NTNU – Trondheim
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MASTER OF SCIENCE IN INFORMATICS

Assessing the Effects of Digitalization using Log Data

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Abstract

This thesis explores using log data to assess the effects of digitalization. A literature review of topics related to digitalization, continuous software engineering, and collecting feedback was carried out to provide an overview and understanding of the topics central to the thesis. A case study into an information and reporting application at Aker Solutions was conducted. Through analysing log data related to progress reporting in a fabrication process, the thesis contributes an in-depth analysis of the lead time in three different projects – before, during, and after the application was implemented. Five interviews with employees related to the process were conducted to provide context to the analysis. The log data lacks complexity and does not account for important factors influencing the lead time. Using the knowledge obtained from the interviews opens for educated guesses regarding the variations in lead time between the projects.

Sammendrag

Digitalisering er utbredt i dagens samfunn, og mange bedrifter prøver å utnytte mulighetene som digitalisering åpner for. Å vurdere om prosessen har vært vellykket er det relevant å måle resultatene av digitalisering opp imot kostnadene. Det er derfor essensielt å finne relevante målinger som kan belyse effektene av digitalisering. Forståelse for samspillet mellom digitalisering og prosesser og prosedyrer innen en bedrift kan også bidra i kontinuerlig programvareutvikling.

Det ble gjennomført en casestudie med søkelys på å avgjøre om loggdata knyttet til fremdriftsrapportering kunne gi innsikt i effektene av digitalisering. Loggdata hentet fra tre prosjekter gjennomført ved avdelingen prefab rør ble analysert for å undersøke om digitaliseringen har ført til at prosessen har blitt mer effektiv. Prosjektene ble henholdsvis gjennomført før, underveis og etter implementeringen av WeBuild. Det ble også gjennomført fem intervjuer med ansatte knyttet til prosessen ved avdelingen prefab rør for å få innsikt i utviklingen og implementeringen av mobilapplikasjonen WeBuild. Denne informasjonen ble brukt til å vurdere om loggdataene ga tilstrekkelig forankring til å analysere effektene av digitalisering.

Prefab rør deltok ikke i kravinnsamlingen som dannet grunnlaget for WeBuild. Resultatet er at applikasjonen ikke reflekterer avdelingens behov. Det virker ikke til å være et mål å utvide bruken av WeBuild slik som funksjonaliteten er i dag. Selv om WeBuild kun har hatt en liten innvirkning på arbeidsprosessen så varierer ledetiden stort mellom prosjekter gjennomført før og etter applikasjonen ble tatt i bruk. Dataen brukt til å utlede ledetiden er enkle og kunne ikke redegjøre for viktige faktorer som arbeidspakkenes omfang eller antall ansatte.

Acknowledgements

I would like to thank my supervisor Joakim Klemets for providing helpful advice, support, and guidance throughout the project.
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Abbreviations

CSE	Continuous software engineering
AKSO	Aker Solutions ASA
SDLC	Software development life cycle
MTO	Material take off
BPMN	Business process model notation
IQR	Interquartile range

Chapter 1

Introduction

1.1 Overview

Companies want to streamline processes and procedures in order to succeed in competitive markets. One of the ways to achieve this is by introducing new digital tools [1]. Parts of the intended user group, however, often reject digitization efforts. The challenges associated with implementing technology are usually less related to technical problems than human ones [2, p. 540]. Promoting an organizational culture receptive to change is critical to increasing the likelihood of technology acceptance [3].

Adapting functionality to conform to the users' needs is a common challenge in digitization projects. This challenge is often addressed through user-centered design before the development begins. Despite this effort, problems still tend to arise when the system is deployed [4]. DevOps enables frequent and continuous delivery of software versions. This approach allows user adaptation to be observed for each release. Problems related to a release can be detected early on and addressed til the next release [5].

Collecting feedback from users in continuous software engineering can help guide the development process. However, manual data capture may reduce the efficiency of the ongoing development process [6]. Automating feedback processing can help to remedy this problem. Furthermore, combining automated capture and processing of user feedback can be an important step in understanding the changing needs of the users [7].

1.2 Problem statement and research questions

Aker Solution's yard at Stord specializes in building offshore constructions. Recently, the company developed and implemented an information and reporting application named WeBuild. Several departments use WeBuild at the yard, including prefab piping.

Among the core ideas of WeBuild is to provide workers with information related to their jobs digitally instead of on paper. WeBuild was also intended to provide a higher degree of independence in the working day. This was going to be achieved by having more easily accessible information and allowing self-reporting of work progress instead of leaving the job to superiors. This way, data quality would also increase since reporting will occur near real-time instead of later in batch operations.

The thesis investigates how the use of the application change during the development and implementation phases. The purpose is to detect underlying reasons for the differences in use and explore methods to localize problems early on. Accordingly, the thesis will explore the following research questions:

> **RQ1**: Do log data provide sufficient grounding to analyze the effects of digitalization?

In the context of this thesis, log data refers to data from progress reporting at prefab piping. The effects of digitalization refer to changes that WeBuild brought about. Analyzing progress reporting can help detecting differences in lead time and data quality after the deployment of WeBuild. For this type of log data to be deemed sufficient to analyze the effects of digitalization, findings in the analysis must reflect and account for events seen in real-life.

> **RQ2**: How did the development and implementation of WeBuild unfold?

Investigating the development and implementation of WeBuild prerequisite to answering RQ1. Understanding how the application has been used at different points is necessary to see whether changes in log data reflect changes in use.

1.3 Aim and Research Objectives

This thesis aims to explore whether the analysis of log data can give an accurate picture of the effects of digitalization. Log data associated with progress reporting at prefab piping are analyzed and compared to insights gained from interviews with workers. These findings will, together with prior literature, answer the research questions.

1.4 Thesis Structure

Chapter 1 introduced the research that the thesis explores, as well as the problem statement and research question. Next, Chapter 2 reviews existing literature related to this thesis's central themes and topics. In Chapter 3, the methodological approach and detailed information about the case subject are presented. Chapter 4 provides the results from the data analysis, while Chapter 5 discuss the findings. Lastly, Chapter 6 summarizes the content of the thesis.

Chapter 2

Literature Review

2.1 Software development

Software development life cycle (SDLC) is a methodology for designing, developing, testing, and maintaining information systems (IS). The waterfall model is a traditional SDLC model, meaning it is composed of clearly defined and distinct phases. The waterfall model was the prevailing SDLC method for decades before the gradual takeover of agile methodology.

Among the criticisms levied at the waterfall model is its inability to respond to changes [8, 9]. The model does not accommodate the iterative creation of artifacts. Hence, mistakes propagate into subsequent phases of the SDLC. Dealing with them typically overruns budgets and leads to late delivery [10]. Customers are typically not involved in the development process between the initial requirement elicitation and the testing phase. At that point, the requirements have likely changed, in which case the system does not reflect them any longer [8, 9]. Furthermore, problems from earlier phases of the development are discovered [9].

Agile methodology has become an established discipline in software engineering and is today the most used approach to SDLC. Agile principles emerged from traditional principles and various experiences based on the success and failure of software projects [11]. Working software is delivered at the end of each iteration which usually spans 1-4 weeks. Short time frames between releases allow for customer and user feedback and accommodate market pressure for rapid releases [11]. Agile methods can adapt quickly to changing requirements throughout the development [11, 12]. The customer can continuously refine the requirements so that the product is more likely to be adopted by the users.

2.2 Collecting user feedback

User feedback can either be explicit or implicit. Explicit feedback is communicated directly, e.g., through interviews, questionnaires, or workshops. On the other hand, implicit feedback is information the user gives without direct interaction, e.g., through a system that monitors the user's actions. An extensive survey of 20 software engineers that apply continuous software engineering (CSE) made several compelling discoveries [6]. All the software engineers collected explicit user feedback, while only eight used implicit user feedback. The study found that manual data capture reduces the efficiency of the ongoing development process. Furthermore, the practitioners' use of tools in the process is limited. The use of automation for processing should be incorporated to counteract the efficiency loss, according to the study.

Combining explicit and implicit feedback can give greater returns than looking at them separately. A study that combined monitoring data from a parking system with autonomous feedback requests found that this approach yielded more significant insights into the users' actions [13]. The application tells which parking slots are available to its users. By asking users for feedback after either getting to the parking space, abandoning it or taking alternative routes, the developers gained insights into the users' minds. The users often took alternative routes or abandoned the parking space due to construction work. Other times, the parking spaces were occupied.

In a dissertation [7], Johanßen explores ways to automate the capture and processing of user feedback in CSE. The outcomes of the dissertation were four widgets aimed at continuous user understanding: FeatureKit, ThinkingAloudKit, EmotionKit, and PersonaKit. The FeatureKit monitors the system's use and visualizes how the users utilize the system's features. The ThinkingAloudKit lets users contribute verbal feedback during the use of the system. The verbal feedback is classified and related to features of the system. The EmotionKit monitors the users' facial expressions to determine their state of mind, e.g., happiness or anger. Features under development are linked to users' requirements for the system in the PersonaKit. Overall, the practitioners found that these tools contributed positively in understanding the users' needs.

