also often enough to still have the desired effect. Timing is key, and these evaluation sessions should not be regarded as a burden on the project team (Validation 3). Therefore the expert proposed meetings at the middle of project phases and in advance of a phase transition. In this way, evaluation can be done most effectively (Validation 4).

The creation of common interpretation is limited due to the nature of the construction sector. Construction projects are characterized by a beginning and an end. Employers and contractors, and their respective teams only work together for the duration of a project. This relation has a fixed ending. It is important to keep this in mind while searching for common interpretations (validation 2). Creating these common interpretations can prevent a lot of problems. Nevertheless, this activity of searching for common interpretations can outgrow its benefits when it takes too long. Therefore the search for a common interpretation should not go on too long. Another aspect of the creation of common interpretations that was discussed is the link with the objectives of different users. Different users can have different objectives during the project, but efficiency is very likely a common object (Validation 3).

8.2.3 Feasibility

The final objective of the sessions was to check the feasibility of the recommendations. The recommendations are based on the interviews and theoretical research. Therefore they are not necessarily feasible in real-world projects. According to the experts, the majority of the recommendations were considered to be feasible. Nevertheless, a few comments were made.

Concerning the crossing of the knowledge barrier between system specialists and other contract management specialists, they concluded the following. The creation of *a single person that has both types of knowledge is very unlikely*. A single developer is not considered to be a problem as long as he is supported by others who have the right contract knowledge (Validation 2). The knowledge he needs can be more easily obtained from others than to find a person who is knowledgeable in both areas of expertise.

Evaluation meetings were intended to take place in attendance of all users. This was regarded to be unfeasible due to practical considerations*. Getting a group of that size together in a coordinated fashion is very unlikely or inefficient*. Therefore, a smaller delegation was proposed to attend the evaluation meetings. This could, for example, be a combination of system ambassadors with the system developer.

8.3 Conclusions

The following conclusions can be drawn from the validation sessions.

First of all, a cyclical approach to the evaluation of support of the system and system use seems to be a useful addition to the implementation strategy. Cyclical evaluation meetings can be used as key moments to decide on the support strategy of the information system. During this meeting, the use of the system, the need for system changes, the rules, and the training approach can be evaluated and adjusted if necessary.

Secondly, a key conclusion of this validations is to introduce the role of system ambassador. The introduction of the information system requires a lot of new responsibilities to be assigned. Examples of these responsibilities are enforcing the system rules, monitoring the use and users of the system, and guarding the inputs by the users. The system ambassador can take on a lot of these responsibilities in this role.

Thirdly, the knowledge users need to receive concerning the system should be limited to user and process-related knowledge. A division needs to be made between user knowledge and system developer IT knowledge. The backend knowledge of the system should stay with the developers, and there is no need to train the users at this level. This would just be a waste of resources.

Finally, some kind of layered or staged training seems to fit the implantation process best. A general session followed by a more detailed instruction is a good way of approaching the training of users for the information system. Similarly, when system functionality changes, training needs to be updated as well.

Due to the feedback loop to the recommendations, the proposed adaptations from this chapter have already been included in the recommendations as discussed in the previous chapter. The next chapter will present the final conclusions of this research.

9 - Conclusions and Discussion

This final section of this research aims to provide answers to the questions that were posed at the beginning of the interview. These questions have been answered by a thorough analysis using scientific literature and concepts. The analysis was based on data created from interviews with contract management specialists. Subsequently, recommendations and a roadmap were produced to improve current practices.

9.1 Conclusions

One of the cornerstones of construction project delivery is contract management. It can be directly related to business and project performance (Muhammad et al., 2019). Nevertheless, contracts and contract management have proven to be a complex and risky undertaking. It has been proven to be one of the main causes of conflict in the construction sector (Jaffar et al., 2011). To mitigate these problems, information systems have been implemented in contract management. Nevertheless, these systems are not fully delivering on their promises, and the implementation process is in need of optimization. Evidence that overall costs were reduced or an improvement in project performance is very limited (Zhai et al., 2009). Contemporary information systems have often failed to realize these goals (Mutschler et al., 2008).

