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Lifecycle view of managing different changes in projects

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Purpose
A project contractor can promote the success of a delivery project by planning the project well and following a project management methodology. However, various changes typically take place, requiring changes to the project plan and actions that deviate from the firm's established project management methodology. This paper explores different types of changes and change management activities over the lifecycle of delivery projects.

Design/methodology/approach
A qualitative single case study design was used. Seventeen semi-structured interviews were carried out during a delivery project in a medium-sized engineering company that delivers complex systems to industrial customers.

Findings
Both plan-related changes and deviations from the project management methodology were mapped throughout the project lifecycle. Various internal and external sources of change were identified. An illustrative example of the interconnectedness of the changes reveals the potential escalation of changes over the project lifecycle. Managers and project personnel engage in different change management activities and improvisation to create alternative paths, re-plan, catch up, and optimize project performance after changes.

Research limitations/implications
The empirical study is limited to a single-case study setting and a single industry. The findings draw attention to the interconnectedness and potential escalation effect of changes over the lifecycle of the project, and the need for integrated change management and improvisation actions.

Practical implications
Efficient change management and improvisation at the early phase of a delivery project can mitigate potentially negative change incidents in later project phases. Changes are not only the project manager's concern; project personnel's skilled change responses are also helpful. The findings emphasize the importance of the project customer as a source of changes in delivery projects, meaning that customer relationship management throughout the project lifecycle is needed for successful change management.

Originality/value
The study offers increased understanding of changes and change management throughout the project lifecycle. The results show evidence of plan-related and methodology-related changes and their interconnections, thereby proposing a lifecycle view of integrated change management and improvisation in projects.

Keywords: Change management; Delivery project; Improvisation; Project lifecycle

Classification: Research paper

Introduction

With delivery projects, a project contractor fulfills a customer's need by delivering a customer-specific solution in the form of goods (tangible), services (intangible), or a combination of the two (i.e., integrated solutions; Brady et al., 2005). For both the contractor and the customer, it is essential that the delivery of these solutions is managed successfully. To promote the success of delivery projects, the supplier company can plan the project well and follow a project management methodology (PMM), both of which have been argued to promote project performance (Lehtonen and Martinsuo, 2006). However, projects rarely proceed exactly to plan or adhere precisely to set methodologies; instead, various changes take place throughout the project lifecycle to adjust the progress of the project in light of new knowledge (Klein et al., 2015). There can be both changes to the original project plans and deviations from the PMM. These changes have to be managed in order for the delivery project to succeed. This paper focuses on different types of changes and change management that occur throughout the lifecycle of delivery projects.

Previous research on changes and change management in delivery projects has particularly focused on the different reasons for changes to occur (Butt et al., 2016; Dvir and Lechler, 2004; Zhang, 2013) and the different tactics used to manage them (Steffens et al., 2007; Whyte et al., 2016; Zhang, 2013). The research on changes and change management typically covers the changes that are needed and made as compared to the original project plan. Literature on improvisation in projects, in turn, deals with the adjustments made in comparison to the PMM. The idea behind improvisation is that, despite the PMMs or formal tools available in the focal firm, project managers often act intuitively, based on their experience and the problem at hand (Klein et al., 2015). The literature on improvisation in projects is interested in the sources, nature, and effects of these intuitive actions in projects.

Despite the relatively active research on change management in projects and improvisation in general, there are several research gaps that this study has been designed to fill. First, there is a need to better understand the nature of the different changes that occur in different phases of the project lifecycle (e.g., Dvir and Lechler, 2004; Zhang, 2013). In particular, there is a need to account for the whole project lifecycle and for both plan-related changes and deviations from the PMM. Second, there is a need for further empirical research covering improvisation in projects, particularly in complex delivery projects (Leybourne and Kennedy, 2015). Third, there is a need to better understand the roles of different stakeholders, both in change management and in improvisation (Aaltonen et al., 2010; Butt et al., 2016; Tukiainen et al., 2010; Zhang, 2013); for instance, what are the internal and external sources of change and what are the roles of different project actors in interpreting and responding to the changes.

The purpose of this study is to explore the different types of changes that occur during a complex delivery project, the sources of such changes, and project personnel's experiences with managing them. The focus is on engineering solution delivery projects that solve the same business problem (and can therefore be repeated for different customers), but need to be carefully tailored to the customer's processes during the design and implementation phases. The goal is to map the emergence of different types of changes over the lifecycle of a delivery project, and thereby identify the means to promote effective change management. This paper focuses on two main research questions:

1. What kinds of changes do project personnel experience during the project lifecycle, including: a) changes to the project plan; and b) deviations from the PMM, and what are the origins of the changes?

2. How do project personnel and managers implement change management and improvisation actions in the different phases of the project lifecycle?

The empirical study is delimited to engineering solution delivery projects that were designed by the focal firm and tailored and delivered to different customers globally. Therefore, organization development, product development, and information system delivery projects are not covered. However, as the existing literature on change management and improvisation is somewhat limited, literature examining topics beyond delivery projects is included.

Next, we analyze the previous literature on change management and improvisation, and how empirical studies have covered the issues recently. Then, the qualitative single-case methodology is introduced by explaining the research context, data collection, and analysis procedures. Results are introduced on the types of changes faced by the case company, as well as its experiences with managing them. We discuss the results in terms of the different changes and different reasons behind the changes throughout a project's lifecycle, and the different change management and improvisational actions related to those changes.

Literature review

Delivery projects as the implementation of a planned process

Delivery projects are a way for a project contractor to solve a customer's problem by delivering a customer-specific solution. Project management research with a focus on (industrial) delivery projects has traditionally taken planning-centric, normative, and deterministic perspectives (Leybourne, 2017). The idea has been to identify the needs of the customer, plan a project to meet these needs, and control the implementation of the project by following the project plan. A similar

planning-centric approach is emphasized by the influential standards and books of knowledge produced by various project management associations (such as APM, 2012; PMI, 2013).

More recently, the adequacy of the planning-centric and deterministic approach to project management has been questioned. Specifically, the uncertainty of projects limits the possibilities of relying heavily on project planning alone (Perminova et al., 2008). Because of uncertainty, it can be difficult to perfectly identify the customer's needs from the front-end of the delivery project, for example, and to include them in the project plan. Similarly, unexpected positive or negative events can occur during the planning and design work phases, thus requiring a change to be made to the project plan. Osipova and Eriksson (2013) argue that uncertainty calls for a flexible (organic) approach rather than a control-centric (mechanistic) approach to project management.

Few projects proceed fully in line with their specific plans, and changes need to be made and managed during their lifecycle (Dvir and Lechler, 2004; Steffens et al., 2007). Similarly, it has been noticed that project managers do not necessarily follow the organization's project management methodology, but instead improvise or adjust their practices and thereby deviate from the project management methodology in order to match the practice to the specific situation (Leybourne and Sadler-Smith, 2006). Both types of changes can take place within projects, and these form the focus of the study.

Changes and change management in delivery projects

In this paper, we acknowledge that various types of changes may take place during a project. Previous research has predominantly focused on reactive changes to the goals or the plan of the project, and their management (e.g., Dvir and Lechler, 2004; Steffens et al., 2007). Some studies adopt a broader perspective on deviations — not only those that deal with the official goals and

plans, but also planned actions. Deviations concern "situations, regardless of consequence — positive or negative, large or small — that deviate from any plan in the project" (Hällgren and Maaninen-Olsson, 2005); however, not all deviations require change management.