2.3 Technology acceptance

The Technology Acceptance Model (TAM) is considered to be the most influential and commonly used theory for describing an individual's acceptance of information systems (IS). The model was proposed by Davis [14], which assumes that an individual's acceptance of an information system is determined by its perceived usefulness and perceived ease of use. Perceived usefulness references each individual's subjective thoughts about whether the IS will increase their job performance, while perceived ease of use relates to the expected effort needed to use the IS. The model is displayed in Figure 2.1.

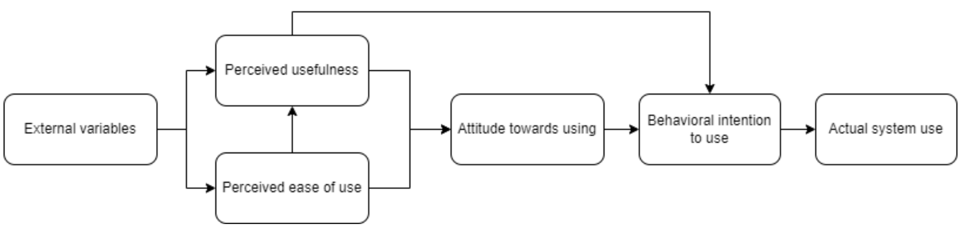


Figure 2.1: Technology Acceptance Model.

2.4 Assessing effects of digitalization

A systematic review of 30 papers identified 51 performance indicators in the context of digitalization [15]. Most papers focused on financial indicators and resource utilization. Work performance and information visualization were among the performance indicators related to resource utilization. A study using questionnaires found that digitalization has a positive outcome regarding users' perception of their productivity [16].

2.5 Change management

The top managers and management team must take strategic and tactical responsibility for digitalization projects. Top management assesses whether the change is necessary, allocates resources, initiates the necessary processes, implements the changes, and makes continuous follow-ups of the process [17]. Although top management will be responsible for making the final decisions, it is important to inform employees why decisions are being made. The management should be visible to the employees during changes to an organization. Good role models can influence the employees' motivation and willingness to work.

Middle managers are particularly important in initiating and maintaining pressure and focus around change [18]. A relational and supportive approach from the middle management to the users is essential. They have insights into the daily operations of the employees and the people in the department and can more easily adapt communication to suit the needs of the employees.

Individuals within an organization cope with change in different manners. Motivation and support from others are essential, as well as having learning strategies and a social environment [17]. On an individual level, establishing a proper support system and delegating time and resources to deal with the change can prove essential.

Setting goals can increase the likelihood of reaching the goal [17]. The basis for setting a goal is the commitment it entails and is linked to the human ability to understand why an action is desired. People believe they are working towards something meaningful by having a common goal in an organization. This can lead to increased motivation, self-confidence, and effective learning among the employees when completing a project. It is found that challenging goals, goals set publicly, and group goal was particularly effective [19].

Chapter 3

Research Method

This chapter presents the research setting and design, including the research strategy, data generation methods, and data analysis.

3.1 Research setting

3.1.1 About the company

The Norwegian company Aker Solutions (AKSO) is an engineering, procurement, construction, and installation contractor (EPCI) within the oil and gas sector. It is an international company with branches worldwide, with headquarters in Fornebu. AKSO operates in several locations in Norway, including yards specializing in various segments. The assignment concerns a case at AKSO's yard at Stord, which assembles large platform topsides and modules for onshore facilities and decommissioning projects.

Simultaneous changes in technological development, regulations, consumer preferences, and investor sentiment have triggered rapid transitions in the global energy sector [20]. AKSO expects declining orders from the oil and gas sector parallel with increasing demand for renewable energy projects. AKSO plans to adapt its operations to accommodate this shift and aims to generate $2/3$ of revenue in renewable energy and low-carbon solutions by 2030. During a transition period, AKSO plans to continue with projects in the oil and gas sector in parallel with developing new market segments, including offshore wind, carbon capture plants, electrification, and large processing plants on land.

Orders from the oil and gas sector are typically large-scale engineer-to-order projects spanning several years. These projects result in highly customized large and complex products. These have extended lead times and undergo frequent changes. On the other hand, renewable energy projects are typically more standardized and smaller in scope. Simplifications and adaptations are a prerequisite to succeed in the new market segments. This process will involve extensive digitalization, multi-skilling workers, multi-tasking, and distributing responsibilities.

3.1.2 About digitalization at the yard

To adapt to the new circumstances, AKSO has planned more than 20 projects operations at the yards. The digital roadmap is shown in Figure 3.3. The *mobile construction workforce project* produced the mobile application *WeBuild*. The application is an information and reporting system aimed at streamlining existing work processes, empowering workers to have more ownership of their work, and improving the company's data quality. WeBuild was developed using agile methods with continuous delivery and DevOps.

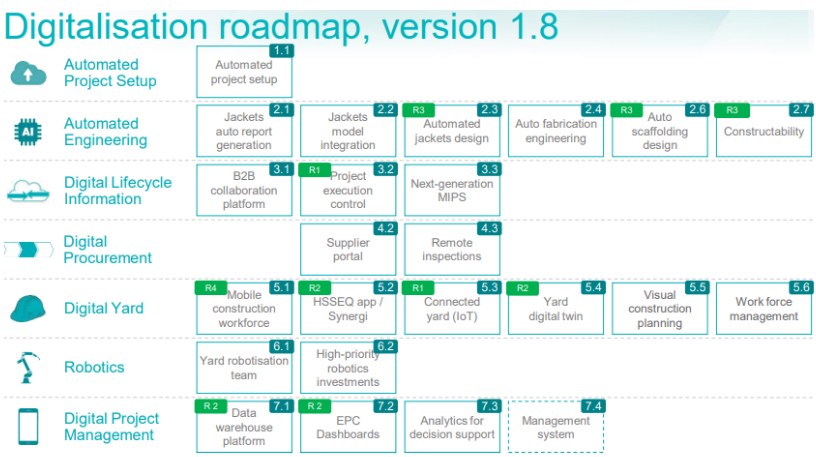
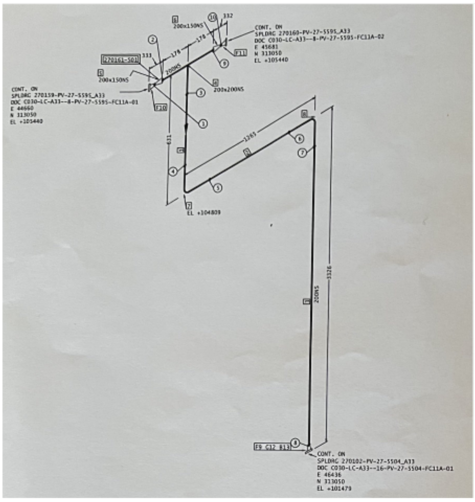


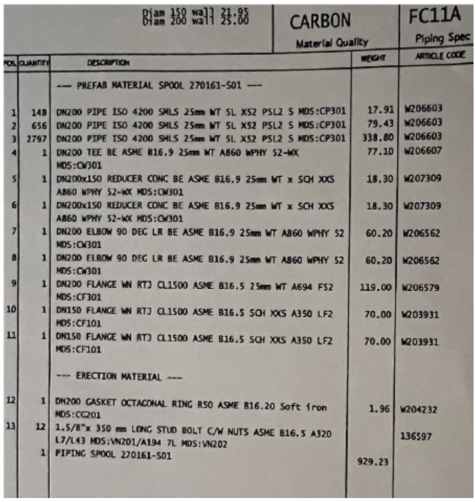
Figure 3.1: Digital roadmap aimed at digitalizing AKSO's yards [21].

The prefab piping department is among the user groups of WeBuild. This department fabricates pipe spools from a number of pipes and pipe fittings. The pipes are cut to the desired length and then moved to an assembly table together with pipe fittings. The components are temporarily fitted before being welded at the welding station. Afterward, a quality check is carried out on the pipe spools before they are sent for surface treatment. Pipe spools are shown in Figure 3.2.

Figure 3.2: Pipe spools [21].

The projects carried out at the yard are divided into work packages, that is, a group of related tasks within the project. In the prefab department, work packages contain tasks related to prefabricating one or more pipe spools. A work package contains information such as the piping isometrics, material take-off (MTO), and quality check procedures. The piping isometrics illustrates how the pipe spool is assembled, while the MTO is a list of the components. The engineering department makes work packages by extracting the piping isometric and MTO from the model of the structure created in the project.





