Master Thesis

# TOWARDS CHANGE MANAGEMENT IN A DIGITAL BUILDING ENVIRONMENT

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# Introduction

In the past years the use of computer tools has become more and more common in the construction industry. Construction professionals use specific software to support different parts of the construction process. Paper drawings are replaced with digital drawings and tasks traditional carried out by humans are done by computers. Construction companies are inevitably going to be confronted with working with digital tools. There are already many computer tools available to support the construction process and a lot of companies use them in what I call a Digital Building Environment. In the next chapter I will elaborate on the concept of a Digital Building Environment.

One of the parts of a construction process that can be supported by computer tools is change management. A change, in this case, is any alteration in design (scope), budget or schedule (Sun & Meng, 2008). Change management means trying to handle a change effectively and efficiently. Effectively, meaning that the change and consequences are resolved. Efficiently, meaning that it is done at minimum costs and time delay.

Change management is a requirement for any construction company. Even while the need for changes is accepted by clients and contractors (Motawa et al., 2006), "letting the changes be" and dealing with them at the end of a project is inefficient and can result in ugly legal issues, higher costs and bad relationships with project partners. Changes are almost impossible to avoid, because even the most thoughtfully planned project may necessitate changes due to various factors (Arain, 2005). To begin with, during the planning phase, many parameters are uncertain and assumptions have to be made. Also, not two construction projects are exactly alike, so each project comes with its own problems and lessons learned cannot always be applied to other projects. Furthermore, construction projects extend over time, the last for weeks, months or even years. During this time requirements may change. For example: client demands can adjust or rules and regulations may change.

Not all changes are the same, there are different kinds of changes. A change can be big, like changing the structure of a building, or small, like changing the paint color of a room. Most changes have negative effects that can result in budget overruns and time delays (Ibbs et al. 2001; Motawa, 2007; Osman, 2009). However, some changes can be positive. They can improve the quality of the building or can save time or money. A change can be obligatory or elective. An obligatory change can occur when government rules change or due to errors and omissions in the design. Elective changes occur when the client or contractor would like to change something, so it is a choice, not a necessity.

Fact is that almost all construction projects are subject to changes. Even though some of them can be positive, most of the changes have severe negative consequences. This is a reason why construction companies want to improve their change management process. Supporting their change management process with computer tools might be an improvement. But in order to determine if computer tools can be an improvement it is important to investigate current change management in practice and if and how a Digital Building Environment is part of this.

The goal of this master thesis is to research the change management processes currently used by construction companies. I did this by conducting interviews with different people on different construction projects. This thesis will show that the change management process is barely supported by the Digital Building Environment, mainly because change management relies heavily on human interactions and intangible knowledge. There are, however, areas in change management where the DBE can be beneficial to the change management process, as I will discuss later.

This thesis is structured as follows: first I will further introduce earlier research about change management systems and change management processes. Also I will discuss the concept of a digital building environment. Next I will summarize the research method and the data that was collected.

Finally I will discuss the results and make recommendations, followed by suggestions for further research.

## Theoretical point of departure

In this section I will first discuss the concept of a Digital Building Environment and the differences with traditional building methods. Then I will discuss a change management system and a change management process model and the steps in this change management process model.

**Digital Building Environment**

Computers are taking up an increasing part of all aspects of our lives, our personal lives as well as our professional lives. This means they are also becoming more important in the construction industry. But the use of computers requires a different way of working. Information is more widely available and reaches us quicker. A lot more information needs to be processed. Computers take over activities that we were used to do ourselves. In this part I will discuss the concept of a Digital Building Environment (DBE) and the implications it can have on the construction process.

I define a Digital Building Environment (DBE) as a physical place where construction professionals work with specific software to support different stages of the construction process. Examples are 3D-modeling software to support the design of a building and scheduling software for the planning of construction activities. Applications like Microsoft WORD and EXCEL or internet browsers and email clients are not part of the definition of a DBE. This software is not specific for the construction industry but common office software.

Working in a DBE differs in many ways from the traditional method and can provide a lot of advantages. In DBE it is possible to make 3D models of a construction project. This makes it possible to estimate the feasibility of a building earlier and better then with the traditional method and costs and quantities can be extracted easier (Eastman et al., 2008), thus allowing for more accurate price estimates. Further, a model that was drawn-up as a preliminary design can be used as the basis for a more detailed design whereas with the traditional method a whole set of new drawings must be made. Different sets of drawings no longer have to be sent back and forth; instead centralized files are updated, thus reducing the risk of missing papers or working with outdated versions (Christianson et al., 2002). This can be an advantage when managing changes, because when an aspect of the building changes, drawings have to be updated and distributed among different parties. Regular mail takes time. Email on the other hand is much quicker, but updating a centralized model can be even quicker, as all stakeholders can receive automatic updates.

Also the ability to support facility management with as-build data can be considered an advantage over the traditional method (Gu & London, 2010). When the model is updated frequently and parts that are already build are indicated, stakeholders can view the current status of the construction. They can make a better estimation whether proposing a change is meaningful or the construction has advanced too much. This can reduce the work pressure of the contractor, who is traditionally tasked with estimating the time effects of a change.

Maybe the biggest advantage of a DBE is that the whole building live cycle can be simulated in virtual reality. Unlike other industries, like car manufacturing, construction projects are often one of kind projects. Building a prototype to test performance and correct mistakes is most of the time not an option in the construction industry. By simulating the building with special software, a virtual prototype of the building is created. This makes it possible to identify design errors and omissions before construction and correcting these errors before they can cause costly time delays in the field, thus preventing changes. But the prototype can also be used for change management during the construction phase. The impact of a potential change can be visualized and the client or architect can make a better estimation whether to proceed with the change or not.

As mentioned earlier, even with help of computer software, not all changes can be avoided. Therefore change management is a necessity. But change management is also an area where computer tools can be of assistance. As discussed in the next part, time plays an important role when dealing with

changes, because time often equals money. Computer tools can provide ways to communicate quicker and therefore address changes quicker. Furthermore, a construction project is a series of interrelated and sometimes interdependent activities or processes where the output of one activity can be the input of other activities. With large and complex construction projects, computer tools can help identify the areas that are affected by a change.