Changes in delivery projects may take place for various reasons (Butt et al., 2016). For example, customers may request changes, the project team may come up with new or better ideas, or managers may require novel solutions later on in the project (Dvir and Lechler, 2004). Some of the problems and consequent changes in projects take place because of faulty or biased assessments and decisions made during project planning (Pinto, 2013). Furthermore, the project owners' assumptions about the future may be wrong (Zhang, 2013), or events that take place in the environment may alter stakeholders' expectations or affect the ways in which certain decisions manifest in practice (Aaltonen et al., 2010; Zhang, 2013). All of the previous examples demonstrate how changes occur for various reasons and why change management is required throughout the lifecycle of delivery projects; however, more research on this topic is needed (e.g., Dvir and Lechler, 2004; Zhang, 2013).

Successfully leading a project requires change control and risk management during its execution (Pinto, 2013). Various aspects of change management and control have been covered in earlier research. For example, configuration management is a relevant change management tactic when the changes deal with the project's deliverable (Whyte et al., 2016). The lifecycle of the project has been pointed out to require coordination across functions and iteration over the project phases (Zhang, 2013). Some studies concern the ways in which project managers and personnel cope with unexpected events that occur as a result of stakeholder involvement in the projects (Aaltonen et al., 2010; Tukiainen et al., 2010). Using data and information on the asset (i.e., the project deliverable) is also needed (Whyte et al., 2016). Communicating changes to stakeholders is key to

keeping them engaged and promoting a positive project culture (Butt et al., 2016). Many such

studies indicate that there is a need for managing and coordinating the changes and that project

personnel need to consider the broader implications for the stakeholder network. Previous

empirical studies have covered relevant aspects of changes and change management in the context

of various types of projects — specifically delivery projects. Table 1 summarizes an analysis of

the key contributions from empirical studies closely linked with this research and points out the

research opportunities and gaps justifying further research.

*** TABLE 1 TO BE ADDED HERE ***

Table 1. Examples of empirical studies on changes and change management in projects and their contribution to this research

The existing research summarized in Table 1 raises three main issues that drive this research effort.

First, flexibility is needed in all the project phases (front-end, planning, execution, and

delivery/commissioning) (e.g., Olsson, 2006). As the benefits of front-end planning may be lost

through changes made during project execution, there is a need to study the changes and change

management over the lifecycles of projects further (e.g., Dvir and Lechler, 2004; Zhang, 2013) in

order to understand the emergence and consequences of changes, and also to learn from them for

the sake of forthcoming projects (Wu et al., 2005). Second, previous research has pointed out the

centrality of external stakeholders, particularly in the context of delivery projects (Aaltonen et al.,

2010; Butt et al., 2016; Tukiainen et al., 2010; Zhang, 2013). As stakeholder relations are

characterized by unexpected events causing changes, there is a need to be clearer on the sources

of changes, whether they are internal or external, and how these are experienced and managed in

delivery projects. Third, there are indications that different types of changes need to be managed

differently (Steffens et al., 2007), and that the measures concerning change need further development (Dvir and Lechler, 2004). These previous suggestions indicate that there is space for further in-depth studies about different types of changes, and their identification and description in different contexts.

Improvisation and adjustment in project management methodologies

Organizations often follow project management methodologies (PMMs) to their project-based operations. These methodologies can be based on the standard project models and methodologies of the professional associations (APM, 2012; Garel, 2013; PMI, 2013), or be more or less tailored to or created for an organization's specific needs (Jerbrant and Karrbom Gustavsson, 2013; White and Fortune, 2002). Even if the organization lacks a formal, written PMM, it may still follow typical, fairly established and commonly agreed upon ways of managing projects. In this paper, we take a broad perspective of PMMs and acknowledge that they can be either formal or informal approaches to an organization's management of projects, and they can be built upon the organization's or individuals' established routines.

Sometimes, the suitability of PMMs to environments with dynamics and variety between the projects has been questioned (Morris et al., 2006). Besides changes made to project plans and goals, project personnel can deviate from the behavior instructed by the PMM. Even with agreed-upon PMMs or formal tools, project managers often act intuitively based on their experience and the problem at hand (Klein et al., 2015). Consequently, they sometimes choose to observe the current situation and act based on its requirements, instead of strictly following the guidelines of a PMM (Jerbrant and Karrbom Gustavsson, 2013). This type of intuitive, spontaneous, and context-dependent practice is called improvisation (Klein et al., 2015).

Project managers and project personnel can have personal reasons for improvising, but generally they are inspired by the perceived inadequacy of existing PMMs or tools to address different situations, or by uncertainty preventing the implementation of a project plan (Klein et al., 2015). It can be argued that improvisation, to some extent, takes place in every project (Baker et al., 2003), and that improvisation in project work is inevitable (Luhmann, 1995).

Improvisation should not be considered a binary action; rather, there are different degrees of improvisation in different projects. Building on Weick (1998), Klein et al. (2015) categorize improvisation into four groups: linear project management (PM), bricolage, pluralist PM, and pure improvisation. At one end of the continuum, linear PM refers to situations in which the degree of improvisation is low, and improvisation refers mainly to minor adjustments made to the existing structures. At the other end of the continuum, pure improvisation refers to situations in which the degree of improvisation is high, and organizational tools and structures play a secondary role. In pure improvisation there is a potentially radical departure from existing plans and the desired outcome is the main concern of the improviser.

Although the body of literature covering improvisation in general is extensive, there are relatively few previous empirical studies focusing on improvisation in project-based organizations, as noted by Leybourne (2006) and Leybourne and Sadler-Smith (2006), for example. Table 2 presents a summary of the existing empirical research on improvisation in project management closely linked with the scope of this study, thereby demonstrating the need for additional empirical research on improvisation in different contexts and different project types.

*** TABLE 2 TO BE ADDED HERE ***

Table 2. Examples of empirical studies on improvisation in projects and their contribution to this research

The previous research raises three main issues that drive this research effort. First, there is a general lack of empirical research focusing on improvisation in project-based organizations (Leybourne, 2006; Leybourne and Sadler-Smith, 2006). Second, there is a need to study improvisation in different projects and contexts. In particular, there is currently a heavy emphasis on the financial services sector in the existing empirical research, which demonstrates the need to study improvisation in other contexts as well — complex delivery projects, for example (Leybourne and Kennedy, 2015). Third, the research focus of the previous empirical literature is mostly limited to the viewpoint of the project manager (or similar, such as the project portfolio manager). Consequently, the roles of other actors in improvisation, such as the project team members, remain unclear.

Research method

Research design and case organization context

We employ a qualitative research approach and follow a case study strategy. Case study designs are suited to answer "how" questions and to explore the key phenomena in real-life settings (Yin, 2009). The research is designed as a holistic single-case study (Yin, 2009, p. 46) and the unit of analysis is a complex delivery project of an engineering company. The rationale behind employing a single-case design is to study a representative case (Yin, 2009, p. 48); in this study, we focused on a typical project carried out by an ordinary company that designs, sells, and delivers systems for industrial customers in the engineering industry.

We used purposeful sampling to choose the case organization (Silverman, 2010, p. 141). We sought out an organization with an established history in project-based deliveries. The chosen case organization (referred to hereafter as EngineeringCo) is a medium-sized engineering company.

EngineeringCo delivers tailored engineering solutions as customer-specific projects, both as individual devices and as factory-level systems. It is a typical example of a manufacturing company that offers its customers both tangible products and intangible services with different levels of tailoring and technological complexity.