During preliminary research, two socio-technical theories were identified that are useful for analyzing human-system interactions during the implementation and use of information systems. Activity theory provides the framework for the analysis of human-system interaction. At the same time, boundary objects seem to be involved when multiple specialists transfer knowledge through the use of objects. Information systems are highly involved in this process. Consequently, boundary objects are also included as a focus of this research.

To subsequently investigate and improve this implementation of contract management information systems, the following research question was created:

How can construction contract management be improved by analyzing the implementation of supporting information systems using socio-technical perspectives?

In order to answer this question, it was decomposed into five sub-objectives. The first sub-objective was to discover the relevance and challenges of contract management. This section identified some challenges and complexities that are involved in contract management. Complexities were found in interrelations in contract management specialists and contract management activities. Similarly, a set of current challenges were identified. This information is not new, but it paints the necessary picture of the current state of contract management practice. These complexities and challenges can be seen as a driving force for developments in the area of contract management. This section limited the scope of the research to a set of main contract management activities and specialist according to Dutch practice. Nevertheless, the goal of this section was to identify challenges and complexities. This goal was still achieved. But this does lead to the reservation that other perspectives of contract management could lead to different results.

The next sub-objective of this research was to find out more about the application of contract management information systems. Information systems are often introduced to cope with upcoming problems in contract management practice. But it is also known that the benefits of these systems are not guaranteed. Therefore the seconds sub-objective was to explore the current state of these information systems in contract management. Many different systems are used in support of contract management information system, and their benefits were a great match with the challenges identified previously. A short overview was made showing which information systems are currently used in contract management. These systems appeared to have very different characteristics ranging from turn-key or custom made products. The support that was provided for the users often appeared to be limited. Finally, some challenges were identified which could be related to the lacking performance of contract management information systems. This section did result in new knowledge. The exploration of currently used contract management information systems and their characteristics was not available yet. Its results can consequently be useful for further research in these types of information systems. On the other hand, the information on the benefits and challenges of information systems was gathered from previous research, and therefore already existing. Nevertheless, it showed a gap in current research, which makes these sections a crucial element for the relevance of this research.

The third sub-question led to a comprehensive analysis of current practices concerning contract management information systems. In order to uncover current challenges, experienced contract managers were interviewed. This information was structured in a codebook describing all important events during the change process. Consequently, a timeline was generated which depicts a generalized change process of the introduction of contract management information systems. Events from the codebook were used to describe what took place during the timeline. This timeline with its respective events was consequently analyzed using activity theory and theory on boundary objects. This resulted in a set of findings of what is wrong with current practices. The main conclusions from this analysis were that current approaches are ad-hoc and reactive. No structured approach to the implementation process was identified. Similarly, turnkey information systems were the least effective, and the use of this type of system should be discouraged. These conclusions subsequently indicated the need for a new and structured approach to the implementation of contract management information systems. This view on the implementation of contract management information systems has not been explored before. Therefore all information contained in these chapters is a new addition to the existing literature on information systems in the context of contract management. The timeline and events can serve as a useful baseline for future research in the implementation process of information systems. Similarly, the conclusions can be used as a basis for research into further improvements of current practices.

The fourth and fifth sub-questions aimed to transform the results of the analysis into usable and functional recommendations to improve current practices. A stable activity system early in the change process was the basis for these recommendations. Consequently, solving previously identified problems early in the change process was a key basis in composing these recommendations. First, recommendations were specified to create the ability to build the right information system. This consists of the creation of a development team containing the right specialists and the right allocation of responsibility for the system design. Similarly, user feedback, the goal of a simple system, and using proper specifications are key in creating the right information system. The next set of recommendations aimed to provide the right supporting structures for a contract management information system. This consists of the creation of a few essential roles and the use of some crucial tools. Finally, these recommendations were simplified and translated to an easy to use tool-support implementation roadmap. These findings are also new contributions to research on contract management information systems. Both the recommendations and roadmap should prove useful in improving contract management practices everywhere where it is supported by information systems. They have been validated in order to ensure their effectiveness. Nevertheless, they are to be applied in practice to confirm their worth in the real world.