In order to support the change management process with computer tools, it is important to know how the change management process looks like. Computer programs exist of predefined rules that form certain algorithms. An algorithm is a procedure for handling information and it takes predefined sequential steps. To come up with good algorithms and computer programs, it is important to identify the steps and procedures that form the change management process. Current literature provides such steps and processes. In the next section I will discuss the basic principles that form the change management process.

**Basic principles of change management**

In this part I will discuss the way construction professionals can handle changes efficiently, based on literature studies. Figure 1 provides an abstract diagram of changes in a construction project.

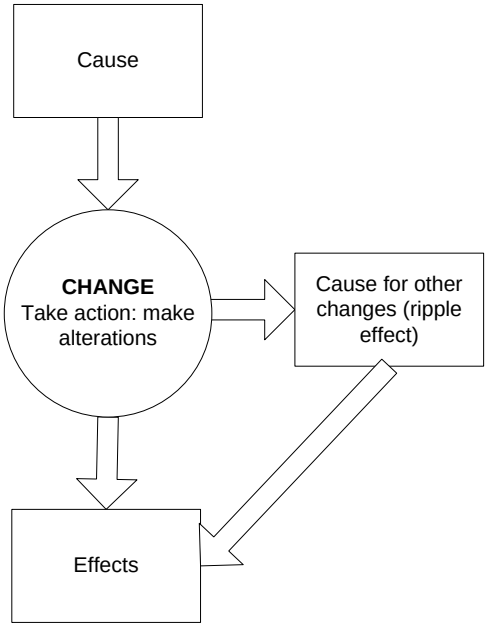


*figure 1: change in a construction project*

First something must cause the need for change. Arain (2005) showed that most of the time (93.8%) the change is client related, and only a small percentage of the change is contractor related (3.2%). When the need for a change emerges, action can be taken, depending whether the change is elective or obligatory.

These actions have effects: some minor, some big, some positive but most negative (Sun & Meng, 2008). Potential effects of changes have been identified by Oman et al. (2009) and include: increase in projects costs, increase in overhead costs, rework and demolition, quality degradation, logistic delay, delay in payment, completion schedule delay, procurement delay, hiring new professional, poor professional relations, poor safety conditions. Besides the direct effects a change can have, most changes are the cause of other changes that in their turn may lead to yet more changes (ripple effect). These subsequent changes also have effects. These effects can be a lot harder to determine. This is an

area where a DBE is an advantage. Computer models can help determine which elements of the design are affected by the initial change.

The potential negative effects justify the need for effective change management. Ibbs et al. (2001) claim that effective change management is based on a system with five principles that work hand-in-hand with each other (figure 2).

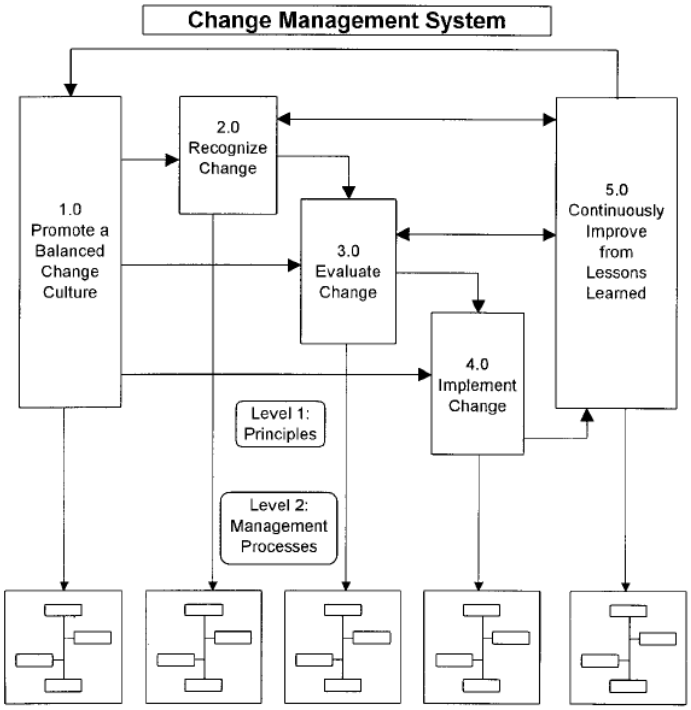


*Figure 2: the change management system by Ibbs et al.(2001)*

The first principle of change management is to promote a balanced change culture. This means referring to previous project for early recognition of a problem. Also beneficial changes need to be promoted, as they help to recuse cost or schedule. Meanwhile detrimental changes need to be discouraged as they reduce owner value or have negative impact on a project (Arain, 2005).

The second principle is to recognize change. Potential change must be identified and described. Describing a potential change is necessary for documentation and communication between different parties. Then the project team needs to determine if the change is elective or obligatory, as elective change can be ignored (because of time limitations). When a change is obligatory or the project team decides to continue with the elective change and the next principle comes into play.

The third principle is to evaluate change. When evaluating a change the first thing to determine is the priority. Sometimes priority is so high, not enough time is available to identify and evaluate all effects. In such case funding should be arranged without evaluating all the impacts and the change should be implemented as soon as this funding is available. When priority is not so high, the effects of the change should be evaluated more thoroughly. Only when the effects on schedule, budget and quality are determined funding must be arranged and a decision whether to continue or not should be made.

The fourth principle is implement change. This is a very important step, as it is the main reason to have a system. Important when implementing change is obtaining the final authorization. Documenting this authorization is important for preventing legal issues. When the alterations are made,

the information on the project should be updated and all changes should be communicated to the appropriate parties. Also the implementation should be monitored closely and corrected if necessary, even if this results in other changes. In this case the process may start all over.

The last principle is continuously improve from lessons learned. The idea is to evaluate changes learn from mistakes that causes changes, so errors can systematically be corrected. The analysis should be openly discussed between members of the construction team so team members can prevent similar mistakes in the future and can take a proactive approach.