Diam 150 wall 21.95
Diam 200 wall 25.00

CARBON — Material Quality

FC11A — Piping Spec

POS.	QUANTITY	DESCRIPTION	WEIGHT	ARTICLE CODE
		--- PREFAB MATERIAL SPOOL 270161-S01 ---		
1	148	DN200 PIPE ISO 4200 SMLS 25mm WT SL X52 PSL2 S MDS:CP301	17.91	W206603
2	656	DN200 PIPE ISO 4200 SMLS 25mm WT SL X52 PSL2 S MDS:CP301	79.43	W206603
3	2797	DN200 PIPE ISO 4200 SMLS 25mm WT SL X52 PSL2 S MDS:CP301	338.80	W206603
4	1	DN200 TEE BE ASME B16.9 25mm WT A860 WPHY 52-WX MDS:CW301	77.10	W206607
5	1	DN200x150 REDUCER CONC BE ASME B16.9 25mm WT x SCH XXS A860 WPHY 52-WX MDS:CW301	18.30	W207309
6	1	DN200x150 REDUCER CONC BE ASME B16.9 25mm WT x SCH XXS A860 WPHY 52-WX MDS:CW301	18.30	W207309
7	1	DN200 ELBOW 90 DEG LR BE ASME B16.9 25mm WT A860 WPHY 52 MDS:CW301	60.20	W206562
8	1	DN200 ELBOW 90 DEG LR BE ASME B16.9 25mm WT A860 WPHY 52 MDS:CW301	60.20	W206562
9	1	DN200 FLANGE WN RTJ CL1500 ASME B16.5 25mm WT A694 F52 MDS:CF301	119.00	W206579
10	1	DN150 FLANGE WN RTJ CL1500 ASME B16.5 SCH XXS A350 LF2 MDS:CF101	70.00	W203931
11	1	DN150 FLANGE WN RTJ CL1500 ASME B16.5 SCH XXS A350 LF2 MDS:CF101	70.00	W203931
		--- ERECTION MATERIAL ---		
12	1	DN200 GASKET OCTAGONAL RING R50 ASME B16.20 Soft iron MDS:CG201	1.96	W204232
13	12	1.5/8"x 350 mm LONG STUD BOLT C/W NUTS ASME B16.5 A320 L7/L43 MDS:VN201/A194 7L MDS:VN202		136597
	1	PIPING SPOOL 270161-S01	929.23	

Figure 3.3: A work package's piping isometric and MTO.

3.1.3 About WeBuild

Information related to the projects at the yard is stored in AKSO's project management system *Method Integrated Project System* (MIPS). Previous to WeBuild, all reporting of progress was also conducted in MIPS. WeBuild retrieves data from MIPS and writes data to MIPS. Facilitators, foremen, and operators are the three types of workers in the prefabrication department. Facilitators manage the work packages, foremen manage the operators, and operators cut, assemble and weld pipe spools. WeBuild has two user designations, i.e., foreman and operator. Facilitators are assigned the role of foreman. The home page for, respectively, foremen and operators is shown in Figure 3.4.

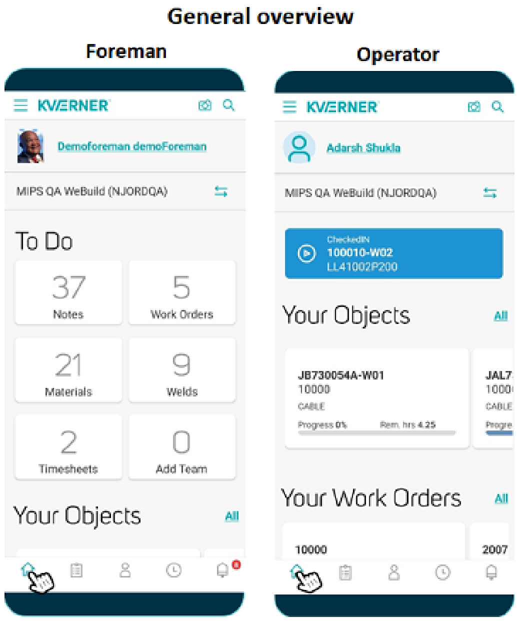


Figure 3.4: The home page for foremen and operators in WeBuild.

The application's functionality is as follows:

- **Material management:** The application provides an overview of work packages, their MTO, and the availability of materials. Foremen can order material, while operators only have read access.
- **Timesheet management:** At the end of each week, the timesheets of operators are sent to their foreman. These must be entered into the staffing system manually.
- **Work package management:** The application provides a list of work packages to foremen.
- **Team management:** Foremen can add operators to their team and assign work packages to an operator or a team.
- **Document management:** Operators can access all documents in the work packages they are assigned.

- **Progress reporting:** Operators can report progress for pipe spools after cutting and welding. Traceability of pipes and materials can also be registered.
- **Alerts and notification:** Foremen get alerted when their operators have reported that welding is completed in WeBuild. Other notifications related to the work are also sent, such as comments on work packages.
- **Presence at yard:** Foremen can see when their operators have signed in to work.
- **Time at yard:** Foremen can see the time sheets for their operators, while the operators can see their own time sheets.
- **Tools and equipment:** Foremen and operators can see a list of tools their team has available. Tools are borrowed or bought for projects through the tools and equipment department.

WeBuild was supposed to be the bridge into a paperless workday, giving workers a higher degree of independence in their work day. However, there has been issues implementing the full functionality of WeBuild at the yard. Prefab piping is considered to have come the furthest in the process of integrating WeBuild into their daily routine. However, it has not been investigated how the application is used and whether it has led to positive changes. As of writing, AKSO is starting to look into how to define and measure the success of WeBuild.

3.2 Research design

3.2.1 Research strategy

A case study was considered the most suitable research strategy. This strategy generates detailed insights into the case and its complex relations

[22, p. 141]. An overview of the business process would be sufficient to describe the findings in the log data. However, a deeper understanding of the factors at play and their interlinking is necessary to have a meaningful discussion around the findings.

The thesis produces a detailed analysis of the case in its context and looks at changes over time. Hence, it is a longitudinal descriptive study [22, p. 143-144]. The case represented a typical instance, making its findings generalizable. In addition, it was a case of convenience in that AKSO granted access to the log data, interview objects, and other relevant documents. The study provides guidelines on how log data can be used to measure effects of digitalization.

3.2.2 Log data

At the beginning of March 2022, log data related to progress reporting at prefab piping was extracted using SQL queries. The log data was related three projects conducted at the yard. For the purpose of this thesis, these projects are referred to as projects A, B, and C. Workers at prefab piping started using WeBuild during project B, continuing into project C. Since WeBuild is used for parts of project B, it is split into projects B1 and B2 for the purpose of this thesis. Project B1 refers to before the implementation of WeBuild, while project B2 refers to after WeBuild was implemented. The timeline of the projects and implementation of WeBuild is shown in Figure 3.5.

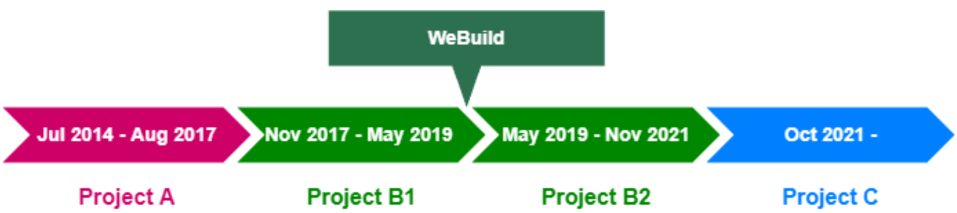


Figure 3.5: Timeline of projects A, B, and C.

The log data contains entries from the status chain of work packages and pipe spools. The data was divided into two documents for each project: one file related to the progress of work packages and one related to the progress of pipe spools. The data fields of progress reporting related to pipe spools and work packages are, respectively, shown in Tables 3.1 and 3.2.

Data field	Description
Work package no	Unique identification within a project.
Pipe spool ID	Unique identification within a project.
Status	Each step of the process has a distinct status.
Status date	The date and time of the data entry.

Table 3.1: Data fields of progress reporting related to pipe spools

Data field	Description
Work package no	Unique identification within a project.
Work package ID	Unique identification across all projects.
Status	Each step of the process has a distinct status.
Status date	The date and time of the data entry.
Estimated start date	When the prefabrication is estimated to start.
Estimated end date	When the prefabrication is estimated to end.

Table 3.2: Data fields of progress reporting related to work packages.

There are three types of progress reporting statuses related to work packages and four related to pipe spools. These are shown in, respectively, Figures 3.6 and 3.7.

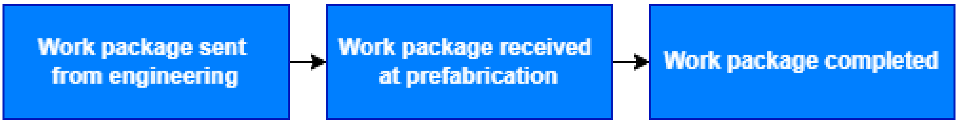


Figure 3.6: Progress reporting statuses related to work packages.