Finally, to bring these conclusions back to the starting point, the following answer to the main research question is provided. Contract management can indeed be improved with an analysis of the implementation process based on socio-technical perspectives. This view on the change process involved in the introduction of contract management information systems was not explored before, as shown by the gap discussed at the end of chapter 3. Consequently, the application of this new perspective brought a new set of problems concerning the implementation of contract management information systems to light. This new set of challenges is a contribution to research on information systems in a contract management context. The next part of the answer is that these challenges can be used as a basis for improvement. By showing what went wrong, changes could be recommended in order to improve current practices. The importance of these challenges lies in the fact they need to be addressed in order to gain the benefits that information systems are supposed to have. To realize this goal of the research, the recommendations, and tool-support implementation roadmap have been constructed. These sections provide a well-structured way of implementing information systems in contract management practice. When these recommendations and the roadmap are applied and followed, the presumed benefits of information systems should finally be unlocked. As a result of these benefits, current contract management practices can be improved. This brings the research back to its starting point and shows how the new perspective becomes helpful in improving current contract management practices. However, this research failed to prove if the TSI framework unlocks the potential of information systems in real-world practice. This remains to be validated by future research.

The resulting tool-support implementation roadmap is a result of a simplification of the recommendations. Because of this simplification of the results and the broad nature of contract management activities and specialists, it is possible the roadmap is also applicable in other areas where information systems are implemented. If this is the case, the benefits of information systems can be unlocked elsewhere as well.

9.2 Discussion

After the conclusions, the implications of the results themselves are to be analyzed. This will be done in this section by presenting the limitations of the research, the relevance of the study, and recommendations for future research.

9.2.1 Limitations of this research

No research is complete without discussing its limitations. Hence limitations of this research are discussed next.

First of all, the use of activity theory can be considered as a limitation. Activity theory and subsequently the analysis of activity systems in this research are always based on the interpretation of the researcher. These interpretations are not set in stone, and another researcher could run into different results. This could be mitigated by creating a separate activity system for each of the situations that were analyzed. But with the limited time available for this research, such an approach was not feasible. Hence a common activity system was created that intends to span all the interviews. This limitation is likely to create difficulty while reproducing the results.

The use of a limited amount of interviews can also be viewed as a limitation of this research. The data, which is the foundation for further analysis and recommendations, is based on only nine interviews. More interviews would certainly lead to more robust data. But with the limited time of this research in mind, more interviews would not have been feasible.

Contract management as an activity can be defined broadly or very narrow. This research has used a broad definition, which has led to the results as they were presented in this report. If a different definition was used, the results could have been very different. Therefore, the analysis of contract management according to a single definition can be seen as a limitation.

The timeline and the events that took place can also be seen as a limitation. A single timeline was created to provide a general overview of what events take place in the change process. Because of this generalized timeline, some events that happened were left out. In the same way, some events did not make it into the codebook because not enough specialists mentioned their occurrence. When, for example, a single or a few specific cases were explored, other timelines are likely to be created. Another timeline with other events is, in turn, likely to lead to the identification of other challenges.

In the same light, the interviews and, therefore, the data are generated mainly from experiences in Dutch practice. Projects located in other countries, other cultures, or different contract management practices could be responsible for different results in different geographical locations. Therefore this research and its results are bounded by a geographical limitation.

Similarly, the interviewees in this research were experienced in different sectors in the construction industry. But, the maturity of information systems implementation and contact management practices can be different from sector to sector. Therefore, this sectoral limitation can also lead to different results.

9.2.2 Relevance of the study

The intended relevance of the study was discussed at the start of this research in section 1.2. Now the research has been concluded, it is a good moment to reflect on the relevance of the study once again. Next, the social, scientific, and project relevance of the final research is to be discussed.

Social relevance

The social relevance of this research was intended to be found in the fact that a sociotechnical, human perspective is included in the technological-minded construction sector. This has been, in fact, been realized in two ways. Firstly, by using the sociotechnical theory of activity theory as the framework of analysis for the human to information system interaction. The second human perspective was included by using theory on boundary objects. This theory was applied to analyze the transfer of knowledge of boundary objects involved in contract management information systems.