**Change process model**

Although the five principles of Ibbs et al. (2001) form the basis of change management, they are abstract. Motawa et al. (2007) have developed a change process model from the five principles that can be applied when managing changes in practice. The process model has four main sections, shown in figure 3, and these are described below. The stages: 'start up' and 'post change' lie beyond the scope of the research. To provide a complete picture, the stages are briefly described.

1. Start up
   At the start up the process model defines a set of proactive requirements that are essential for effective change management. These requirements enable the project team to respond readily to change, to manage change effectively, and to facilitate contingency plans for any unanticipated changes (Motawa et al., 2007).
2. Identify and evaluate
   Change identification should cover change causes, types and effects. It should also define the relevant project processes and departments affected by the change or involved in the change decision. The change management process model requires project teams to keep records of all relevant information on change cases to build a case base for future use. Analysis of change options is required for decision-making – whether to go ahead with any of the change options or to undertake further investigations. The criteria required to carry out this analysis may include tangible and intangible criteria. The evaluation steps include options evaluation, implications assessment and optimum selection of change options. Different models and decision support systems can be used to help decision-makers select an optimum solution and evaluate the change options using quantitative and qualitative criteria (Motawa et al., 2007).
3. Approval and propagation
   Client approval is an important step in the process while different outputs are expected, as shown in figure 3. The client needs to review potential changes against the project baseline using tangible and intangible criteria gathered during the' identify and evaluate' stage. When the client is not sure about the change, more evaluating might be needed, represented by the bold line on the left. The client can approve the change, with or without negotiating the cost/time estimation, in which case information about the change is distributed among members of the project team. In turn, they distribute the information further down to suppliers and subcontractor. Of course the client can also reject the change, in which case the project team also needs to be informed. The change can be permanently rejected or can be designated as a latent change because of its potential to be reconsidered later on. The bold line on the right shows this process. In any case, the decision reached needs to be recorded for future needs.
4. Post change
   In case of a dispute, an investigation of direct and indirect causes of change is required. In this situation, the analysis of the effect of multiple change causes could be prepared (Motawa et al., 2007).

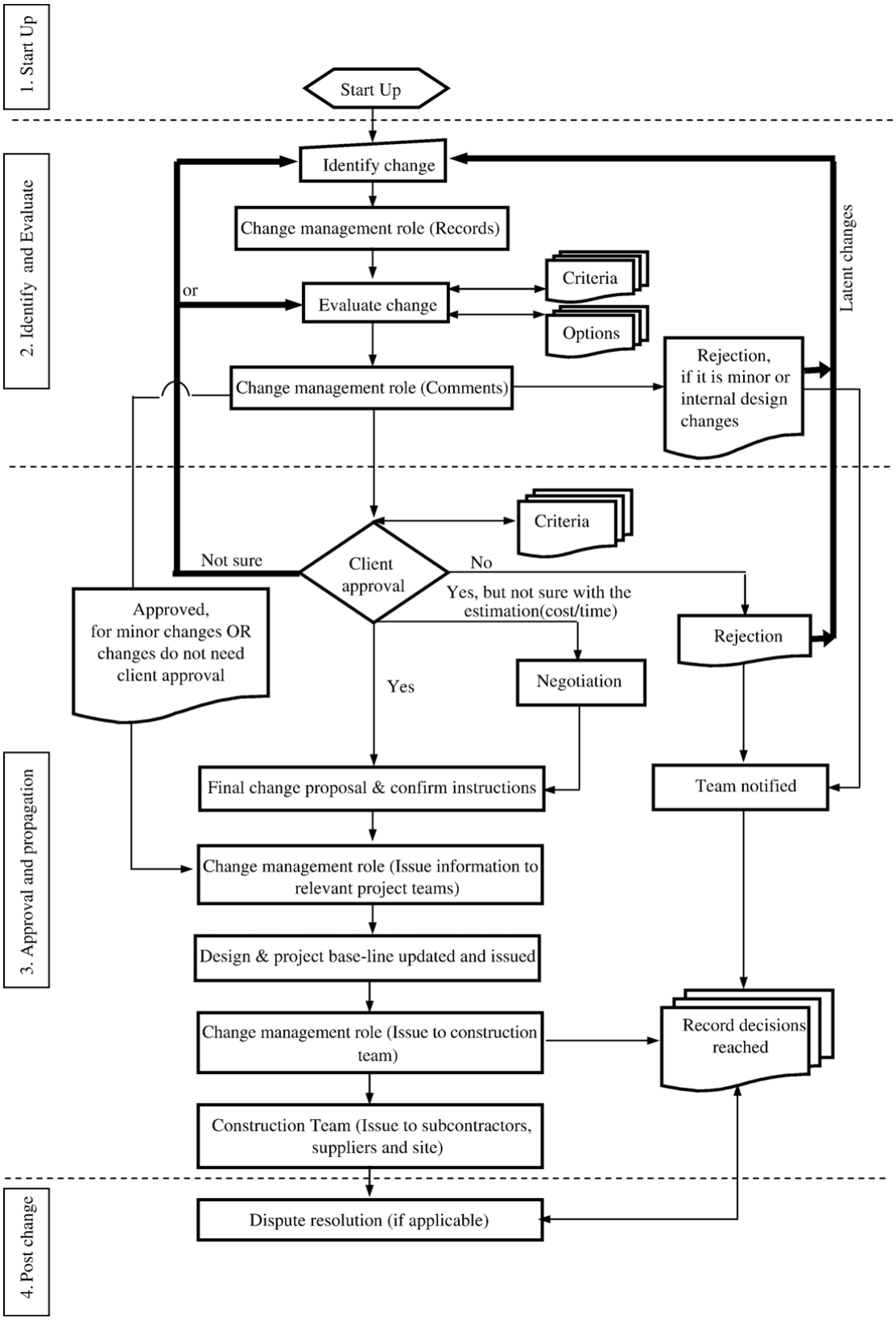


*Figure 3, the change process model by Motawa et al.*

**Formal and informal change management**

Figure 3 provides us with a process model of how changes are best managed; this is the theoretical change management process. But is this the way companies manage their changes in practice? The change management process of a company consists of two parts, the formal part and the informal part. Any company will have some rules that dictate how to manage changes. These might differ per company or even per project. The rules that companies use are what I define as the formal change management process. I assume that this formal process will have some resemblance with figure 3.