Purposeful sampling (Silverman, 2010, p. 141) was also used when choosing the case project. Together with a representative from the case organization, we sought out a typical, but complex (as perceived by EngineeringCo, in comparison to the different projects carried out in the past) delivery project that had been recently completed or was almost complete. At the time of the study, the chosen case project was near completion. According to the interviewees, the complexity of the case project arose from:

- The size of the project (both in financial terms and its number of subsystems);
- A project schedule that was considered as demanding by the project personnel;
- The customer's requirements considered as demanding and atypical and the customer's actions considered as uncertain by the project personnel;
- The tailoring and engineering requirements (a complex solution to be delivered; technical complexity);
- The challenges linked to the requirements of the installation site, i.e., the old factory building where the project was to be delivered.

Overview of the case project

The case project was a factory-level solution delivery consisting of multiple systems and subsystems. Its lifecycle was typical of that of EngineeringCo's delivery projects (and of similar delivery projects in general). First, there was a sales negotiation phase and a project planning

phase, which took place partly simultaneously. These two phases together are called "pre-project phases" in the following subsections. After the project planning phase, the engineering phase began. Partly simultaneously with the engineering phase, the procurement phase began with the components and subsystems to be procured. The manufacturing phase began with the most urgent components and subsystems as soon as the necessary engineering specifications and designs were ready. After the procurement and manufacturing phases, some of the subsystems were tested and then transported to the customer's factory, while some other subsystems were directly transported to the factory. Finally, when the first shipments arrived at the factory site, the installation and implementation phase began. Here, "installation" mainly refers to the physical installation of the components, subsystems, and systems. "Implementation," in turn, refers to the efforts to make the different subsystems and systems work together optimally as a factory-level solution. After the installation and implementation phases, commissioning will take place.

In the case project (and in the context of EngineeringCo generally), PMM refers more to accepted norms and typical behavior than to a formal project management methodology. Although all of EngineeringCo's project deliveries are tailored solutions, they follow similar lifecycles and project managers tend to manage their projects in much the same way, leading to an accepted norm-based approach to PMM.

This study took place during the later stages of the installation and implementation phase, when the project was relatively close to commissioning. When discussing the success of the project with the interviewees, most of them were quite satisfied and considered the project to have been relatively successful. There had been difficulties throughout the project's lifecycle, particularly in the installation and implementation phase, but interviewees emphasized how, despite the

challenges, a solution meeting the customer's scope requirements had been delivered to the customer's site on time.

Data collection

The primary data consists of 17 semi-structured interviews with the case project's core project personnel. The interviewees included the responsible project managers (three people), the main people responsible for the project's different business functions, and several operative employees implementing the project. Interviewees from different organizational levels were included to avoid managerial bias. Data collection is summarized in Table 3.

*** TABLE 3 TO BE ADDED HERE ***

Table 3. Summary of data collection

A semi-structured interview protocol was followed. The interview protocol focused on the whole lifecycle of the delivery project. The interviewees were asked to describe the different changes and deviations throughout the project lifecycle, the perceived reasons for those changes and deviations, the response actions taken by project personnel, and the relationships between the project personnel. The interview protocol included the thematic areas to be covered, but the exact wording and the order of the questions varied between the interviews, depending on the flow of the discussion.

The interviews were recorded and transcribed by an external service provider. The interview data was supplemented with project documentation, particularly project plans. After the interview data collection, a workshop was organized to summarize the key results of the interviews and enable an open-ended discussion on the project and its changes. Besides serving as an additional data

source, this workshop was designed to validate the research findings and the authors' interpretations.

Data analysis

The analysis of the data followed a three-step process. In the first coding round, an inductive approach was taken, and all the sections related to changes to project plans and deviations from PMM (and the project phase in which the change occurred) were coded using open coding. In the second coding round, the open codes were re-coded according to the types of changes, the reasons for the changes, and the different types of response actions taken by the project personnel. The coding framework after the second coding round is summarized in Table 4.

*** TABLE 4 TO BE ADDED HERE ***

Table 4. The main coding categories used in data analysis

In the third phase, four main change management patterns were identified inductively from the data for the different response actions concerning the two types of changes (plan-related and PMM-related): creating alternative paths, re-planning, catching up, and optimizing project performance. The four change management patterns emphasize how the different reasons behind the changes led to different types of response actions taken by the project personnel.

During the coding process, the interviewees' discussions revealed the possibility of the changes and the change management actions being interconnected. A representative example of the interconnected changes was identified among a few potential alternatives based on its repeated emergence in most of the interviews. To illustrate the interconnections of this example, we mapped the changes, their underlying reasons, and the change management actions onto a flow chart.

For the purposes of this article, selected interview quotations were translated from the original language to English. The original quotations were mostly used verbatim, but the quotations were modified so that the anonymity of the case company and the case project were retained. We additionally used cross-tabulation of the key results to highlight key findings in the data.

Results

Plan-related changes and deviations from the PMM throughout the lifecycle of the case project

An overview of the different changes identified throughout the lifecycle of the case project is presented in Table 5, and an analysis of the changes in each of the project phases is presented in the following subsections. Further analysis of the interconnectedness of the changes is then introduced, and the management actions (change management and improvisation) are analyzed throughout the project lifecycle.

*** TABLE 5 TO BE ADDED HERE ***

Table 5. Summary of the different changes throughout the lifecycle of the case project

As Table 5 demonstrates, both changes to the project plans and deviations from the PMM took place throughout the lifecycle of the case project. In addition, there were different internal and external reasons behind those changes. The different changes and reasons for the changes are discussed further next.

The pre-project phases

Three important changes took place in the early phases of the project: a major change in the project schedule, a deviation from the desired (typical) resourcing of the project, and deviations from the

desired (typical) ways of working by EngineeringCo, forced by the challenging customer requirements.

Regarding the schedule change, in the sales negotiations phase discussions were ongoing between EngineeringCo and the customer about a demanding, but relatively typical (from the perspective of EngineeringCo), project schedule. In the earlier bidding phase, EngineeringCo's personnel had calculated a rough estimated schedule. Then, because of the demanding schedule, project personnel had already begun planning the project in greater detail, based on this schedule. In the very last phases of the sales negotiations, however, it turned out that a representative of EngineeringCo's top management had agreed on a new schedule that was several weeks shorter than the already tight original schedule. This was considered a difficulty by the project team — not only because of the shorter schedule, but also because the project team had already planned the project activities based on the original schedule. As one of the project managers explained:

> *"Well, what could we do? We had to accept the new schedule and start to look for ways to speed up the schedule. We started from the new deadline and worked backwards. When do we have to start shipping material to the site? When do we have to start procurement? Which activities could be started a bit earlier or finished a bit faster?"*

The resourcing of the project deviated from the EngineeringCo's typical ways of working as well. Due to the turbulent nature of project-based business, EngineeringCo subcontracts out a majority of its engineering and a large part of its manufacturing work. To manage the potentially negative side-effects of subcontracting, EngineeringCo tries to collaborate with the same partners from one project to another. However, at the same time as the case project, EngineeringCo was delivering several other major projects. This challenging situation, together with the relatively large size and

demanding nature of the project, forced a deviation from the typical ways of working (i.e., the typical resourcing; the PMM) and created several challenges for the project team.