Finally, the social goal of improving collaboration was mentioned at the beginning of section 1.2.1, But this research failed to prove if this is realized. Therefore, further research into the application of the recommendations and subsequent roadmap needs to be conducted to prove if this is the case or not.

Scientific relevance

The scientific relevance of this research was realized by combining specific theories with a specific aspect of construction projects. Contract management information system implementation processes have, until this research, not been researched before. Information systems within construction projects were subject to research before. Nevertheless, this was focused on aspects such as maintenance and operations or design processes. Therefore, research into this specific niche of information system implementation processes adds to the scientific relevance of this research.

Another unique result of this research was the resulting recommendations and roadmap for the implementation of contract management information systems. Recommendations tailored for the implementation process of these specific information systems are still new.

Consequently, the combination of using activity theory and boundary object to analyze the information system implementation processes within contract management, in order to provide an implementation roadmap, provided the scientific relevance of this research

Project relevance

The final relevance to be discussed is the project relevance. While the previously discussed scientific and social relevance can be confirmed, project relevance remains to be validated. Nevertheless, some remarks on project relevance can be made.

First of all, it seems likely that the improvement of information systems in contract management would be able to improve general project performance. Better use of information through the systems can decrease the number of conflicts or litigation concerning specification documents and requirements, decreases the likelihood of delays. Similarly, conflicts and the resulting cost increases can possibly be limited by providing common interpretations of requirements earlier in the project's duration. If this is proven to be the case, the results of this research can support these gains in project performance.

Another important thing to note is that the resulting roadmap could possibly be applied in a broader way than just in contract management information systems. Due to the many specialisms involved in contract management, the recommendations and roadmap have become very general. Therefore other project activities that combine many specialisms could also benefit from the use of the presented roadmap. Nevertheless, this remains to be tested by further research.

Together these elements provide the project relevance of this research. On the other hand, further research is necessary to confirm if this is the case.

9.2.3 Recommendations for future research

To conclude this report, the recommendations for future research are discussed.

First of all, it makes sense to conduct further research on the result of this research. The TSI roadmap presented in this research is based on the theoretical foundations of activity theory and boundary object combined with objective data gathered from interviews with contract management specialists. On the other hand, a good theory is never a guarantee for good results. It is aimed to unlock advantages of information systems. Nevertheless, this research failed to prove if this is actually the case. Hence, further research in the use of the tool-support implementation roadmap could deliver interesting results for its application or possible improvements.

Based on the limitation that the interviewees provided data that was mainly generated from Dutch practice, a more international approach to this research could prove very interesting. Using data from contract management practice in other counties could provide new insights. Consequently, these new insights could lead to new additions and improvements to the tool-support roadmap.

Similarly, the single timeline analyzed in chapter 6 was mentioned as a limitation of this research. Analyzing different timelines containing different events of the change process could lead to different results. This could be done by, for example, zooming in on specific cases or a group of cases instead of providing a general timeline as this research did.

Further research can also be conducted into the application of the tool-support implementation roadmap in other areas of construction projects than contract management. As identified in the project relevance, the applicability of the tool-system implementation roadmap has become a very general implementation strategy. Therefore it could be interesting to test if this is actually the case or that applications are actually limited to contract management information systems.

Another continuation of research that could prove useful is research into the physical information system themselves and their creation. The results of this research create the right contextual conditions for the creation and support of the information system. Nevertheless, building the information system itself and the process behind it is not covered. Therefore, research into this aspect of (contract management) information systems would be of interest.