Even though a formal change management process might exist in a company, this does not guarantee that changes are managed this way on a daily bases. The rules set by the company might not be best practice, or they might suffice in certain situations. This can lead to actions that differ from what the formal change management process dictates. This deviation of the formal change management process that happens on the construction site is what I define as the informal change management process.

It is important to notice that change management is a very social process. Most of the arrows in figure 3 represent communication between people. Part of this communication is between people that represent different parties: clients, advisors, contractors, suppliers. This communication is not simply 'informing' the other party, but consists of discussions, evaluations and negotiations. Trust (or lack of trust), experience and intuition play a part in this communication. Brown and Duguid (2000) show that these aspects cannot simply be reduced to logic and transformed into computer programs. The people that play a role in this communication are very important, there are social resources. Successful design of computer tools to support the change management process depends on drawing from these social resources (Brown and Duguid, 2000). These people who frequently deal with changes, do not only have information about the process, they are part of the process.

While the literature has a clear view of how changes can be managed best, the question is if companies shape their change management process accordingly, and also, if this formal change management process is used in practice. And since human interactions are a great part of change management, and these interactions cannot simply be transformed into computer programs, the question arises: how is the Digital Building Environment part of the change management process, both formal and informal. The purpose of my research is to get a clear overview of the change management process of construction companies, formal and informal, and what role the Digital Building Environment plays in this process.

## Research statement

The goal of this master thesis is to research the formal and informal change management processes currently used by construction companies, and what role the Digital Building Environment plays in this process. To get a clear understanding of how changes are managed, the following question need to be answered.

What does the change management process currently used look like and what role does the Digital Building Environment play in this process?

## Research method

To get a clear understanding of current change management processes, this research is conducted at a construction company. In this case the Koninklijke BAM Groep, in short BAM. BAM employs 25.000 people and operates in several countries, like The Netherlands, Belgium, The UK and Germany. For six months I was working at the division A&E (advise & engineering), part of BAM utiliteitsbouw.

The first part of the research was familiarizing myself with the company. Therefore I first conducted two interviews to get a general understanding of the process and procedures used by BAM at the constructions sides. After these preliminary interviews, together with BAM, I selected five projects.

Since the number of projects a company can work on at once is limited, the number of available projects is also limited. The most important criterion for this selection was that the construction project was ongoing at the time of the research. The reason for this criterion is that, first, documents were supposed to be easier to access, because after the completion documents usually end up in an archive, and secondly, it is more likely that the respondents do remember more details about ongoing project then about projects that might have ended two or three years ago. The last criterion was that the construction projects were supported by some sort of digital tools, whether this was only the comparison of 2D drawings or the modeling of the complete building, because the research focusses on change management in a digital building environment. The projects that were studied for this research are listed in table 1. The scope, budget and duration vary. The fact that three of the five projects are hospitals is a coincidence.

| Project | Description | Duration | Budget |
|---|---|---|---|
| **Project A** | Hospital | 4 years | 200 mln |
| **Project B** | Office building | 10 months | 4 mln |
| **Project C** | Hospital | 4 years | 113 mln |
| **Project D** | Office building | 3 years | 330 mln |
| **Project E** | Hospital | 8 years | 449 mln |

*Table 1*

Because this research focuses on the construction phase, I decided to conduct interviews with project leaders execution and work planners. These are the people that handle the changes for BAM on a project. The project leader execution oversees the change management process. The work planner is tasked with checking the drawings, distributing drawings and contacting suppliers and sub-contractors. Multiple work planners work on one project. They each are tasked with a specific area, for instance: pre-fab concrete elements, floors and carpet or doors, windows, hinges and locks. When the construction progresses, parts of the job are done and certain work planners are no longer needed. They move on to other projects. Figure 4 shows a simplified organogram that indicates the position of the project leaders and work planners in the project hierarchy.

On each project the goal was to interview at least a work planner and a project leader. This goal was not always achieved because not everybody replied to the invitations for an interview. In order to contact people for an interview, I sent out emails. When people did not respond after several tries, I assumed that the person was not interested or available.

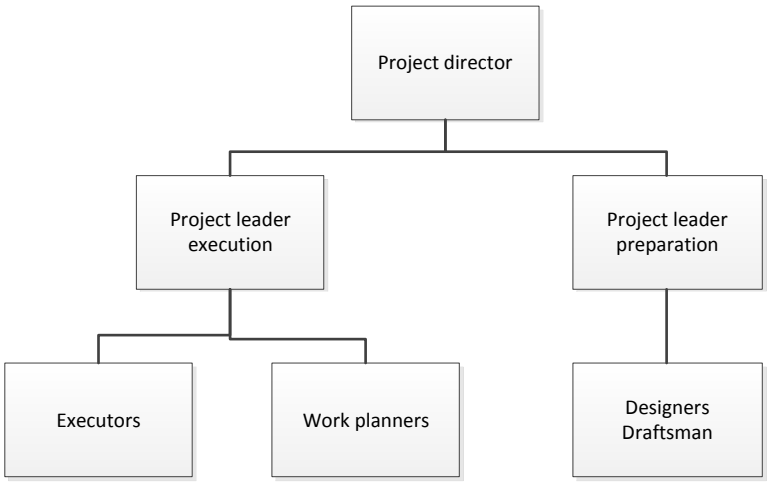


*Figure 4*

Not all people that were invited for an interview worked for BAM. With two of the five projects (D and E) the project was executed by collaboration between two contractors, BAM and Ballast Nedam, so as a result, another company was involved and the people from this company were a bit harder to contact. In the end, the only respondent that worked for another company is a project leader at project D. In addition to the interviews with the project leaders and work planners, an interview was conducted with an estimator. This specific estimator is not committed to one project, but works on multiple projects at the same time. A detailed list of interviewed people can be found in table 2.