The customer had a strong position in the sales negotiations phase. This was particularly due to the large financial importance of the project for EngineeringCo and the size difference between the customer and EngineeringCo. This situation led to several alterations to the work methods in the later phases of the project. Specifically, EngineeringCo's delivery contracts typically adhere to the company's own templates. In this case, however, the customer's contract template was used instead, which required EngineeringCo to deviate from its standard work practice. For instance, the usage of several materials was prohibited and more detailed documentation and reporting was required than what was typical in EngineeringCo's own PM methodology.

The engineering, manufacturing, and procurement phases

After the pre-project phases, the project progressed to the engineering, manufacturing, and procurement phases. Here, the most important changes were related to the schedule and quality of the engineering work, and the related adjustments to the manufacturing work.

When estimating the schedule for a project, EngineeringCo relies on the expertise of its key personnel and knowledge gained from working on similar projects in the past. A similar approach was followed in the case project. Because of the size of the project and the other simultaneously ongoing projects, EngineeringCo had to subcontract engineering work to subcontractors with whom it had little or no history of collaboration. This, together with the demanding nature of the project and the extremely demanding project schedule, led to several major delays in the engineering schedule, according to the interviewees.

There were also several problems with the quality of the engineering work. In hindsight, most of the interviewees linked the quality issues to three elements: the inexperience of the (subcontracted) engineers, the incomplete information about the factory site where the solution was delivered, and the customer's requirements. One interviewee explained the demanding nature of the factory site:

> *"...had to go to the factory and really measure how the systems can be installed. If you design this element this way, it could fit under that beam. But then you would have to modify that element that way..."*

The engineering challenges experienced during the engineering, manufacturing, and procurement phases all caused issues in the installation and implementation phase. When discussing ways to control the progress and the quality of the engineering work, a principal designer described the limited possibilities of noticing potential faults in the designs and specifications. According to him, he just had to trust the accuracy of the other designers' work:

> *"[because of time pressure and tight schedules] It is not possible to check all the details of all the designs. Based on my experience, I should know where the potential [problematic] issues are."*

Regarding manufacturing, the challenging and atypical customer requirements affected the manufacturing operations of EngineeringCo as well. In particular, several material choices and work methods were prohibited by the customer. As a manufacturing planner explained:

> *"The use of [a specific work method] was prohibited in the project contract ... It meant extra work for us, when we had to go through specifications and look for places where those work methods should be changed to a different work method."*

For the most part, it was simply a matter of going through the specifications and making the required modifications, as explained above. However, there were several situations in which these modifications could not be made and the prohibited work method was the only way to manufacture the specific elements. These situations required the manufacturing planner to instruct the manufacturing employees to alter the approaches to their work; that is, to explicitly instruct improvisational actions. Improvisation was required because the manufacturing employees would follow an engineering specification by default, and carry out the manufacturing based on those specifications. As the manufacturing planner explained:

> *"Then there were cases where [the prohibited work method] could not be avoided. We had to instruct the employees that in these cases, with this work number and this project number, you should not follow the specification but instead use [another work method]."*

In terms of the improvisational actions instructed, mistakes were made. Employees manufactured some elements by following the specifications and forgot the instructions that were specific to this project. Thus, work had to be redone.

Most of the interviewees considered the customer's special requirements relatively unnecessary, particularly because the customer's background was in a slightly different industry in which there was a need to prohibit the use of specific materials and work methods in their products. However, in the systems provided by EngineeringCo, those requirements were not needed. To further complicate matters, not only were the requirements unnecessary, but some were impossible for EngineeringCo to fulfill. As one interviewee explained:

"It would also be important to take into account the manufacturing viewpoints in the sales negotiations phase. So it would not happen that we have agreed on something and then later it turns out that we can't fulfill those obligations."

The second group of manufacturing-related changes dealt with the delayed engineering work. The criticality of the installation and implementation phase was regularly emphasized by the project personnel. Consequently, the delayed engineering work put pressure on the manufacturing phase to catch up some of those delays. Several re-planning tactics were used to achieve this, including the modification and prioritization of job queues, hiring contract workers, and overtime work. In fact, a big part of the project's delayed schedule was compensated for during the manufacturing phase.

The installation and implementation phase

The installation and implementation phase was considered to be the most problematic by a clear majority of the interviewees, both as it related to EngineeringCo's delivery projects in general and to the case project in particular. The interviewees explained how different issues in the earlier phases of a project might not be immediately noticed and might only become apparent in the installation and implementation phase, thereby causing several deviations from the preferred approaches to the work and changes to the project plan.

An illustrative example is an error in the engineering specifications of several of the project's systems. The case project was delivered to an old factory building, which created several difficulties for the engineering functions. One central item of information regarding the measurements of the factory building was missing from the specification data provided to the engineers. It was not until the installation phase that the assemblers noticed that the systems could

not be installed as planned, due to the incorrect measurements. As an assembly supervisor explained:

> *"Yep, the floor plans of the factory did not match the original specifications. We had to modify the system and build alternative solutions at the site. It does not look good to do those things at the customer's site, you know. And of course it took time."*

Having had problems in the installation and implementation phase of its delivery projects in the past, EngineeringCo had proactively prepared for this to occur in this phase of the case project. For example, the company had tested many subsystems before transporting them to the customer's site, and had invested more in the planning and resourcing of the installation and implementation than it normally would. Despite these efforts, several challenges still took place in this phase. Various reasons for the difficulties in the installation and implementation phase were identified by the interviewees. Errors in the engineering specifications or issues with the quality of the manufacturing work in the earlier phases could not have been noticed before the installation and implementation phase on-site. This was partly because some of the subsystems were too large to be tested before they were transported to the site. As an experienced assembly supervisor explained:

> *"Yes, you can prepare better and plan better. Still some fixing etc. takes place every time. You just can't picture how the system will work in real life just based on the specifications and sketches; you have to see it in reality."*

The sentiment professed in the quotation above was shared by many of the interviewees. The interviewees perceived that a certain level of improvisation was inevitable in the installation and implementation phase. Many of them described how EngineeringCo's systems *"don't work*

perfectly immediately after you switch on the power." As the aforementioned assembly supervisor stated:

> *"For instance, you notice that two subsystems don't work correctly in synchronization with each other. Then you just take a pen and a paper and try to figure out what could be done to improve the situation."*

What makes the nature of the installation and implementation phase problematic is the uncertainty related to the changes and deviations. As many managers and designers emphasized, and a clear majority of the interviewees agreed, when the schedule of the installation and implementation phase cannot be followed, it is problematic for the company. One of the managers described the following:

> *"Having learned from earlier projects, we had built a buffer of several weeks into the project schedule, because we wanted to have extra time in the installation and implementation phase. In addition, we really focused on calculating the schedule and resourcing this phase. But still, all the extra buffer was used."*

Other reasons for the challenging installation and implementation phase were errors in the installation work. Similar to the engineers, a number of the employees working on the installation were either inexperienced or not familiar with working with the case company. This was problematic because the control of the installation phase relied to a certain extent on the employees' experience. As an assembly supervisor explained:

> *"Yes, in theory you just check the specifications and install the system following that. But in practice not everything is written and you just have to know how our systems are designed and how they work."*

As the company's PMM relied on people knowing its standard work practice, it is clear that subcontracted engineers with limited previous experience were unfamiliar with the methodology, thereby causing deviations to occur.