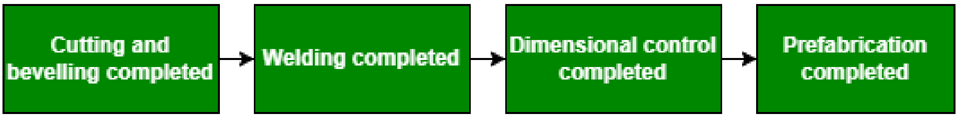


Figure 3.7: Progress reporting statuses related to pipe spools.

Combining these progress reporting statuses, we get the whole picture of the work process at prefab piping. This is illustrated in Figure 3.8.

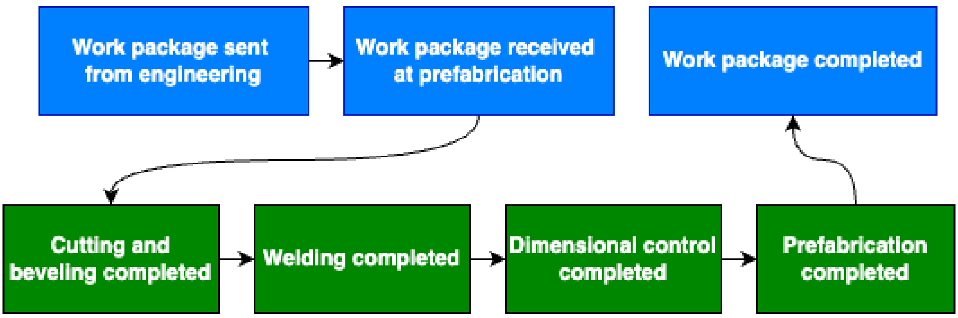


Figure 3.8: Overview of the prefabrication process. Statuses related to work packages are blue, while statuses related to pipe spools are green.

Table 3.3 shows the progress reporting for one work package and its pipe spool.

Status	Status date
Work package sent from engineering	2021-10-28 10:20
Work package received at prefabrication	2021-10-28 12:05
Cutting and Beveling completed	2021-10-28 16:04
Welding completed	2021-11-04 10:12
Dimensional control completed	2021-11-04 12:36
Prefabrication completed	2021-11-10 12:12
Work package completed	2021-11-22 12:49

Table 3.3: Progress reporting for a work package with one pipe spool.

3.2.2.1 Analysis of log data

Apache Spark [23] is a data processing framework that was used to analyze the log data. It quickly performs processing tasks on large data sets and supports multiple programming languages. This framework was chosen due to its suitability for the data processing task and the author's familiarity with it.

Projects A and B was conducted at several yards. Work carried out at other yards was removed by filtering the *work package ID* entry in the files related to work packages. Also, project B was split in two based on the date WeBuild was implemented. These segments are referred to as projects B1 and B2, respectively, before and after the implementation of WeBuild. Lastly, the files were merged so that lead time could be calculated for each step of the process.

Data quality: Based on the log data, it was possible to examine its completeness. Measuring completeness includes looking at the percentage of missing data entries. This was only done for pipe spools, since WeBuild did not change the process for reporting progress related to work packages. The steps of doing this is listed below:

- Count the number of pipe spools in the project.
- Count the number of distinct entries selecting for *pipe spool ID* and *status*. The reason for checking for distinct entries is that one pipe spool can have more than one entry with the same status. However, we know that all pipe spools should have at least one entry for each status.
- Subtract the count of pipe spools with the status from the count of total pipe spools.
- Divide the difference with the count of total pipe spools.

This process was done for each of the progress reporting statuses for pipe spools, shown in Figure 3.6.

Lead time: The analysis of lead time was broken into the steps of the fabrication process, shown in Figure 3.8. Outliers have a significant impact when analysing the mean of a data set [24]. They were therefore removed using the interquartile range [25]. The interquartile range (IQR) is the difference between the 75th and 25th percentiles of the data set. Outliers are defined as follows:

- Lower bound = 25th percentile - 1.5 * IQR
- Upper bound = 75th percentile + 1.5 * IQR

After the outliers were removed, the lead time of each step of the process was found by finding the difference in status date between each step of the process and its prior step. E.g., the lead time *cutting and beveling completed* is found by subtracting the status date of *work package received* *at prefabrication* with its status date. This was done for each work package and its pipe spools. Then, taking the mean of all the time differences granted the average lead time for each step of the prefabrication process.

Growth rate or percentage change are the percent change of a variable over time. A positive growth rate show that a variable is increasing over time, while a negative growth rate that it is decreasing. The growth rate is calculated using the following formula:

Percentage change = (V2 - V1) / V1 * 100

3.2.3 Interviews

At the end of March 2022, five semi-structured interviews with employees related to the prefabrication process were conducted. This type of interview allows for changing the order of the questioning and asking for follow-ups. Also, interviewees often contribute more details about issues raised and introduce issues of their [22, p. 188]. It was a strategic sampling, choosing workers in different roles in or related to prefab piping. The interviewees' positions were facilitator, foreman, operator, department manager, and factory manager. An initial analysis of the log data and the literature review formed the basis for the interview questions. Additionally, insights gained from interviews were carried forth in subsequent interviews. The interviews were recorded and transcribed, and the interviewees signed a notification form in person or agreed to its content verbally.

3.2.4 Linking data analysis to research questions

The thesis aims to answer the following research questions:

> **RQ1**: Do log data provide sufficient grounding to analyze the effects of digitalization?
>
> **RQ2**: How did the development and implementation of We-Build unfold?

RQ2 focus on how WeBuild was developed and implemented at prefab piping. The qualitative data analysis from interviews is mainly linked to this research question. Understanding how the application was used at different times and the user sentiment will help to answer RQ1. All the data analysis findings must be combined to answer RQ1. This is because the results from the analysis of progress reporting data must be seen in the context of changes to the underlying changes. Arriving at a positive conclusion to RQ1 will require the log data to reflect and account for changes seen in the real world.

Chapter 4

Results

This chapter presents the findings from the data analysis. Section 4.1 explores how the work process changed after implementing WeBuild. Sections 4.2 and 4.3 reports on the lead time and data quality across projects conducted pre and post-WeBuild. Lastly, Section 4.4 introduces findings from the interviews.

4.1 Work process at prefab piping

A business process consists of a set of activities and their logical order and dependencies, whose purpose is to produce a defined business result [26]. The business result can, for instance, be a product such as pipe spools. Understanding the work process at prefab piping is essential to both research questions. Comparing the work process to its previous state can help explain changes in lead time and data quality found in the data related to progress reporting. At the same time, seeing how prefab piping uses the application is necessary to describe how the implementation unfolded.

As mentioned in Section 3.1, information related to work packages and pipe spools is stored in AKSO's project management system MIPS. Information related to progress reporting is among the stored information. When work progress is reported, the status of the work package or pipe spool is updated. The work process was depicted in Figure 3.8.

4.1.1 Work package sent from engineering

Pre and post-WeBuild

AKSO divides the piping systems manufactured at the yard into smaller units. Each of these units, in turn, is divided into work packages by the engineering department. As described in Section 3.1, a work package contains information such as piping isometrics, components required for the build, and quality check procedures. Before sending the work package to prefab piping, an engineer must verify its content, and all components must be in storage. Optimally, work packages should be sent to prefab piping two weeks before the planned start date. The engineering department is not using WeBuild, and thus the process of creating work packages is no different.

4.1.2 Work package received at prefabrication

Pre and post-WeBuild

There is typically a large backlog of work packages at prefab piping. A facilitator manages and selects the work packages available for the operators depending on the planned progress of the project. Also, the facilitator ensures that various work packages are available since operators have different certifications.

The facilitator retrieves work packages from MIPS and marks them as *received at prefabrication*. A quick review of their content entails checking for apparent errors. Since an engineer verified the content before issuing the work package, detecting errors are rare. However, in the case of errors, the facilitator contacts the engineering department. If the inquiry requires changes to the work package, the engineer makes the changes and reverts the status to *sent from engineering*.

Components required for the work package, except pipes, are ordered by the facilitator through a website if all checks out. The facilitator then prints out the work package on paper. If the work package's pipe spools do not require pipe cutting, the facilitator registers *cutting and beveling completed* in MIPS. The facilitator then places the work package on the shelf for either cutting or welding jobs. The implementation of WeBuild had no impact on this part of the process, illustrated in Figure 4.1.