Before the interviews I promised respondents anonymity in order to get them to speak freely. I did not want them to worry about consequences if they had controversial opinions or when the confessed to not following the rules. Because I interviewed only one or two people on some projects, it is not always possible to say: "the work planner on project B said:…." in order to preserve anonymity. I will only link statements to projects when I feel that I am not betraying their confidence.

| | |
|---|---|
| **Project A** | Project leader |
| | Project organizer |
| | Work planner |
| **Project B** | Project leader |
| | Work planner |
| **Project C** | Work planner |
| **Project D** | Project leader |
| | Project leader |
| | Work planner |
| **Project E** | Project leader |
| | |
| **Orientation interview** | Project leader |
| | Project leader |
| **Other** | Estimator |

*Table 2*

The interviews were ethnographic interviews. Important for ethnographic interviews is that the informant gets the idea that the researcher is ignorant. This way he will not assume prior knowledge and

thus skipping potential significant information (Spradley, 1979). This was done by asking the same basic questions in each interview, even when the knowledge was present with the researcher. The interview was an open interview and I did not know on forehand what the interesting parts were. The interview protocol that was used for this research can be found in attachment 1. After the introduction and some general questions about the project, the questions about changes and change management were addressed. In most of the interviews not a lot of questions were needed to cover all the topics. In almost every case the respondents were very eager to show and tell about their work. So while the respondent talked the interview needed only little steering in the right direction. Most interruptions were to clarify certain points or to ask for more details or examples. After the part about change management some extra question were asked about the company's digital building environment and its relation to changes and change management. Most interviews lasted between 1 hour and 1.45 hour.

During the interviews on the projects described above data was collected. All data was put in the data analysis program 'Atlas.ti'. This program provides a structured way to analyze all the available data and to structurally support claims made based on the data analysis. To structure the data, I made several rounds of coding the data. In the first round I coded all examples of changes being handled. I recognized 15 examples of changes. As tags I used the three main steps used in the change management system by Ibbs et al.(2001): recognize, evaluate, implement. It showed that evaluate and recognzie are not always used in this order. Sometimes the change is first implemented and then later evaluated. To me, this indicated that the formal change management process is not always followed, as the literature is very clear about the sequence of the steps. So in another round of coding I used the tags: 'use of a fromal change management process and 'no use of a formal change management process. Respondends also gave an indication if the use of a change management process had a positive outcome or a negative outcome. Positive and negative in this case are based on the interpatation of the respondends and are not supported by qualitative evidence. Mainly a positive outcome means gaining, or at the least not loosing, time and/or money. A negative outcome means loss of time and/or money or disrubted realatoins between stakeholders. The term 'formal change management process' indactes a process that is agreed upon at the start of the project by the stakeholders and is often recorded. The 'informal change management process' refers to actions that deviate from or even contradict the fromal change management process.

The coding of the data structured the data in such a way that the examples had one of the four possible outcomes show in table 3. Table 4 show the number of examples provided for each category.

| | |
|---|---|
| 1. Use of a **formal CMP** which results in a positive outcome | **2. Use of an informal CMP** which results in a positive outcome |
| 3. Use of a **formal CMP** which results in a negative outcome | 4**. Use of an informal CMP** which results in a negative outcome |

*Table 3*

| | |
|---|---|
| 0 | **7** |
| 6 | 2 |

*Table 4*

Table 4 shows that the number of examples for categories 2 and 3 is higher than for 1 and 4. Category 1 doesn't even have examples. I think this is because category 1 can be considered 'the normal practice '. The formal change management process is used, and the outcome is positive. But the respondents were more eager to tell about situations that are not 'normal'. Either the formal process was not used (category 2), the outcome was not positive (category 3) or a combination of those (category 4). Because of the lack of examples in category 1, in the next section I am going to focus on categories 2, 3 and 4.

## Change management in practice

In this part I describe what the formal change management process of BAM looks like. I also describe why the formal change management process is used and how it is used and where. Early analysis of the data showed that the process is not always used. Certain steps in the process are skipped or are taken in a different order than the order the formal process dictates. I will also describe why this is done and what practical implications this has. At last I will describe what role digital tools play in the change management process.

**The formal change management process**

When I asked the project leaders and work planners to describe how a change is managed at their project, they started to describe in general terms how a change is managed. All twelve began with a brief description of the process they use. All five work planners told that the project leaders are tasked with designing the process. All seven project leaders stated that the design of the process is done in agreement with different important stakeholders: the client and his advising parties and the contractor. One of them said:

*"In the first construction meeting, we discuss how we are going to deal with changes".*

Two of the seven project leaders told they used ideas they had seen on former projects to design the formal change management process.

*"On previous projects you learn what works and what doesn't. So the things that work well I try to take with me to a next project and suggest them there."*

Only two of the seven project leaders said they made use of the centralized documents that BAM provides for its employees. Three of the seven project leaders stated they used new ways to manage changes. One of them said:

*"We knew there were going to be changes. To prevent problems* [cost disputes] *we now use a form that has to be filled in. As far as I know we are the only project that uses this kind of form"*

When asked if they would use this new way on another project, they all confirmed and said they would if they got a chance. They said that when a project leader steps in during a project rather than at the start they have little influence on the design of the formal process. One of them said:

*"It works rather well, I certainly would like to use it in the future, but it is not only up to me."*
*"Sometimes you get assigned half way during a project. Then you don't have any influence on the change management."*

None of the work planners indicated that they were involved in the design of the formal change management process.

Even though the formal change management processes of each project differ in details, the outline looks the same:

The client or the contractor expressing the need for a change, this is the the start of the process. The client or contractor fills out a form to express this need, and the change is discussed in the construction meeting. It can go the other way around, a possible change is mentioned in the construction meeting, and then an official form is filled out. The construction meeting is a regular meeting, like once a week, where the main parties of the construction project discuss progress and important issue. Parties attending this meeting are the contractor, the client or a party on behave of the client, advisors of the client, the architect and main sub-contractors. As argued earlier, changes can lead to other changes and can affect al lot of activities and by discussing them all parties can indicate how they might be affected. Therefor it is important that all relevant parties involved are informed. The construction meeting also functions as an early evaluation point. The contractor can indicate that a change is not feasible or very expensive. This is mostly done based on experience. The client can then decide to abandon the change on forehand. Or, if the contractor proposes a change, the client sometimes rejects the change without needing further costs and time estimations.