Lastly, several issues in the installation and implementation phase were caused by the customer's behavior since the customer lacked experience in the field of systems delivered by EngineeringCo. Notably, the customer's project team lacked expertise in the earlier phases of the project, which caused them to make several wrong decisions. In the later phases of the project, the customer strengthened its project team, after which time it demanded several changes be made to the system design. EngineeringCo had to respond to the requests, which meant additional changes had to be made to the installation and implementation phase timeline. As an example, major changes were required to be made to several items of safety-related equipment, but only after the equipment had been almost completely installed.

Another group of changes originating with the customer related yet again to the old factory building. Because the building had previously been used for a different type of business, it was not entirely suitable for the new systems. It was decided that it was the customer's responsibility to arrange for the required modifications to be made to the factory building. However, the customer struggled with this responsibility and several renovations were delayed — some by several weeks. From EngineeringCo's perspective, this required additional changes to be made to the original project schedule. As the project manager responsible for the installation and implementation phase described:

> *"For instance, one room of the factory building required a new floor, because the old one would not support the weight of the new systems. It turned out, however, that the floor work would be delayed by almost a month. We couldn't do anything about it, we*

just had to figure out alternative tasks to be done while waiting for the new floor to be built."

Interconnected changes throughout the lifecycle of the case project

The case project featured some patterns in which many of the identified changes were clearly interconnected, and thereby caused an escalation of the changes — or at least increased the possibility of such an escalation occurring over time. A clear majority of the interviewees described episodes where "a later event occurred due to a change or deviation earlier in the project."

Interconnections were especially evident when the interviewees discussed the problems in the installation and implementation phase. Having learned from numerous previous projects, EngineeringCo — and its project managers in particular — had a strong feeling that the biggest challenge would be the last phase of the project lifecycle. A thought similar to that expressed in the following quote was shared by many interviewees:

"Our projects progress very well until the shipments leave the factory and we start installing the system. Then we can spend weeks or months "fumbling" at the customer's premises, in front of the customer's eyes."

When further analyzing the interconnected changes, a clear majority of the interviewees expressed the view that many of the issues causing problems in the installation and implementation phase could trace their roots to earlier in the project lifecycle. These issues just had not become visible or topical until reaching the installation and implementation phase. Figure 1 shows an example of the interconnected changes and related actions in the case project. The figure is divided into the perceived reasons for changes, the different changes throughout the project's lifecycle, and the

respective change management and improvisational actions performed by project personnel. The arrows illustrate the relationships between the changes and the change management actions, as perceived by the interviewees.

*** FIGURE 1 TO BE ADDED HERE ***

Figure 1. An illustrative example of interconnected changes and change management and improvisational actions

The example in Figure 1 shows that several changes took place in different phases of the project lifecycle and that different personnel performed different actions to react to those changes. This path of actions finally led to the problems experienced in the installation and implementation phase, which were most visible to the outside the project.

Change management and improvisation throughout the lifecycle of the delivery project

The previous subsections have discussed the two types of changes and touched on the respective change management and improvisational actions taken throughout the lifecycle of the case project. Table 6 summarizes the change management and improvisational actions employed by EngineeringCo in relation to those actions.

*** TABLE 6 TO BE ADDED HERE ***

Table 6. Change management and improvisational actions taken by EngineeringCo's project personnel throughout the lifecycle of the case project

The analysis shows that managers and project personnel were active and responsive during all project lifecycle phases when changes took place. Indeed, it was not just project managers who

responded to changes, but assembly workers, supervisors, designers, and other project personnel figured out their own unique ways to resolve change events. Four somewhat different change management and improvisation actions were identified as responses to changes, all oriented toward achieving the best possible project performance: creating alternative paths, re-planning, catching up, and optimizing project performance.

Re-planning can be considered a rather typical change management action as a response to plan-related changes, and it was performed mostly by project managers. Following this change management action, project managers reacted to changes in the project plans by creating new, adapted and feasible plans. An illustrative example was the project managers' response to the schedule change demanded by the top management of EngineeringCo.

The three types of improvisational action were all highly interconnected and focused on the need to deviate from the typical ways of project work in EngineeringCo. Regarding alternative paths, the project personnel sought for alternative ways of working due to, for example, work methods prohibited by the customer. Catching up, and optimizing project performance were more improvisational in nature and were mostly performed by other personnel groups, not project managers.

Discussion

In this paper, we have explored the different types of changes that emerged during a complex delivery project, the reasons behind those changes and the project personnel's experiences when dealing with them. The case project — despite experiencing a variety of unforeseen events and carrying out various changes — fulfilled its promise to the customer, and is thereby a good

example to show that even with updates and modifications, project success is possible. Below, we discuss the main findings in light of the previous literature.

Different types and sources of changes

In the first research question, we asked: What kinds of changes do project personnel experience during the project lifecycle, including: a) changes to the project plan; and b) deviations from the PMM, and what are the origins of the changes? We purposefully sought out changes to the project plans and deviations from the PMM. Although both types of issues have been covered in previous research, they have either been addressed in separate papers, or not clearly differentiated. This paper has revealed the dynamics and drivers of changes during the delivery project and the interconnections of different changes over time, thereby increasing understanding about the path-dependent nature of changes and change management.

The findings of this study highlight the need to understand and track changes and change management over the lifecycle of a project, instead of describing them merely cross-sectionally. The study demonstrates how changes took place throughout the lifecycle of a delivery project, with the first changes having actually taken place before the official start of the project, and the final changes occurring in the late stages of the installation and implementation phase. The evidence from the case study responds to the identified need to study changes and change management throughout the lifecycle of a project (e.g., Dvir and Lechler, 2004; Zhang, 2013) and thereby offers a novel, dynamic view to changes and change management.

In this study, we have argued that different types of changes occur in delivery projects. In particular, both plan-related changes and deviations from the PMM took place throughout the project's lifecycle (Table 5). Although the existing literature has acknowledged the existence of

both types of changes, they have been studied mostly separately. The findings from the case project offer an example about project personnel resolving the emerging challenges successfully by using change management actions and improvisational actions selectively. Where the project management research and practitioner literature have traditionally followed normative and planning-centric perspectives (Leybourne, 2017), the findings suggests thatunderstanding the role of improvisational actions is important, for the project personnel to master the dynamics of change in complex and uncertain delivery projects.

The reasons behind the changes were identified as internal or external, from the perspective of the project contractor. This follows the generally accepted view that changes can be due to both the project contractor's own behavior and external environmental factors. Concerning the external factors causing the changes, the role of the customer was heavily emphasized by the interviewees. In this case, the customer compelled the project contractor to make changes for three different reasons: stating partly unclear and changing requirements, by setting atypical requirements during the sales negotiation phase, and by not keeping its own commitments during the installation and implementation phase. The problem of having unclear requirements, and to some extent the setting of new requirements, is discussed in the existing literature (e.g., Dvir and Lechler, 2004). The customer's failure to adhere to its own commitments, however, has not been explicitly addressed by existing studies. This issue was also perceived as problematic by the interviewees; the interviewees discussed how difficult it is for the project contractor to properly complain about the customer's behavior, or make strong demands. Whether this was a unique phenomenon witnessed in one project implemented by a single company should be studied more in future research.

The findings revealed that many of the changes were interconnected and that changes initiated in the early phases of the project transformed into other changes later. For instance, the schedule

delays in the engineering phase caused subsequent changes to be made during the manufacturing phase. Similarly, the incomplete information gathered about the installation site in the earlier phases of the project was one of the reasons for the challenges experienced during the installation and implementation phase. The interconnected changes included both plan-related changes and deviations from the PMM, highlighting again the importance of taking into account both types of changes and the dynamics of changes over the lifecycle of the project.