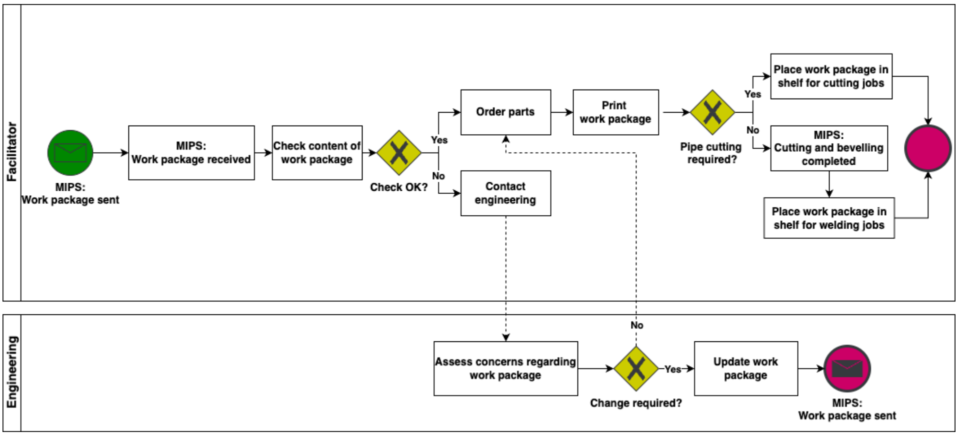


Figure 4.1: With and without WeBuild: Work package received at prefabrication.

4.1.3 Cutting and beveling completed

Pre-WeBuild

An operator working with sawing machines collects one or more work packages from the shelf in the office. The operator usually brings multiple work packages to the workstation to spare time compared to walking back and forth between executing the cuts for each work package. Besides, the operator can order pipes for multiple work packages, reducing downtime. It also allows for doing similar cuts for different work packages consecutively, saving time on setting the cutting machine.

At the cutting station, the operator uses machines to cut the pipes to the length specified in the work package. Then, the pipe ends are beveled to prepare for welding. The operator then transports the pipes into a storage location. At this point, the operator would note the tracking numbers of the pipes physically on the work package. After delivering the work package to the office, a facilitator would report the progress and register the tracking numbers in MIPS. The facilitator would then place the work package on the shelf for welding jobs. Figure 4.2 illustrates as described.

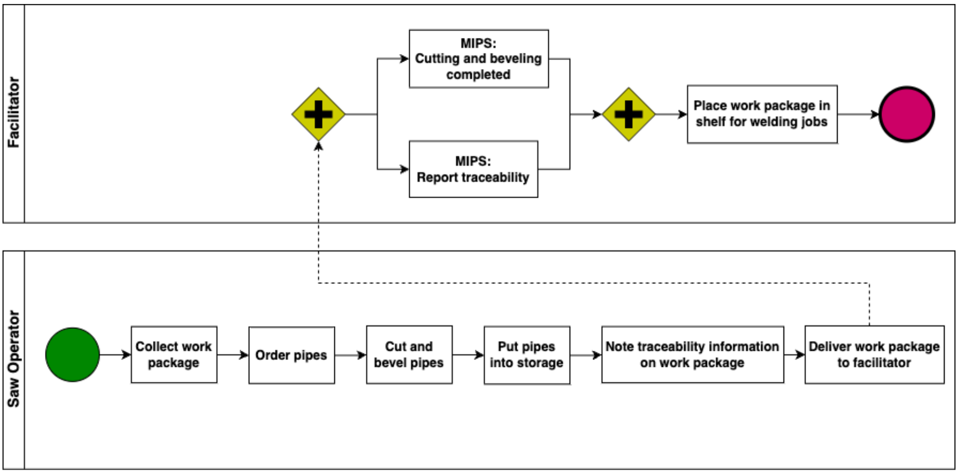


Figure 4.2: Without WeBuild: Cutting and beveling

Post WeBuild

The process is the same until the point that the pipes are put into storage. The saw operators then utilize WeBuild to report both work progress and traceability instead of noting the tracking numbers and the facilitator plotting the information. Figure 4.3 illustrates the work process as it is today.

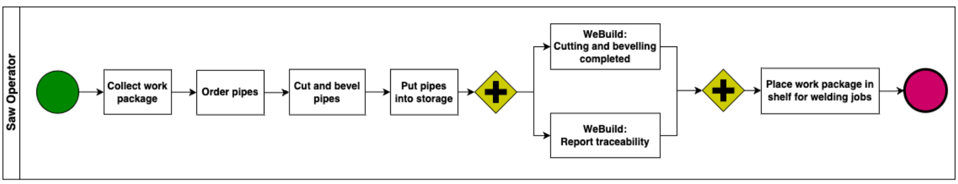


Figure 4.3: With WeBuild: Cutting and beveling

4.1.4 Welding completed

Pre-WeBuild

Welding operators typically choose the work package on top of the stack. The operator chooses another if they are not certified for the welding job required in the work package. After selecting a work package, the operator notes their name and which work package they took. The operator's foreman enters the form into MIPS.

The operator brings pipes and other components required to fabricate the pipe spools in the work package to the workstation. At this point, the operator would note the tracking numbers for the components, excluding the pipes, on the work package. Afterward, the operator assembles and welds pipes, flanges, and fittings, making the pipe spool. A foreman than inspects the job and registers that the it is ready for dimensional control. The operator then brings the pipe spool to another location awaiting the control. The process is illustrated in Figure 4.4.

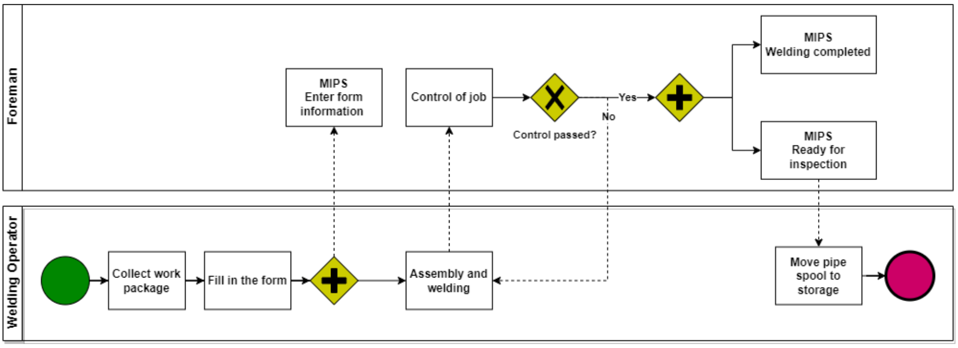


Figure 4.4: Welding without WeBuild

Post-WeBuild

The process of selecting a work package is equal compared with before WeBuild. An additional step is required for operators that desire access to the work package in WeBuild. The operator needs to notify their foreman, who grants access to the work package. After bringing the pipes and other components to the workstation, the operator registers traceability for the components in WeBuild. Otherwise, the process is similar to before. The process is illustrated in Figure 4.5.

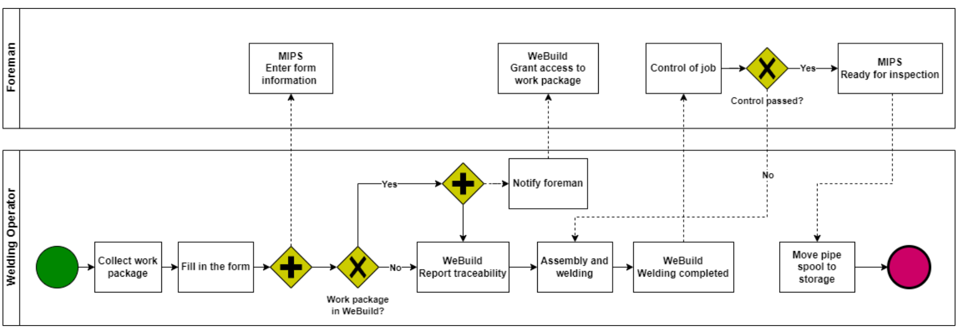


Figure 4.5: Welding with WeBuild

4.1.5 Dimension control

Pre and post-WeBuild

Dimension control involves high-accuracy measurements to ensure that the pipe spools conform with the design. The dimensional controller reports their findings in MIPS. Any deficiencies must be rectified before another control takes place. If the pipe spool is approved, it is put on a wagon awaiting dispatch for surface treatment. Afterward, the foreman reports the completion of the prefab process in MIPS. The work package is then brought to the facilitator, who reports the completion of the work package. For work packages prior to WeBuild, the facilitator would also need to report the traceability for components of the work package. The process, shown in Figure 4.6.