When a change passes the construction meeting the official form is transferred to the employee at the contractor that is tasked with managing the changes. Usually this is a project leader. He is tasked with gathering the necessary information to make a good evaluation. He has limited time to do this; a common timeframe is two weeks. First step in the evaluation is estimating the effects on the schedule, because when a change is undesired because of the schedule there is no need to calculate the extra costs. The project leader often makes the time estimation himself. If additional information from sub-contractor or suppliers is needed, the appropriate work planner contacts them and reports back to the project leader.

If the change has acceptable impact on the schedule, the variation in costs needs to be calculated. The project leader contacts an estimator. Some projects have their own estimator, some projects share an estimator. Especially the estimators that work on multiple projects are under pressure, as all estimations need to be returned within the two weeks (or other agreed timeframe). For his budget calculations, the estimator might also contact a work planner, depending on who has the better contacts with a supplier or sub-contractor.

While the change is being evaluated and effects are investigated the project continuous. But the change can have effect on the part that is being constructed at that moment. Therefore agreements have to be made about the progress pending the change evaluation. When the impact on the budget and schedule are clear the form with the request for the change is updated with the new information and passed through the project director who signs of on it, and goes back to the client. The client has one week to decide on the change. The client agrees with the change or does not agree with the proposed costs or schedule. Sometimes the client tries to negotiate lower costs. When client and contractor agree after this negotiation, the process continues. If not, the change is rejected. If the change is accepted, it is communicated to all parties affected by the change. Where necessary, new drawings are made and new supplies are order by work planners. The new drawings are then distributed to the appropriate parties. This way the change is implemented.

It must be noted that changes are not managed one by one. Multiple changes are handled simultaneously. So all the changes that have been accumulated during the time between construction meetings are discussed in that meeting and are sent to the project manager as a bunch.

**Why is a formal change management system used?**

Respondents indicate several reasons for using a formal change management process. Ten of the twelve respondents gave as a reason: "*because it [not using a formal change management system] went wrong in the past*". When the elaborated more, they indicated that on previous projects in the change management process was less strict. They told agreements were made on the work floor between people who were not authorized to do so. Also, most of these agreements were oral. And while these agreements are legally binding there are hard to prove. This practice led to disputes and disturbed relationships. Five of the twelve respondents remembered one or more cases in which the company often changed something and ended up not getting paid for it, because no official order for a change was given. A respondent stated: "They say: *"Just do it [implement the change], we will work out the details later. Trust me, it will be fine"*. But later nobody takes responsibility". One respondent claimed that the amount of uncollected payments can rise up to tens of thousands of euros.

The lack of documentation was also mention by four of the seven project leaders, and two of the five work planners. The project leader on project E gave an example of what can happen when you do not communicate changes to other parties (this was on an earlier project):

*"A steel beam was a little bit too long. To make it fit it was decided on the spot to remove some insulation, it seemed harmless. A few months after the completion it turned out the removal caused moisture to get through, which resulted in water damage. Had we discussed the change, chances are that somebody from the mechanical engineering company would have said something about it."*

Documentation is not only needed for communication, but also for when disputes develop afterwards, to provide evidence for claims about responsibility and payments. Several respondents told about lawsuits that relied heavily on documentation for evidence.

These are examples of when an informal change management was used but the results are negative (category 4 of table 3). They are used to show why a formal change management is important. But table 3 also shows that there are plenty of examples of a formal change management process that has a negative outcome (category 2 of table 3).

**The disadvantages of a formal change management system**

While all project managers stressed the importance of a formal change management process, all work planners gave examples why a formal change management process is not always best practice. One of the major disadvantages that four of the five respondents pointed out is the timeframe. As said above, evaluating the change takes time and may take up to two weeks. But for changes that are identified just after the construction meeting another week needs to be added (that is if the construction meeting is held weekly). During this period two things can happen. The construction is put to a hold, which means delay when the change is rejected. Or the construction is continued, which may lead to demolishing and rework, which imply extra costs. Especially small changes suffer from this. The work planner at project C demonstrated that with an example.

> *"Sometimes you need to make a small change. Let's say I need to change the window frames a little bit. It can be done in a couple of minutes per frame. I know I will get permission, there is no alternative to the change. But first I need to fill in a form and in two weeks I get permission. But when I cannot finish the frames, I cannot paint the frames. So I will have to reschedule the painters. But when the room isn't painted, I cannot put carpeting in, so I have to reschedule the carpenters. But the painters and carpenters do not just have one project, in two weeks they might be busy somewhere else and become unavailable. "*

Another example demonstrates the negative effects of continuing construction pending a change on project D:

> *"On every floor there is a little kitchen. When the first kitchen was placed, the client was unhappy with its location. It needed to be relocated a couple of meters down the hall, there are not much extra costs involved. But while the change was being processed, other kitchen were being placed on the original location. So when the change was official, multiple kitchens had to be demolished. This made the change more expensive. "*

**The use of an informal change management process which results in a positive outcome**

Although all project managers admitted that the formal change management process takes time, they did not gave examples of cases were it was beneficial to not use a formal change management process. The project manager on project D even claimed the formal process was always used. However, all work planners admitted that the not always followed the process. The next citations demonstrated this:

> *"When I know about a change that is going to happen, I inform my sub-contractor so that he can prepare. When the change comes through, the sub-contractor already knows about it and work can continue faster."*

When asked how he knew if a change was going to be accepted or rejected he replied: "Experience, I just know if a change is most likely to be accepted".

> *"Some new calculation showed that the wind load was two and a half times bigger than the original design could handle. You just know that this is going to be a huge change, the structure need to be changed, so I informed my supplier [of pre-fab elements]"*

> *"With little changes, sometimes I first make the change and fill out the necessary forms later. Like when they want to change the paint color of a room. I know that is not going to be a problem, a different color costs just a much. It makes no sense to wait a couple of weeks for it. That would just make it more expensive and disrupt the work flow."*

Not using the formal change management process does not only save money and time, it also keeps good relationships. The next example shows that time and money can be saved while a good relationship is maintained:

> *"The architect's assistant sits down the hall. When the client or architect is thinking about a change the assistant sometimes quickly runs by a work planner and asks: 'how far is this or that?' or 'what will I costs when we take a different stone?' That way the architect can estimate whether it makes sense to formally require a change. This saves everybody a lot of time and energy. But it is against the rules, the project leaders do not want it to happen. So on this project it happens less, but it still happens. For this to work a good relationship is very important".*

All interviewed work planners indicated that they deviate from the formal change management process when they thought it was better to do so than following the formal change management process. They stated that when they did this, it had positive effects. But when asked how much time

they had saved or how much money that had saved, they could not give exact numbers. They all responded: "*I don't know exactly*".