Although the escalating plan changes and PMM deviations could have potentially led to failure, the case project demonstrated that various change management and improvisational actions were used successfully in order to keep the project on the right track. The examples of path-dependency between the changes suggest that changes in projects should not be treated as isolated events or episodes, but rather their interdependencies should be understood as well. The results also highlight the importance of information sharing within the complex delivery project to ensure that all the various implications of the plan changes and PMM deviations are considered, even when moving from one phase to another within the project lifecycle. In a similar vein, poor or ineffective communication between the project actors has been identified as a reason for critical changes in construction projects (Yap et al., 2017). The findings of our study highlight that effective information sharing is even more crucial in situations in which different personnel are responsible for different phases of a project, which is typical in industrial delivery projects.

Improvising and managing changes over the project lifecycle

The second research question inquired: How do project personnel and managers implement change management and improvisation actions in the different phases of the project lifecycle? To answer this research question, the change management and improvisational actions performed by the different project personnel were identified (Tables 6 and 7). By distinguishing between the two

types of actions and mapping them by the active project actors, this study contributes to the general need to study improvisation in project contexts, especially regarding delivery projects (Leybourne and Kennedy, 2015). This paper offers evidence on change management and improvisation as a shared responsibility among project personnel (instead of project manager's task), and on four different patterns of change management.

Our findings raise the need to consider change management and improvisation from the perspective of the whole project team (or project personnel even more widely), instead of focusing only on project managers. The improvisation literature in particular (Table 2), and to some extent the literature on change management as well (Table 1), has focused on the role of the manager — particularly the project manager — in performing the improvisational or change management actions (e.g., Leybourne and Sadler-Smith, 2006). According to the findings of this study, however, project managers were not the only project actors active in performing change management and improvisational actions; instead, different actions were performed by different project personnel. In fact, improvisational actions were taken more often by other project personnel than they were by the project managers, as illustrated in Table 7. Here, the two types of actions are distinguished so that "change management" refers to the responses to the plan-related changes and "improvisation" refers to the responses to the deviations from the PMM.

*** TABLE 7 TO BE ADDED HERE ***

Table 7. Examples of change management and improvisational actions performed by different project personnel

As Table 7 shows, project managers mainly carried out change management actions, whereas middle managers and experts performed both types of actions, while operational employees

engaged in improvisational actions. This finding contributes to the existing literature that focuses on managers and project managers and is yet another main finding that should be tested in future research.

In addition to different personnel performing different change management and improvisational actions, Table 7 also reveals a different focus between the two types of action. In change management actions the focus was mainly on scheduling and customer aspects, while in improvisational actions the focus was mostly on project scope and system functionality. Both the role and the focus aspects contribute to the previously expressed need to understand the nature of improvisation in project contexts better (Leybourne, 2006; Leybourne and Sadler-Smith, 2006), suggesting that different change management and improvisational actions should be designed for different purposes.

Due to the uncertain, dynamic, and turbulent nature of projects, the improvisation of and adaption to the changing requirements of the external environment are essential for project organizations (Leybourne, 2017; Lindkvist, 2008). The four patterns of change management and improvisation actions — creating alternative paths, re-planning, catching up, and optimizing project performance — show how this adaptation can take different forms in different phases of the project lifecycle. The results demonstrate that these actions are not only performed by the project managers, as emphasized in most of the previous literature, but by other project personnel as well. Nor is the need for adaptation limited to the external environment; rather, the actions of the project organization itself can also necessitate later improvisation.

Conclusions

This study has contributed to the existing body of research on change management and improvisation in delivery projects. The case study provided evidence of the internal and external reasons for changes, described two types of changes (plan-related changes and deviations from a PMM), and highlighted the interconnected nature of changes. As a whole, the study has responded to the calls to understand changes in projects over a project lifecycle (e.g., Dvir and Lechler, 2004; Zhang, 2013), to acknowledge both internal and external reasons for changes and to study improvisation in a project context (Leybourne, 2006; Leybourne and Sadler-Smith, 2006), delivery projects in particular (Leybourne and Kennedy, 2015). The primary contribution of revealing the lifecycle view to changes and change management complements a cross-sectional and static approach to changes and suggests researchers and practitioners to acknowledge path-dependencies between changes and change management.

The study has revealed the distributed responsibility for different types of change management and improvisational actions among project personnel, and the different purposes of the actions. The results of the successful and, yet, constantly changing case project showed evidence that change management and improvisational actions are not only performed by project managers, but also by middle managers, work supervisors and operational employees. The case study suggested that project managers mainly perform change management actions and operational employees mainly perform improvisational actions, whereas middle managers perform both types of actions. The focus of change management actions was mainly on scheduling and customer aspects, while the focus of improvisational actions was mainly on project scope and system functionality. In all, these findings draw attention to project personnel as micro-level change agents, differing in their

championing and scope of influence in managing changes. Thereby, the study contributes by pointing out the actor-centric view to change management.

Finally, the results have demonstrated four different patterns of change management and improvisational actions that were performed due to the changes: creating alternative paths, re-planning, catching up, and optimizing project performance after changes were made. Understanding of such tactics that project personnel use contributes to research in two primary ways. First, they offer more fine-grained knowledge of the practice of change management and improvisation than categorization through the degree of improvisation only (e.g. Klein et al., 2015). Second, they could be further developed into change management templates that combine previously identified change management practices of configuration management (Whyte et al., 2016), coordination (Zhang, 2013), coping mechanisms (Aaltonen et al., 2010; Tukiainen et al., 2010), using information (Whyte et al., 2016), and communication (Butt et al., 2016). The discovered change management and improvisational tactics could be further elaborated, to guide project personnel in dynamic contexts.

Our study has several implications for managers and project management practitioners. First, practitioners should be aware of the two types of changes and the internal and external reasons for them so that they can identify the changes and drivers in practice. Second, the study has identified two types of change-related work practices — change management and improvisational actions — and four alternative patterns of these practices, offering potential ways to guide personnel in adopting appropriate actions for certain types of changes. The study has also shown how different project personnel have a tendency to follow one or another of the two ways of reacting to changes, and that the two types of change-related actions focus on different purposes. This again may be relevant, when educating project personnel for their change management tasks. Third, the study

has emphasized the role of the project customer as a source of changes, and discussed why it is difficult for the project contractor to prevent customer-related changes from occurring. Findings concerning the sources of change are helpful for project personnel when they need to justify and explain their responses to customer-driven changes.

The single-case research design limits the generalizability of the findings, meaning that the extent to which the findings reflect a phenomenon unique to an individual company's single project can be questioned. Therefore, these findings should be tested in a variety of industries and contexts and by using different research designs. The choice of the case company and the case project may cause validity limitations, too. We have justified the choices, described the characteristics of the company and project, and offered background information of the lifecycle of the project, to improve validity.

It is possible that some findings concerning the interconnections between changes and the improvisational responses reflect the particular nature of the PMM in the case company (i.e. it being an established routine, instead of a formal guideline). For example, a more formal PMM with its capability requirements could have been reflected in other kinds of changes and change management and improvisation tactics, and avoidance or easier mitigation of path-dependent changes. Therefore, it would be of interest to study and understand if the use of a more formal PMM would cause different results in terms of changes and change management patterns.