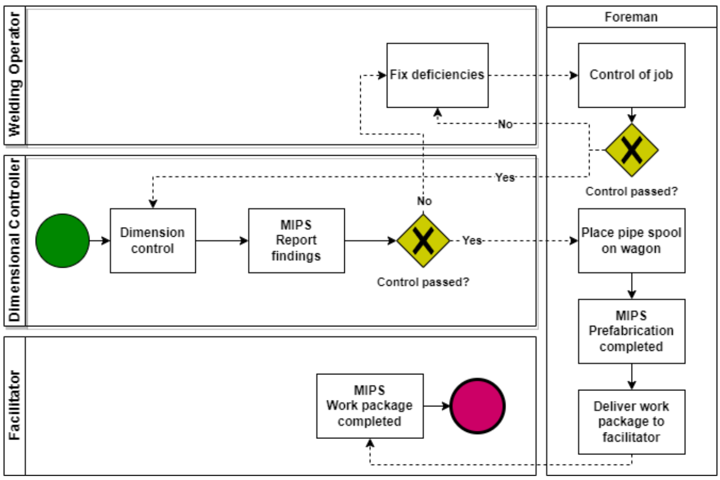


Figure 4.6: Dimension control with and without WeBuild

4.2 Lead time at prefab piping

The results related to lead time follows the prefabrication stages. Each stage is detailed in Section 4.1, and an overview is given in Figure 3.8. It is important to keep in mind that projects A and B1 were conducted prior to the implementation of WeBuild, while projects B2 and C has been using WeBuild.

4.2.1 Work package sent from engineering

Work packages should be sent at least 14 days before their planned start. The department regulates the workforce by hiring external operators based on the planned amount of work hours. Planning necessitates having the work packages available. Projects A and B1, unlike projects B2 and C, had a majority of work packages delivered on time. This result is displayed in Figure 4.7.

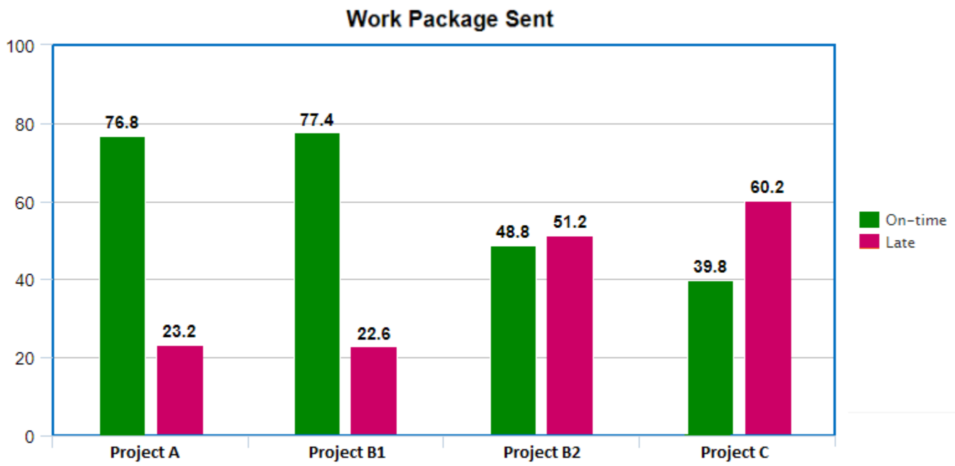


Figure 4.7: Percentage of work packages 14 days ahead of planned start-date.

Compared to work packages delivered on time, projects A, B1, and B2 had fewer work packages completed on time. On the other hand, Project C completed almost all work packages on time. This result is shown in Figure 4.8.

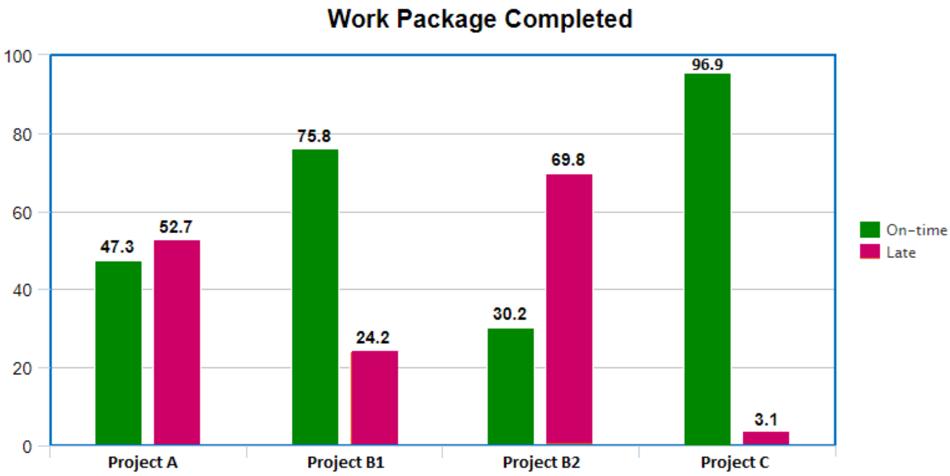


Figure 4.8: Percentage of work packages completed before planned end-date.

4.2.1.1 Work package received at prefabrication

Table 4.1 shows the average days it takes between a facilitator reports a work package being received at prefab piping after it is sent from engineering. For work packages that have been re-sent due to changes being issued, the measure accounts for the last time it was registered as sent til the last time it was registered as received. The number of days decreases project over project.

Project A	Project B1	Project B2	Project C
8.74	2.57	1.13	0.66

Table 4.1: The average number of days between a work package is sent from engineering til it is reported as received at prefab piping for each project.

As seen in Table 4.2, the growth rate shows a 70.6% decrease in lead time between projects A and B1. This pattern propagates from project to project, showing 56% and 41.6% decreases, respectively, from projects B1 to B2 and B2 to C.

	Project B1	Project B2	Project C
Project A	-70.6%	-87.1%	-92.4%
Project B1		-56.0%	-74.3%
Project B2			-41.6%

Table 4.2: Growth rate related to the lead time of work packages being received at prefabrication. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.2.2 Cutting and beveling completed

Table 4.3 shows the average days it takes for the pipes related to a work package to be reported cut and beveled after the work package is received at prefab piping. The progress reporting for this step can be made at different times if the work package includes multiple pipe spools. Hence, the measure shows the time til the last pipes for the work package are reported as cut and beveled. The lead time is relatively similar between projects A, B2, and C, while project B1 is a significant outlier.

Project A	Project B1	Project B2	Project C
5.45	15.96	6.47	5.07

Table 4.3: The average number of days between a work package is received at prefab piping til its pipes are reported as cut and beveled for each project.

As seen in Table 4.4, the growth rate shows a 192.8% increase between projects A and B1. It is hard to discern a pattern otherwise, as project B2 has an 18.7% increased growth rate compared to project A, while project C shows a 7% decrease. Overall, project C has the lowest lead time, followed by, respectively, projects A and B2.

	Project B1	Project B2	Project C
Project A	192.8%	18.7%	-7.0%
Project B1		-59.5%	-68.2%
Project B2			-21.6%

Table 4.4: Growth rate related to the lead time of the cutting and beveling of pipes being completed. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.2.3 Welding completed

Table 4.5 shows the average days it takes for the pipe spools of a work package to be reported welded after being cut and beveled. The progress reporting for this step can be made at different times if the work package includes multiple pipe spools. Hence, the measure shows the time til the last pipes for the work package are reported as welded. The lead time of projects B1 and B2 are relatively similar, while the lead time of projects A and C is significantly longer.

Project A	Project B1	Project B2	Project C
20.02	9.48	10.43	16.88

Table 4.5: The average number of days between a work package's pipes are cut and beveled til they are reported as welded for each project.

As seen in Table 4.6, the growth rate shows a decrease in lead time from project A to the others of 15.7-52.6%. However, when comparing projects B1 to projects B2 and C, it is an increase in lead time. There does not seem to be a pattern in the lead time related to the use of WeBuild.

	Project B1	Project B2	Project C
Project A	-52.6%	-47.9%	-15.7%
Project B1		11.6%	78.1%
Project B2			61.8%

Table 4.6: Growth rate related to the lead time of the welding being completed. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.2.4 Dimensional control completed

Table 4.7 shows the average days it takes for the pipe spools of a work package to be reported controlled after being welded. The progress reporting for this step can be made at different times if the work package includes multiple pipe spools. Hence, the measure shows the time til the last pipes for the work package are reported as controlled. The lead time of projects fluctuates within one day of each other.

Project A	Project B1	Project B2	Project C
1.75	2.65	2.09	2.48

Table 4.7: The average number of days between a work package's pipe spools are welded til they are reported as controlled for each project.

As seen in Table 4.8, the growth rate shows an increase in lead time from project A to the others of 19.4-51.4%. However, when comparing projects B1 to projects B2 and C, it is an decrease in lead time. There does not seem to be a pattern in the lead time related to the use of WeBuild. Project A has the lowest lead time, while project B1 has the highest. The projects using WeBuild has the ones in between.