**The change management process and the Digital Building Environment**

In the last section I did not mentioned the Digital Building Environment. That is because the Digital Building Environment takes almost no part of the change management system at BAM, neither formal nor informal. BAM uses a variety of digital tools that they call xd4all; it is BAM's Digital Building Environment. It supports the building process in different ways, but it is absent in the formal change management process. There are no documents that describe the use of digital tools in the change management process. But it goes even further than that. The formal change management process as used currently on most projects discourages the use of digital tools. Almost all visited projects had contracts that required that the documents be printed and mailed.

Xd4all is mainly used to make 3D models of buildings. Hereby certain omission and errors in the design are detected that otherwise might go unnoticed or would be detected during construction. This way changes are being prevented. But one can argue if this is part of the design process or part of the change management process. Either way, it falls outside the scope of this research, because this research studies changes that occur during the construction phase, not the design phase.

# Analysis

When I look at the previous part about the formal process it becomes clear that on all projects the basics of the process are similar but vary in detail. On all projects a form needs to be filled out (recognize change), the contractor estimates the time and costs of the change (evaluate), the client approves the change and then it is incorporated in the construction (implement) or the client regards the change. The details that vary are for example: what form needs to be filled out, how long do you have to evaluate, what is done during the evaluation? I think this is because on each project the details are renegotiated and redesigned. From the interviews I get that the exact outline of the process depends mainly on the past experience of the project leader, the relationship with the client and the fact if BAM needs to work together with another contractor.

The Digital Building Environment is strikingly absent in the change management process. The only tools that are used are email and pdf viewers, which fall outside the definition of a Digital Building Environment. Drawings are often mailed, and the ones that are emailed are sometimes printed as well. I thinks a big improvement can be made.

In table 4 the number of examples is shown. It stands out that using a formal CMP which results in a positive outcome does not have any examples. I think this is because the common practice, most changes are dealt with this way and the respondents are able to remember unusual outcomes much better. Also, no use of a formal CMP which results in a negative outcome has only 2 examples, while to two remaining categories have more examples. I think the explanation lies in the fact that giving examples in this category is admitting that the respondent made a bad estimation. Admitting you were wrong is always hard.

The fact that the categories No use of a formal CMP which results in a positive outcome and Use of a formal CMP which results in a negative outcome have more examples I think is because it shows the weak points in the formal change management system. Especially the work planners came up with these examples.

During the interviews it became clear to me that there was a difference in opinion about the change management process among team members. The difference can be traced back to the position of the respondent in the organization structure. The project leaders were more supportive of a strict and

formal change management system. While they acknowledge that not using a formal process “is popular culture on construction sites” they wanted to use a formal process on their project and bypassing it was not allowed. Work planners however agreed that a change management process can be effective and useful but they stated that they avoided the process when they felt it would make more sense to “cut some corners”. They gave several reasons and examples to justify their activities.

## Discussion

The sections above indicate that the DBE is nearly absent in the cases I researched. The conducted interviews and data I collected show no evidence that these projects are exceptions. In this section I am going to discuss how the change management process can be supported by the DBE.

First, I think it is important that any support from the DBE should be an improvement. Changing something only for the sake of change is not a good reason. The DBE should add value to the change management process. It should make handling changes more efficient. Therefore it should try to solve the drawbacks of the current practice while utilizing the benefits the current process offers.

The most obvious drawback of the current formal process is that it is time consuming. Paper forms have to be mailed back and forth, kept track of and different versions have to be physically stored. On the other hand, digital documents that are distributed on the internet are instantly available to multiple users. In that way, email is a step forward, although it is not a big step. While email utilizes the speed digital communication offers, it still faces some of the disadvantages regular mail does. Email messages are often stored among other messages with very little structure, little relation between them and not directly linked to project information. My suggestion is to make use of a digital communication tool that is more fit for the purpose of change management. It should help keep communication strictly about the current construction project so there is no ‘noise’ that interferes. Documents and messages about changes should be stored in a structured manner, and should be link to the parts of the project they have an effect on (for example foundation, certain floors or to the mechanics or), but also to other changes.

With this information stored and linked other possibilities emerge. Changes can be ‘flagged’ in the other parts of a DBE, like a model or the schedule. By clicking on such a ‘flag’ other stakeholders are directed all information regarding the change and its status (proposed, denied or applied).This way communication about changes become part of the project information and will be widely available. Also keeping track of different versions of documents becomes easier and stakeholders can receive a warning when new versions become available.

Also, information that is digitally stored is available anywhere where there is an internet connection. This means that people on the construction site can have access to communication as well as people in an office. For this to apply certain conditions must be met. Workers need access to internet and devices that can access the information they need.

Besides benefits to the change management process of the construction project the digital communication tool is used on, such a tool can be beneficial for future projects. I found that step 5 of the change management system by Ibbs et al. (2001), continuously improve from lessons learned’ gets neglected in practice due lack of time. After finishing a project all paper work is stored at some archive far from the future projects, and the potential knowledge it contains is stored with it. Any lessons learned become intangible knowledge and experiences only for the people involved with the project. Well stored and structured digital information can become an easy accessible source of knowledge, essential for preventing making the same mistakes multiple times.

A positive side effect of using a digital communication tool as described above, that keeps track of all communication, is that it will leave less room for legal conflicts. It includes all communication and a clear timeline can be constructed, provided that any and all communication is done with this tool.

I think using digital communication as described above partially overcomes the major drawback of the current formal process, that it's time consuming, while it offers the opportunity to preserve the benefits of the current informal practices: fast decision making. The informal process is fast because it avoids the formal paper communication. I think that with the possibility of using the much quicker digital communication, the need to avoid the formal communication will be much less.