Finally, there is a limited amount of research on improvisation in projects (Leybourne, 2006; Leybourne and Sadler-Smith, 2006). Many of the few existing studies have focused on the financial industry and a need for research on improvisation in delivery projects has been expressed (Leybourne and Kennedy, 2015). This study is among the very few answering to that call and acknowledging the role of improvisational actions in delivery projects. The findings of this study,

especially the alternative patterns of change management, the actor-centric view and the different purposes of the two types of response actions should be studied further and tested with different types of delivery projects.

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Table 1. Examples of empirical studies on changes and change management in projects and their contribution to this research

	Research design, data and context	Key findings for this study	Gaps/opportunities for this study
Butt et al., 2016	Two-case study, action research; qualitative data from meetings, documents, etc.; infrastructure and renovation project.	- Relevance of communication routines for stakeholder engagement and evolution of project culture. - Customization of routines for the needs of the project. - Different kinds of changes and change management; relevance of change management throughout the lifecycle of the projects.	- Focus on communication and stakeholder relations – not other aspects of change control. - Construction-centric data – need for studies on other project types.
Dvir and Lechler, 2004	Questionnaire study; data from 448 projects; different project contexts and types.	- Positive effects of good project planning are almost completely overridden by the negative effects of goal changes. Combined effects also significant. - Contextual issues relevant in the planning process.	- Need to study causes of goal changes and develop the change variables further. - Need to study the lifecycle of projects to understand the interactions of planning and changes.
Steffens et al., 2007	Exploratory research, embedded case study with seven projects; interviews, project documentation and change database; telecommunications product development.	- Decision criteria for different changes. - Different decision-making approaches for different changes and projects, even within the same company. - The dangers of too formal change management.	- Need to study the link between types of changes and their control (decision criteria), i.e., contingency view to change management. - Need to understand also other project personnel and not just the managers' views.
Zhang, 2013	Qualitative embedded two-case study (four projects); observation, interviews, documents; two system/solution provider firms.	- "Stage iteration" over the lifecycle of the project because everything cannot be planned in the beginning. - Different levels of planning and iterations. - When project size/complexity increases, issue management becomes more relevant. - Optimization in change decisions due to tensions between stakeholders' expectations.	- Explore the issue in other industries and economies. - Need for in-depth studies on decision-making patterns regarding changes and stakeholders' conflicting interests and objectives concerning them.
Whyte et al., 2016	Qualitative multiple-case study; interviews, documentation, workshop; three organizations delivering complex product systems using digital technologies.	- Different approaches to configuration management in different organizations. - Lifecycle aspect of configuration management is relevant, particularly if the organization is involved in post-project services or operations. - Information of the asset (and related big data) is important for managing changes.	- The idea of "baseline" must be clearly understood and agreed upon. - Itemization of the subsystem of the complex product and related information requires mapping and frameworks. - Models for developing the validity of asset information in digital systems are needed.
Wu et al., 2005	Embedded case study (three subprojects); qualitative analysis of 1038 change orders and statistical analysis of their cost effects; a highway project in Taiwan	- Mapping of change orders, their internal and external causes, and cost effects. - Different engineering properties – different change concerns.	- Need to learn from past projects to anticipate changes in the front-end and planning of new projects.

Table 2. Examples of empirical studies on improvisation in projects and their contribution to this research

	Design, data, and context	Key findings for this study	Gaps/opportunities for this study
Gallo and Gardiner, 2007	Research design and data: Three company cases, interview data Research context: UK financial services sector	- Ten different "triggers" (reasons for flexibility and improvisation). - Projects perceived as more important by project personnel are implemented so that a maximum amount of flexibility, i.e., possibility for improvisation, is retained.	- Focus on financial sector — other industries and project types should also be studied. - The links between flexibility (i.e., improvisation) and control. - Focus limited to managers' perceptions.
Jerbrant and Karrbom Gustavsson, 2013	Research design and data: Two company cases, observation and interview data Research context: Two project management offices: a medium-sized engineering company and a medium-sized private telecom operator	- Structures and situated actions in project portfolios, both at the level of the portfolio and concerning projects. - Methodologies do not provide enough support for sense-making and, therefore, situated actions (i.e., improvisation) are needed.	- Need to understand different types of organizations and different ways to improvise. - Focus limited to improvisation practiced by portfolio managers (and implicitly project managers).
Leybourne, 2006	Research design and data: Case study with six organizations, multiple methods Research context: UK financial services sector	- Extensive use and acceptance of improvisation among the organizations, emerging from the circumstances and context. - Acceptance, application, control, and effectiveness of improvisation differed across organizations.	- Focus on financial sector and strategic change — other industries and project types should also be studied. - Focus quite generally on the organizations' different ways of developing and managing improvisational working practices. - Projects and project-based ways of working only implicitly form part of the study.
Leyborne and Sadler-Smith, 2006	Research design and data: Cross-sectional survey design Research context: Members of APM engaging in project-based change initiatives within the UK financial services sector.	Identified a positive relationship: - between the use of intuitive judgments and improvisation; - between experience and improvisation; - between the use of intuitive judgments and experience; - and between the use of intuitive judgments and externally focused project outcomes.	- Need for research on the relationships between project type, contextual factors, and improvisation outcomes. - Focus limited to the improvisation practiced by project managers.

Table 3. Summary of data collection

Project supplier	EngineeringCo: a medium-sized engineering company delivering tailored engineering solutions as customer-specific projects
Case project	A demanding factory-level solution consisting of multiple systems and subsystems
Interviews	17 individual interviews, average duration 75min (42min-93min)
Interviewees	Job profiles of the interviewees: project managers, managers, planners, supervisors, sales people, operational and assembly workers Areas of responsibilities covered: project management, sales, planning and design, procurement, manufacturing and assembly, safety, installation and implementation

Table 4. The main coding categories used in data analysis

Coding category	Description	Details and examples
The relevant project lifecycle phase	When (in which project lifecycle phase) did the change or deviation take place?	- Sales negotiation - Project planning - Engineering - Procurement - Manufacturing - Testing - Logistics - Installation and implementation
The type of the change: - A plan-related change - A deviation from the PMM	Was it a change to the original project plans, or a deviation from the PMM?	Plan-related changes, for example: - A new project schedule - Work design tactics (job order, overtime work, etc.) Deviations from the PMM, for example: - Altered project resourcing - Altered product design in the manufacturing phase
The reason(s) behind the change: - External - Internal	What were the reasons for the change or the deviation, as perceived by the interviewee?	External - i.e., the reason/s for the change originated outside of EngineeringCo, for example: - Customer's actions or requirements - Supplier's actions or requirements Internal - i.e., the reason(s) for the change originated within EngineeringCo, for example: - Simultaneous projects - Problems in internal communication
The response action taken by the project personnel: - Change management action - Improvisational action	How did the project personnel response to the change or the deviation? Who were the people active in responding?	Change management action - response action to a plan-related change, for example: - New/modified project plans (e.g., a modified schedule) Improvisational action - response action to a deviation from PMM, for example - Alternative work design tactics

Table 5. Summary of the different changes throughout the lifecycle of the case project