	Project B1	Project B2	Project C
Project A	51.4%	19.4%	41.7%
Project B1		-21.1%	-6.4%
Project B2			18.7%

Table 4.8: Growth rate related to the lead time of the dimensional control being completed. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.2.4.1 Prefabrication completed

Table 4.9 shows the average days it takes to report that the prefabrication is completed after dimensional controllers control the pipe spools. The progress reporting for this step can be made at different times if the work package includes multiple pipe spools. Hence, the measure shows the time until the last work package pipes are reported as completed. The lead time is relatively similar for projects A and B1. Likewise, projects B2 and C have a comparative lead time that is significantly lower than the projects prior to WeBuild.

Project A	Project B1	Project B2	Project C
7.18	8.31	3.78	3.26

Table 4.9: The average number of days between a work package's pipe spools are controlled til prefabrication are reported as completed for each project.

As seen in Table 4.10, the growth rate shows a significant drop in lead time in projects using WeBuild. From project A to projects B2 and C, there are, respectively, a 47.7% and 54.6% reduced lead time. From project B2 to C, there is a 13.8% reduced lead time.

	Project B1	Project B2	Project C
Project A	15.7%	-47.4%	-54.6%
Project B1		-54.5%	-60.8%
Project B2			-13.8%

Table 4.10: Growth rate related to the lead time of reporting prefabrication as completed. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.2.5 Work package completed

Table 4.9 shows the average days it takes to report that the work package is completed after the prefabrication is reported completed for the pipe spools. The lead time is relatively similar for projects A, B1, and B2. On the other hand, project C has a significantly lower lead time.

Project A	Project B1	Project B2	Project C
12.52	12.62	13.40	4.64

Table 4.11: The average number of days between the prefabrication is reported as completed for the work package's pipe spools til the work package are reported as completed for each project.

As seen in Table 4.10, the growth rate shows a significant drop in lead time for project C. The lead time is reduced by 62.9%, 63.2%, and 65.4% from, respectively, projects A, B1, and B2.

	Project B1	Project B2	Project C
Project A	0.1%	7.3%	-62.9%
Project B1		6.2%	-63.2%
Project B2			-65.4%

Table 4.12: Growth rate related to the lead time of reporting the work package as completed. Positive percentages show an increase in lead time, while negative percentages show a decrease in lead time.

4.3 Data quality of progress reporting

WeBuild could be affecting multiple dimensions of data quality. By reporting progress in near real-time, the accuracy of the data would improve in theory. However, this cannot be measured using the progress reporting data without making a comparison with additional information regarding when the actual processes were completed. On the other hand, the completeness of the data can be measured. The progress related to pipe spools should be reported for each step of the prefabrication process.

An expression for the completeness of the data is given by measuring the proportion of missing data entries. In the data, there are missing rows related to the progress of pipe spools. The percentage of missing progress reports for pipe spools is provided in Table 4.13. It is necessary to keep in mind that project C is still ongoing. Therefore, the pipe spools can, for instance, be cut and beveled but not yet welded. The process of reporting progress has changed for cutting and beveling, as well as welding. Project B2 has a lower proportion of pipe spools reported as cut and beveled. When comparing the reporting of welding, project B2 falls between project A and B1. Project C has the highest reporting of cutting and beveling.

Project	Cutting and beveling	Welding	Dimensional control	Completed
A	17.1%	45.1%	19.5%	10.3%
B1	8.8%	77.3%	5.5%	1.2%
B2	21.3%	49.2%	8.8%	3.2%
C	4.5%	55.0%	25.6%	33.7%

Table 4.13: Missing data entries as a percentage of total pipe spools.

4.4 Findings from interviews

4.4.1 Factors influencing the lead time

The facilitator, foreman, and operator confirmed that the work packages are similar from project to project. However, the content of work packages within a project differs immensely. The most influential factors affecting the workload of each work package are the number of cuts and welds required to fabricate the pipe spool. A work package with no cuts and only welding of a sign to a pipe may demand an hour. On the other hand, a work package with many cuts and welds can require hundreds of hours. The factory manager said that comparisons of lead time have to account for the complexity and other factors. The workforce at the department fluctuates. It is regulated based on the planned workload from week to week. When the interviews were conducted, there were approximately 40 workers, of which 40% were hired-ins. According to the facilitator, the number of workers could vary between 10 to 80 based on the workload. The department has a plan regarding the number of work hours for each week. More workers are hired to cover the discrepancy when falling behind compared to the planned progress.

4.4.2 Productivity related to use of WeBuild

Both facilitator and factory manager point out that WeBuild is perhaps more designed for the installation phase than fabrication. The interviews found that the development of WeBuild was not based on a need from prefab piping or other departments. The factory manager points out that no tools can weld pipes, and since WeBuild only provides information and progress reporting, it is more suitable for the installation phase. When talking about the efficiency of using WeBuild, the fabric manager said:

> "I am measured on productivity every week, and I cannot see that this gives us a profit today. I can see that it could bring other benefits to the operators who find it more exciting."

The factory manager notes that reporting traceability and progress saves time for the facilitators but not for the operators. As there are two operators and approximately 40 operators, it will accordingly cost more time than it spares. In conclusion, the factory manager said that WeBuild does not make them become extremely cheap or efficient or reduce costs. Neither of the interviewees were sure whether WeBuild improved the efficiency of the work process overall at prefab piping.

The facilitator and foreman are happy that operators can report traceability in WeBuild. Previously, if the operators noted illegible or incorrect tracking numbers on the work package, it could take up much time for the facilitator when reporting the traceability. The facilitator then had to find the information in binders or contact the engineering department. When reporting traceability in WeBuild, the input is matched against records in MIPS. Hence, operators have to choose a valid tracking number.

4.4.3 Development and implementation

The development of WeBuild targeted the piping, electrical, and structure disciplines. The initial requirement analysis spanned nine weeks, followed by a 27-week development phase. During the facilitator's interview, it was discovered that the prefab piping did not partake in this process. The result of the development phase was a minimal viable product.

AKSO implements digital tools using pilot programs. Each department targeted by WeBuild chose a small group of super users. These groups tested the application and contributed feedback to the development team regularly. Super users from prefab piping were involved after a minimal viable product was developed and deployed in January 2019. At this point, the application's functionality was not suitable for the work conducted at the department.

After several releases, super users began using the application in May 2019. WeBuild was distributed to the remaining workforce a few months later, at which point the application's functionality was considered good enough. Super users conducted training with their coworkers. The training was initially done in small groups at launch and later in a one-on-one setting when onboarding new workers. Super users were also available for questioning when needed.

The fabric manager and department manager at prefab piping points to disconnects between the development team and WeBuild's users. The department manager said it is one thing to develop things, but when you use them, it does not turn out the way the developers intended. The fabric manager also said that developers have greater expectations of the use of newly introduced digital tools than the users. The fabric manager said that the developers are not so concerned with productivity and progress. The developers instead think that everyone should be allowed to do everything. He added that this makes it more challenging to control the project's flow.

Only a few operators ask to get access to work packages on WeBuild. According to interviews with the foreman and fabric manager, these operators are mostly super users of the application. According to the fabric manager, many reasons can affect this. For one, these users have gotten more training in the application than the rest. Also, they are typically younger and more interested in technology. The foreman said it almost feels like they are ambassadors for the application.

On the other hand, some workers at prefab piping had not used a smartphone before. It is a significant shift to look at drawings of the pipe spools on a small screen compared to an A4 paper. A pilot is recently launched trying out tablets as a substitute for smartphones. Also, WeBuild had significant performance issues in the beginning. The foreman said it could feel like minutes before the application was responsive. Although it still takes seconds to load, the performance issues are mostly fixed.

The fabric manager emphasized how important it was that the management was coordinated in the digitalization process. AKSO has a hierarchical management model, where the factory manager is above the prefab piping manager, who in turn has foremen and facilitators before the operators. Superusers probably functioned more as middle managers since they were the ones who conducted training with coworkers and was available for questioning. If for instance the factory manager loose faith in WeBuild, the sentiment quickly propagates down the chain.

4.4.4 Obstacles to further integration of WeBuild

The functionality of WeBuild was described in Section 3.1.3. The *document management* function could alleviate the need for physical work packages. However, only a few operators make use of this. In this case, the access in WeBuild is a supplement to the physical work package, not a substitute. In connection with the implementation of WeBuild, all employees were given smartphones. The experience of viewing work package documents on a smartphone differs from viewing them on an A4 paper. The findings from the pilot using tablets will therefore be interesting, as it more closely resembles the experience of using paper. Moving away from physical work packages would require changes to all subsequent process stages.

In WeBuild's role designation, the facilitator is a foreman. Hence, the facilitator could order the materials for work packages in the application. This function is not used because the facilitator considers it more efficient to do it through the website. Usually, several work packages are processed in one session. The facilitator can insert the ID of the work package from MIPS into the website. This procedure requires fewer clicks than navigating through the application.