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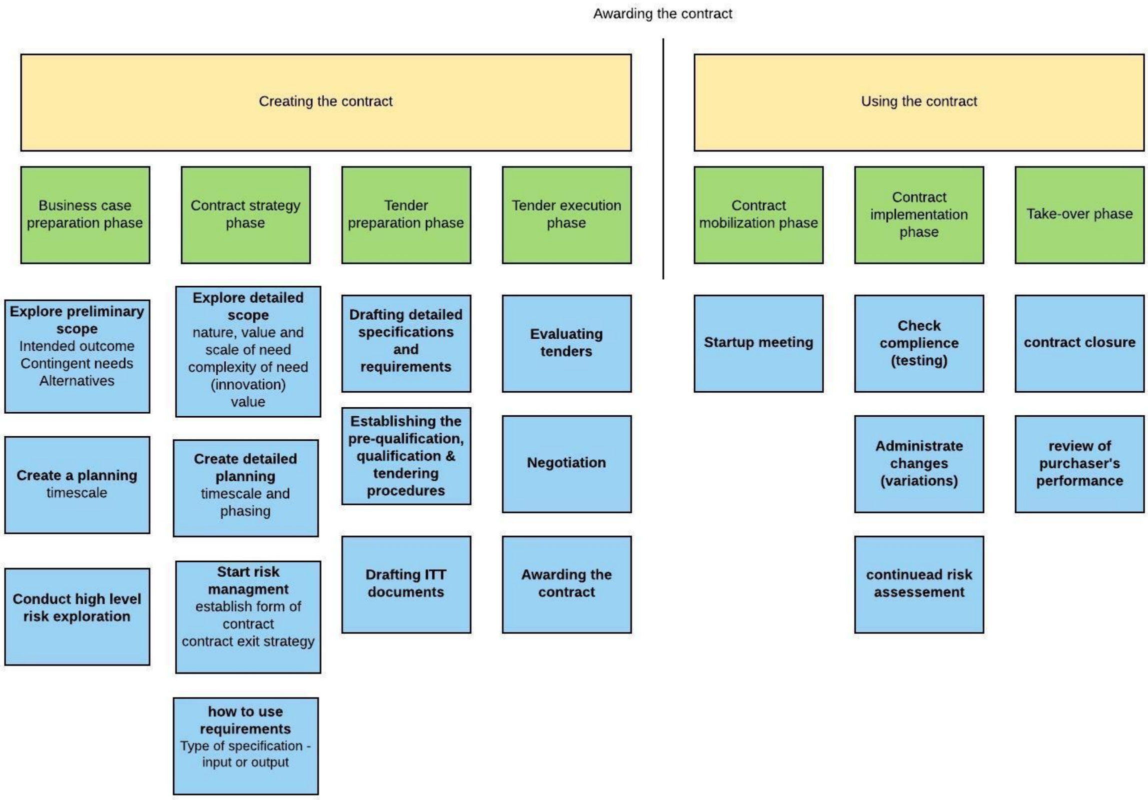
Appendix A - Contract management activities



Appendix B-1 Interview protocol

In order to uncover problem areas that can be identified in the current change process, semi-structured interviews were chosen as the appropriate method for collecting the data. This section discusses the full interview protocol. The following parts of the interview protocol are explained next: The purpose of the interviews, the methodology that is followed during the interviews, the questions that are to be answered, the selection of the interviewees, the interview process, and the analysis of the results of the interviews.

Purpose of the interviews

These interviews are intended to support the answering of 2 of the sub-questions posed for this research. Empirical information is necessary to create an objective overview of current practices concerning contract management information systems

The interviews are intended to provide the basis for the answer to sub-question 3:

Question 3 – What new information concerning the implementation of information systems in contract management can be identified using an activity theory and boundary object lens?

The empirical perspectives from these interviews are used to identify drivers, problem areas, and coping mechanisms that are included in the implementation and use of a contract management information system. Next, the activity theory framework is used to identify and characterize these contradictions.

A second purpose of the interviews is to help with the recommendations to mitigate the problem areas that are discovered by analyzing the activity systems in contract management. This aspect relates to sub-question 4:

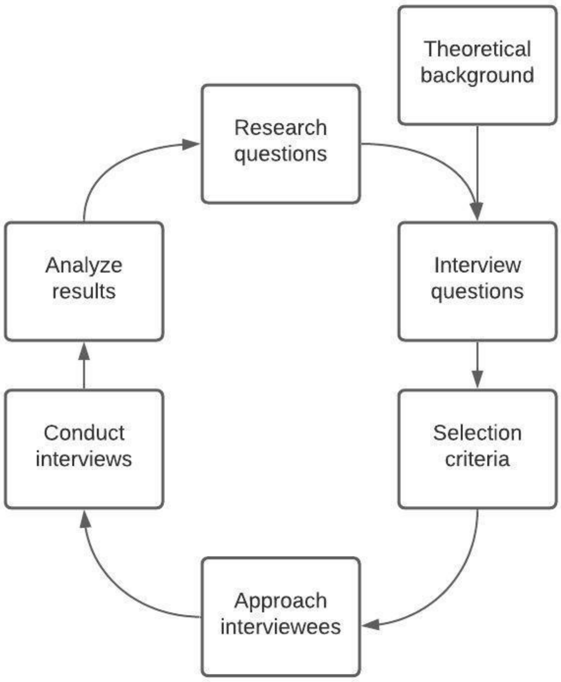
Question 4 – How can activity theory and boundary objects help to solve the identified problems in contract management?