Lifecycle phase and change (including the type of change)	Perceived reason for the change • internal = the reason(s) for the change originated within EngineeringCo • external = the reason(s) for the change originated outside of EngineeringCo
Pre-project phases	
Plan-related change: A demanding schedule change negotiated by top management without the project team knowing.	External: - The high importance of the project for EngineeringCo and the strong bargaining position of the customer enabling the customer to set requirements for EngineeringCo. Internal: - Lack of internal communication between the top management of EngineeringCo and the project team representatives.
Deviations from the PMM: Several requirements set by the customer. For instance, requirements for documentation, reporting, and prohibited materials.	External: - The high importance of the project for EngineeringCo and the strong bargaining position of the customer enabling the customer to set requirements for EngineeringCo. Internal: - Lack of internal communication between sales and other departments of EngineeringCo.
Deviations from the PMM: Changes to EngineeringCo's desired/customary project resourcing.	Internal: - EngineeringCo's strategic choice to rely heavily on subcontracting in engineering and manufacturing. - Simultaneously ongoing projects combined with the demanding nature of the case project made it difficult to find suitable subcontracted resources.
Engineering, manufacturing, and procurement phases	
Plan-related change: Delays and quality issues in the schedule of the engineering work.	Internal: - Some of the subcontracted designers were less experienced than usual. - The different experience levels were not sufficiently taken into account when planning the project schedule, particularly after the schedule change.
Deviations from the PMM: Work methods prohibited by the customer create difficulties and require innovative actions in the manufacturing phase.	External: - The high importance of the project for EngineeringCo and the strong bargaining position of the customer enabling the customer to set requirements for EngineeringCo. - The customer's background in a different industry, where the prohibition of specific materials and work methods makes sense. For the systems delivered by EngineeringCo, these types of requirements are mostly unnecessary. Internal: - The customer's requirements being agreed to without considering the manufacturing aspects of EngineeringCo.
Plan-related change: Work design tactics in the manufacturing phase.	Internal: - Because of the delays in engineering work, different tactics were used in the manufacturing phase in order to catch up on some of those delays.
Installation and implementation phase	
Deviations from the PMM: Changes and modifications in system installation and implementation.	External: - Incomplete/incorrect data (e.g., about the factory building) provided to EngineeringCo. - Incomplete and changing customer requirements. Internal: - Insufficient internal communication within EngineeringCo. - Errors in engineering specifications and mistakes in equipment installation or manufacturing quality. - Fewer experienced personnel than usual.
Plan-related change: Schedule modifications due to customer's actions.	External: - Customer failing to follow the agreed upon schedule on making factory building modifications.

Table 6. Change management and improvisational actions taken by EngineeringCo throughout the lifecycle of the case project

Lifecycle phase and change	EngineeringCo's change management and improvisational actions
Pre-project phases	
A schedule change negotiated by top management without the project team knowing.	- The project managers had to estimate a new schedule for the project. (re-plan) - The fear of significant financial sanctions increased the importance of the project schedule even further. This led to project managers focusing more heavily on schedule planning and on emphasizing the importance of meeting the targets. (re-plan, optimize)
Several changes made to EngineeringCo's standard work methods. For instance, documentation requirements and prohibited material choices.	- An atypical contract had to be taken into account by all departments. (create alternatives, optimize)
Deviations from EngineeringCo's preferred resourcing of the project.	- The less experienced project team members created uncertainty in the project schedule (as they were not completely familiar with EngineeringCo's solutions). Later, the designers and project managers realized that this should have been taken into account in the project schedule by adding time to some tasks. (re-plan, optimize) - In many phases of the project lifecycle, responsible personnel had become used to working with more experienced employees. The responsible personnel had to alter their ways of managing and controlling the work of the less experienced personnel. (create alternatives, optimize)
Engineering, manufacturing, and procurement phases	
Delays in the schedule of the engineering work.	- The delays in the engineering work put pressure on the subsequent phases. Due to the delays, several tactics were used by the manufacturing planners, etc., to catch up with the schedule. (create alternatives, catch up) - The personnel responsible for the manufacturing phases followed the progress of the engineering phase actively and reacted correspondingly. (catch up, optimize)
Prohibited work methods required by the customer caused difficulties in the manufacturing work.	Two types of actions were taken to meet the requirements of the delivery contract: - Specifications were modified by the manufacturing planners and their teams to eliminate the prohibited work methods. (re-plan) - When a prohibited work method could not be avoided, manufacturing employees were instructed to work against the specifications. (optimize, create alternatives)
Work design tactics in the manufacturing phase.	- Several tactics were used by the manufacturing planners, etc., to compensate for the engineering phase's schedule delays. These included the modification and prioritization of job queues, contract work, and overtime work. (catch up, optimize, re-plan)
Installation and implementation phase	
Changes and modifications in installation and implementation.	- Improvisational actions were taken by the assembly workers and supervisors, etc., to figure out the issues in the installed systems and to get the systems working optimally. (optimize, create alternatives)
Schedule modifications due to customer's actions.	- Installation and implementation schedules were modified and alternatives were sought out by the project manager responsible for the installation and implementation phase. (re-plan, create alternatives)

Table 7. Examples of change management and improvisational actions performed by different project personnel

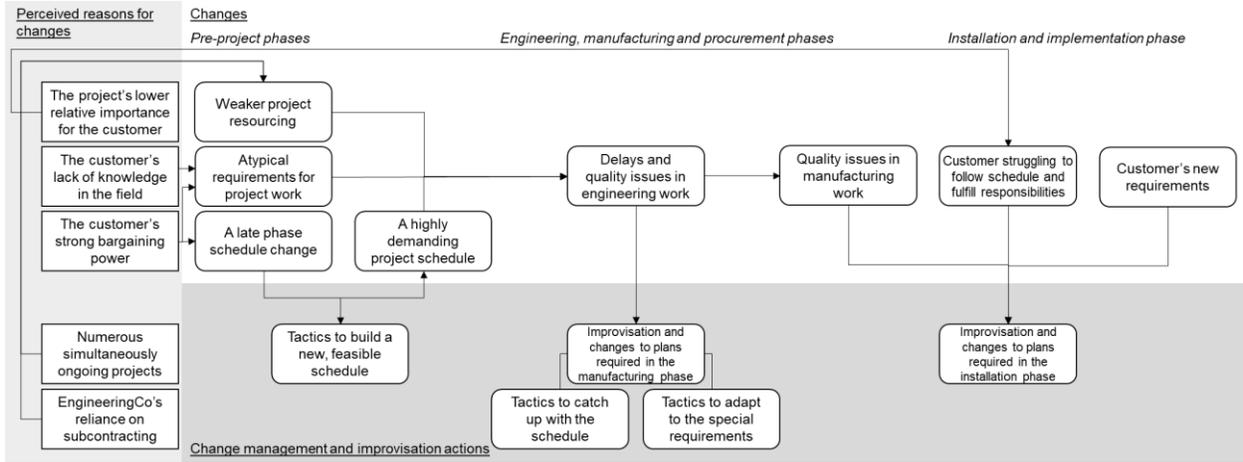| Project actor	Change management actions	Improvisational actions
Project managers	- Schedule modifications. - Negotiations with the customer related to the changing requirements and their fulfillment. - Work design tactics.	
Planners and manufacturing employees	- Work design tactics (e.g., overtime and altered work instructions) to make up for schedule delays.	- Improvisational work and instruction of improvisational work to meet difficult/incompatible customer requirements.
Middle managers, work supervisors	- Work design tactics (e.g., overtime and altered work instructions) to make up for schedule delays.	- New ways of managing the work of less experienced employees. - Improvisational work and instruction of improvisational work to adapt to challenging situations in the installation and implementation phase.
Assembly		- Improvisational work to achieve an optimally functioning system in the installation and implementation phase.

Figure 1. An illustrative example of interconnected changes and change management and improvisational actions.