Communicating and documenting changes is only part of the process. But a digital building environment can offer more to the change management system. When evaluating a change the DBE could offer assistance.

When all information about a construction project is centralized and available for stakeholders, for example the building information model (BIM) it could be possible to identify potential effects of changes before implementing them. On the projects I studied, if a computer model of the building was used, it would only be used in the design fase. Some project leaders had never even seen the model. I think great opportunities lie in using the building model for evaluating potential changes. But in order to be helpful, the model has to be up to date all the time. Not only does the model need to be updated when a change is applied, to effectively evaluate a change the current state of the project must be reflected by the model. Only then the possible effects of changes can be realistically be simulated and well thought-out decisions can be made based on more accurate information. This in contrast to making decisions based on cost estimates from estimators with little knowledge of the project, other than the drawings they have available, and the time estimates based on the experience of the project leader.

Another advantage of updating the model with any change is a reliable as-is model of the finished building.

Even though the potential of evaluating change with the help of a digital building environment is large, it requires updating the model with all changes. Every change that is not in the model increases the chance of errors and diminishes the value of the model and thereby the accuracy of the evaluation. Digital communication as described above would be the first step on the way of supporting the change management with a digital building environment.

## Limitations

The data collected from this research gives a good insight in how changes are managed on construction projects. A limitation of the research is that is that only one company is studied. So it cannot be undoubtedly held representative for other companies. Also a limited number of projects has been researched. Four of these five projects are very large and three of them are hospitals, which are very specific building projects. This should be kept in mind when projecting the findings on other projects. Another limitation is that the role of the interviewed people is limited to project leaders and work planners – with the exception of one estimator. This can lead to a unilateral perspective of the change management process. Client and related parties (architect, advisors) were not involved in the research.

Furthermore, labeling the result of using a formal or informal as positive or negative is based on the interpretation of the people interviewed. No quantitative data is available in this research.

## Further research

Data obtained from this research suggests that avoiding the change management process can be more efficient. This claim is based on interviews and qualitative data is missing. The people that bypassed the process on occasion were all work planners. They were not able to estimate the time or money they saved. This is not surprising. As described earlier changes can affect many areas and cause other changes. Work planners generally deal with specific parts of the project, so they are not likely to have all the information to make a good estimation. Further research can try to calculate these savings by taking a broader perspective.

Even though the principles 'promote a balanced change culture' and 'continuously improve from lessons learned' are not inside the scope of the research, from the interviews it became clear that little or no attention is paid to them. There is little communication between projects. The only information that is transferred is the experience of people. No tangible information seems to be exchanged. Good ideas and processes can go lost this way. It can be interesting to study the reasons for this or to try to improve this area.

## Conclusion

The goal of this master thesis is to research the change management processes currently used by BAM. It became clear that on every project there is a formal change management process. This process is used to manage the majority of the changes. Currently, that process is not very much supported by digital tools. In fact, it is almost not supported. In general, formal change management process is the same on every project. The step recognize, evaluate and implement are very clear present. However, the details of the process vary. On the five different projects, not one process was exactly the same. This means that possible digital support needs to hold this into account, by being flexible.

Even though all projects have a formal change management process, this process is not always strictly followed. Work planners sometimes deviated from the steps in the process when the feel that this will save time and money. Their interaction with suppliers and sub-contractors plays a big part in this. It is important that this aspect does not get lost when implementing digital tools.

The main reason the formal change management process is sometimes not used is because it is considered time consuming. I think that this is the area where digital tools can make the most difference.

## Reflection

During my master thesis I learned several things. I found it very difficult to start working on something without knowing exactly what the end goal is. The research question changed during the process and I found this difficult to cope with. I was gathering data without knowing what to look for, and it was during the end of the research that I had goal, an end project to work towards. But at that point I had collected all the data and I could not change that, I had to deal with what I had. If I had to do it again, I would ask questions that are more focused. But that is with the experience I have now.

Also I never conducted interviews in this way, so that was a learning experience on its own. In the future I would try to think more about the structure of the interviews and about what information I need. The open character of the interviews provided very different data, which I found hard to structure and turn into something useful. So I learned that I have difficulty structuring data. While it all makes sense in my own head, I find it hard to write it down in such a way that a reader can follow my steps and can come to the same conclusions I did. Next time I will try to do this from the beginning.

If I had to do it all again, I probably would do research on quantitative data, i.e. hard numbers. This way the data is far less open to interpretation.

Last but not least found it very interesting to visit such big projects. I learned a lot of the common practice on construction sites, but this learning experience is not directly applicable to this thesis.

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# Attachments

## 1. Interview protocol

**Introduction**

- *Who am I*
- *What is my research about*
- *What is the purpose of the interview*

**General questions**

Can you tell me something about the project?

- *Size*
- *Duration*
- *Costs*
- *Problems*

Can you tell me about your function on this project? Can you describe a typical day?

**Change management**

Are changes common on this project?

What type of changes do you encounter on this project? Can you give an example of such changes?
*The goal is to get detailed knowledge of how a change of each type is handled. Things that need to be clear afterwards are:*

- *What needed to be changed*
- *Who initiated the change*
- *Who handled the paperwork*
- *Was authorization needed*
- *Who gave authorization*
- *What procedures were used (BAM KMS maybe?)*
- *Is this the typical way of how change is managed*

What did you do after you found out about the change?

What are problems you encounter when a change occurs? How would you solve these problems?
*The goal is to identify problems that arise from the perspective of the informant and the solutions they may give.*

**xD4All**

Are you familiar with xD4All?
Can you describe what xD4All is?
Does xD4All make your job easier? How? Can you give an example?
*The goal is to identify how the informant feels about a digital building environment.*

Does xD4All helps you handle change better? How? Can you give an example?

If you could change something about xD4All, what would it be?
If you could instruct the people working with xD4All at the office, what would you tell them?

*The goal is to get information of how to improve the management systems.*

**Ending the interview**

- Thanking the informant
- Asking if a follow-up interview is possible