The data that is generated in the interview serves as a basis for the analysis that is to take place. Consequently, this data is also the foundation for the recommendations that will be made later on.

Methodology

To make sure the method of interviewing is used correctly for the gathering of empirical data, the following steps have been followed.

- First of all, the research questions have to be composed by doing background research
- Then, the interview questions are set up using the research questions and the theoretical concepts
- The third step is to create selection criteria for the requirements of the interviewees
- Next, the interviewees are to be approached to check their willingness to be interviewed
- The fifth step is to conduct the interviews
- This step is followed by analyzing the results, which in turn leads to a concluding answer to the research question



Questions

As explained in the previous section, the questions for the interviews are based on the research questions and the background of the theoretical concepts that are used. The interviews are intended to be explorative and semi-structured. This pre-structuring of the strategy for the questions is aimed to provide as consistent results as possible from all the interviews (Verschuren et al., 2010).

The interviews were aimed at providing information on the experience of experts on the change process related to information systems in contract management. Therefore, the decision was made that the questions should lead to an expert's account of this implementation. Three points in time were important for this account. Firstly, the situation before an information system. Secondly, what happened during the implementation. And finally, how they coped with the problems that occurred. These three parts should provide a complete account of the implementation of an information system. Consequently, the questions are not based on the theories that will be used to analyze the results to prevent but rather on the timelines that are to be created. The second advantage of these questions is that no direction or steering is implied. This provides freedom for the interviewees to answer the questions how they see fit.

Example questions

- What is the goal of the system?
- In what way have you experienced the introduction of information systems in contract management?
- What was the situation before the system?
- What happened when the new information system was introduced?
- Did the dynamics of collaboration change?
- How did you handle that situation/overcome the problems?
- What is a bad information system?
- What is a good information system?

Selection of the interviewees

Therefore some criteria are set for selecting the interviewees. First of all, experience, the main requirement is to have at least ten years of experience in contract management. This will help in the ability to understanding the historicity of developments in contract management. Secondly, information from both sides of contract management is very important to compare and analyze activity systems. Therefore, when a contract manager from the employer's side is interviewed, it is tried to also interview his opposite at the contractor's side. Finally, to make the results as robust as possible for the whole construction sector, interviewees are to be selected from different sections of the industry. The main selected categories are infrastructures, oil, and gas, on and offshore wind.

The interview process

The interviewing process will also follow a few essential steps. Before the interview, the interviewee is approached by phone or email to agree on a date for the interview. After this first contact, a document will be sent to them which contains: the purpose and goals of the research, the main goals of the interviews, a short explanation of the theories that are used. This document is provided to make sure all interviewees have a basic knowledge of what is going to happen in advance of the interview.

During an interview, a certain structure was followed as well. The interview starts with a moment to get to know each other. At this time previous experience of the interviewee can be discussed. Next, the official interview starts by asking if the interview may be recorded. This provides an opportunity to focus on the interview instead of capturing the answers. The following step is to prepare the interviewee by introducing the research and discussing the theoretical concepts and activities involved in contract management in short. When this part is finished, the recording is started if possible, and the prepared interview questions are started.

Analyzing the interviews

After the interview has been held, the next challenge is to analyze and present the results. This is done first of all by creating a transcript of the interview based on the audio files recorded during the interviews. Next, these transcripts are reads multiple times to mark interesting and surprising sections. These sections are consequently copied to a master excel sheet from which the final step will be conducted. The final step is to start the coding process, which is explained in chapter 5 of the report. This codebook will serve as the main basis for the final analysis using activity theory and boundary objects.

Appendix B-1 Interview protocol

Appendix B-2 – Interview transcripts

-confidential-

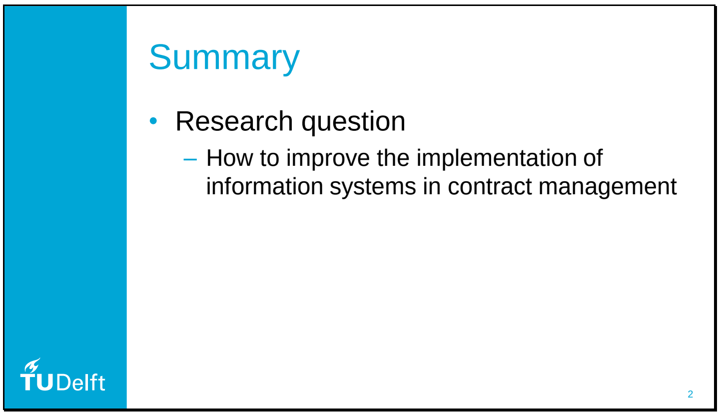
Appendix C – Codebook

	Drivers			**Problems**		**Coping mechanisms**
		Problem	**Coping mechanism**			
Added complexity	**Intrinsic project drivers**	Specialized knowledge	Change task allocation	**Unprepared user community**	Improve informal communication	**Correct**
Need accessible and clear information		Individual characteristics	Show value/ deregulation		Change task allocation	
					External Informal process	
Rule driven	**Coercive use**	Lacking guidance	Regulate	**Coordination insufficiency**	Alternative system structure	
Management driven		Unintended use	Improve informal communication			
		Different interpretations	Create common interpretation		Show value	**Discuss**
		Bad input			Create common interpretation	
		System interface	Change task allocation/Alternative system structure	**Poor system design**	Pressure	**Force**
		System architecture	Change task allocation/Alternative system structure/ External Informal process		De-regulate	
			Alternative system structure		Regulate	

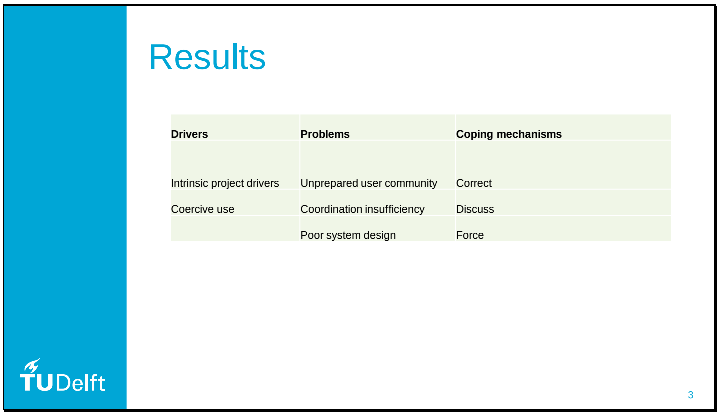
Appendix D-1 – Validation meeting slides

Slide 1

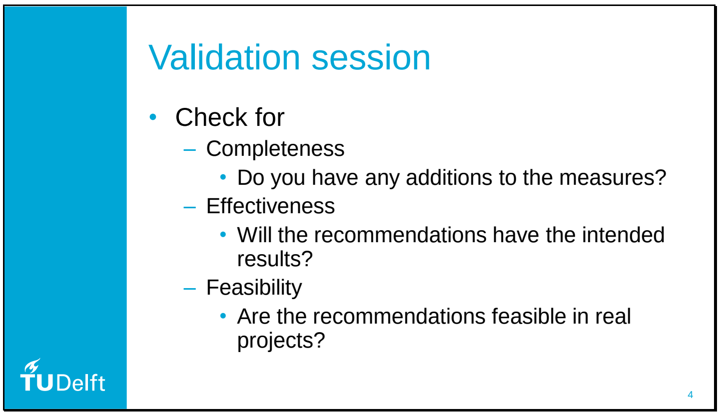
Slide 2



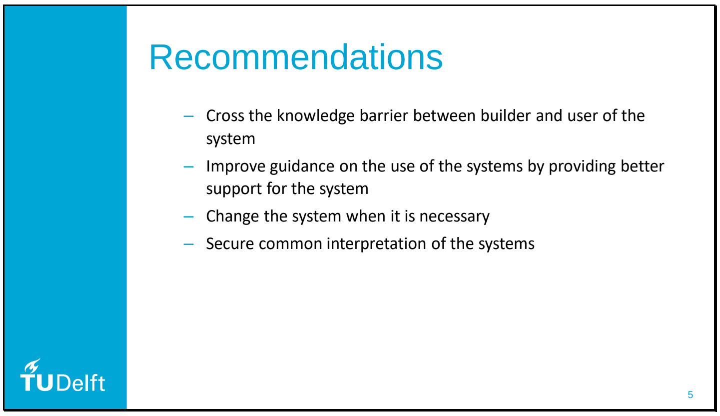
Slide 3



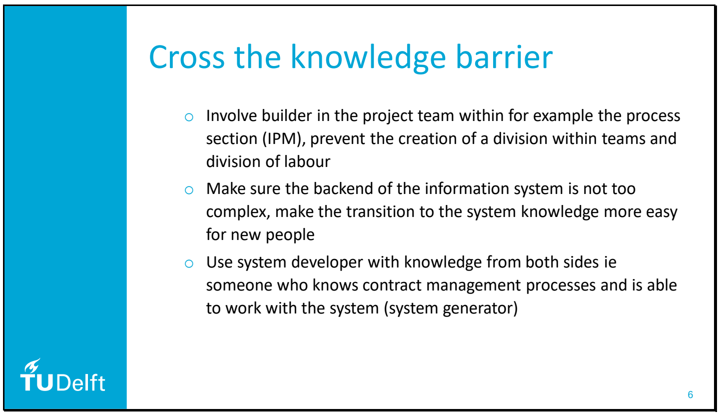
Slide 4



Slide 5



Slide 6



Slide 7

Improve guidance

- Rules
  - formal and informal in starting phase
  - Discuss the use regularly and update rules
  - Make sure rules fit the tool, users and the local situation
  - Give the rules a clear place where they can be found and make sure this list is current
  - Do not over-regulate and constrain the users, this is likely to take away willingness to work with the system
  - **Assign clear responsibility for enforcing the rules**

7

Slide 8

Improve guidance

- Proper training/instruction for all users
  - Training at the start of project in general session to provide a general feeling
  - User instruction individually tailored to needs of single person
  - New users get instruction
  - Make them use the system during instruction sessions
  - Explain the system is not a communication tool, it is there to facilitate the necessary information flows, it is not designed as a communication tool

8

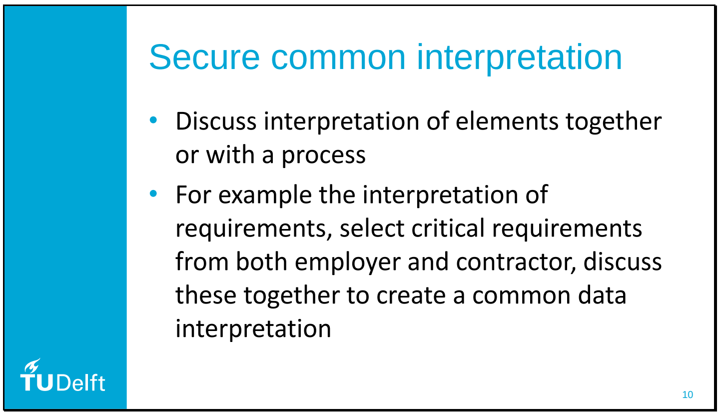
Slide 9

Change the system when it is necessary

- Facilitate these changes during the project, do not use a rigid system the whole time be open to change
- Correct harmful practices when they arise
- Do this proactively, be ahead of the problems

9

Slide 10


Secure common interpretation
• Discuss interpretation of elements together or with a process
• For example the interpretation of requirements, select critical requirements from both employer and contractor, discuss these together to create a common data interpretation
TU Delft
10

Appendix D-2 – Validation meeting reports

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Appendix D-2 – Validation meeting reports