Since the prefab department is under one roof, the foreman keeps track of which employees are at work in other ways than checking WeBuild. This makes functions like *presence at yard* and *time at yard* obsolete. Furthermore, foremen enter timesheets for their operators daily while WeBuild sends timesheets at the end of each week. The operator's work hours are registered against the work package they are working on. Since only a few operators request the work packages on WeBuild, the *timesheet management* function is not particularly useful today. The function might prove useful if prefab piping was only to have digital work packages in the future.

The data quality analysis shows that welding is only reported for about half of the pipe spools. Foremen are alerted in the *alerts and notification* functionality when their operators have reported welding. However, as seen in the data quality analysis in Section 4.3, welding is only reported for about half of pipe spools. This makes it difficult to depend solely on this functionality.

Chapter 5

Discussion

5.1 Revisitting the research questions

The research questions explored in this thesis are as follows:

> **RQ1**: Do log data provide sufficient grounding to analyze the effects of digitalization?
>
> **RQ2**: How did the development and implementation of WeBuild unfold?

Results from the data analysis were presented in Chapter 4. Findings from the interviews, as well as the description of the work process at prefab piping, will help guiding the discussion around RQ2. A holistic approach combining all the findings is necessary to arrive at a conclusion for RQ1.

Among the core ideas of WeBuild is to provide workers with information related to their jobs digitally instead of on paper. WeBuild was also intended to provide a higher degree of independence in the working day. This was going to be achieved by having more easily accessible information and allowing self-reporting of work progress instead of leaving the job to superiors. This way, data quality would also increase since reporting will occur near real-time instead of later in batch operations.

5.2 Efficiency of work process

5.2.1 Work package sent from engineering

Section 4.1.1 describes the work that goes into making work packages. The work in engineering was not a focus area of this study. Looking at this process in and of itself is not particularly interesting for this thesis. However, looking at when the work package is sent to prefab piping in relation to its estimated completion date provides background information that could help describe the lead time at prefab piping.

The work packages were sent from engineering at a similar rate between projects A and B1. However, the outcomes are vastly different, considering how many projects are finished within their estimated completion date. The completion rate within the time frame drops by 29.5% in project A while being stable in project B. Similarly, project B2 drops by 18.6%. Almost all work packages for project C are finished on time. However, it is important to remember that this is an ongoing project. A majority of the work packages are not yet completed.

5.2.2 Work package received at prefabrication

Section 4.1.2 describes the work that goes into the initial processing of work packages. Despite the process being the same as before WeBuild was implemented, there are significant differences in lead time. From project A to project B1, there is a 70.6% reduction in lead time. Likewise, there is a 56% decrease from project B1 to B2 and a 41.6% decrease from project B2 to C.

Since the underlying process is the same, other factors must influence the results. One factor that could affect the results is the relation between when work packages are sent from engineering in relation to its estimated start date. Projects A and B1 have higher percentages of work packages sent more than two weeks before their start date. The work package must be processed quicker if the start of production is upcoming.

However, more factors must be at play since projects A and B1 have approximately the same number of work packages delivered on time. When asked about the decrease in lead time, the facilitator explained that there had been an increased focus on their side on using the storage space the department has available. Having the components in storage affords more flexibility in choosing the execution order of work packages. When the storage is exhausted, the processing of additional work packages must halt. Projects A and B1 were more extensive than projects B2 and C. This could also play a role in the reduced lead time.

5.2.3 Cutting and beveling completed

Section 4.1.3 describes the work that goes into cutting and beveling pipes in preparation for welding. WeBuild has changed progress reporting and traceability at this process stage. After cutting and beveling are completed, and the pipe is put into storage, the operator uses WeBuild for reporting. Previously, the operator noted the tracking numbers of the pipes on the work packages and delivered them to a facilitator who would do the reporting.

The lead time is relatively similar for projects A, B2, and C, while project B1 is a significant outlier. It is hard to explain why the average lead time increased by 192.8% from project A to B. These projects were relatively similar in scope and received work packages from engineering at about a similar rate compared to the estimated start date.

However, project B1 had a much lower lead time in the previous stage of the process. Hence, work packages could have been waiting longer for processing at this stage. If more work packages are awaiting cutting and beveling, it will take longer to process them. Projects B2 and C being relatively lesser in scope compared to projects A and B1 can help explain why the same increase in lead time is not evident. Furthermore, since the operator does the progress reporting, the lead time is reduced since the reporting is done at a comparatively earlier point. A more detailed analysis is not attainable since the log data lack important information, such as the extensiveness of work packages and how many operators work at prefab piping at different points in time.

5.2.4 Welding completed

Section 4.1.4 describes the work that goes into welding pipes and other components into pipe spools. WeBuild has changed how progress reporting is done at this process stage. To gain access to the work package in WeBuild, the operator must request access from a foreman. Instead of the foreman reporting progress, the welding operator does this procedure.

The lead time varies significantly between projects. There is a 52.6% decrease in lead time from project A to B1. Both these projects did not use WeBuild, indicating that other factors heavily affect the lead time. Selecting project A to compare to the projects using WeBuild would show a drastic improvement, while the opposite could be said if selecting project B1.

Since the welding operator reports progress, the reporting is comparatively done earlier than if the foreman would do it. However, this difference is probably offset by having the saw operator report progress for cutting in the previous stage. By looking at the percentage of missing welding reports in Table 4.13, it is clear that the comparison of lead time between projects is compromised. In project B1, welding for 77.3% of pipe spools was not reported.

5.2.5 Dimensional control, prefabrication and work package completed

Section 4.1.5 describes the remaining work process at prefab piping. The work processes have not changed since WeBuild was implemented. However, there are still differences in the lead time between the projects.

In terms of dimensional control, project A has the lowest lead time. WeBuild could indirectly increase the lead time of this stage by having the welding report done earlier. The lead time varies, but there does not seem to be a pattern in the data. The lead time of reporting prefabrication completed was significantly improved after WeBuild was implemented. However, there has been no change to the process. Both projects A and B1 are greater in scope with more work packages and pipe spools. There might perhaps be a bottleneck at this point, but it is uncertain. The lead time for reporting that a work package is completed is relatively similar between projects A, B1, and B2. The lead time is reduced by more than 60% in project C compared to the other projects. However, the author did not find any explanation for this result.

5.3 Data quality

Improved data quality in the progress reporting was among the goals in implementing WeBuild. The progress reporting by saw operators has improved in project C. Only 4.5% of pipes are not reported cut and beveled. This shows that WeBuild has been accepted by its users for this task. WeBuild was implemented during project B2. Compared with project B1, the percentage of missing reports increased from 8.8% to 21.3%. This might indicate some resistance from the workers in the beginning. This matches up with findings from the facilitator's interview, who said there was some initial skepticism but that everyone is on board now.

Related to welding reports, it is unclear whether WeBuild has had an effect. The missing records vary significantly between the projects. Project A has the most reporting, while project B1 has the least reporting. The projects where WeBuild has been used are in the middle but closer to project A than B1. It is important to remember that project C is still ongoing in this regard. This can make it look like there are a higher number of missing reports since some of the work packages still are awaiting welding.

5.4 Development and implementation of WeBuild

AKSO has changed to an agile SDLC. In theory, this change should make the development more adaptable to changing user needs. Since prefab piping did not participate in the requirements gathering prior to the development phase, this change could have been important. Since prefab piping was involved after the MVP was developed, the necessary changes to adapt WeBuild's functionality was minor compared to what they could have been. Rapid releases has allowed the users to be contribute feedback to the development team, which has adapted the existing functionality to conform to the user needs.

The development team relied solely on explicit user feedback. Super users were involved in the development process in the end of each sprint. The MVP was released in January 2019. Super users began at prefab piping began using WeBuild in May 2019, while the rest of the department adopted the application some months later. Manual capture of user feedback without the aid of tools to process it can delay the development process. Hence, integrating tool support in this regard and integrating automating feedback capture should be considered.

Combining interviews and log data provided a more holistic picture of how WeBuild is used at prefab piping than either one could do on its own. Talking to the workers at prefab piping, it seems like WeBuild is has been fully integrated in both the reporting of cutting and beveling and welding. The log data shows that the almost all pipes are reported cut but the same cannot be said about welding. Welding is only reported for about 50% of pipe spools in the projects using WeBuild.

WeBuild had significant performance issues when first released at prefab piping. In terms of the TAM, this reduced the perceived ease of use of the application. Furthermore, this influence its perceived usefulness negatively. The facilitator mentioned that it could feel like minutes before the application was responsive. In these situations it is easy to give up on using the application, at least when an alternative approach of completing the task is available.

5.5 Discussion of research questions

Answering RQ1 is not possible since the log data related to the process reporting lacked the complexity necessary to determine what effects WeBuild had in terms of making the work process more efficient. The log data neither provides information regarding the extent of the work packages nor the size of the workforce. WeBuild is an information and reporting tool that do not affect how fast an operator cuts, bevels or welds pipes. Therefore, it is the flow in between the fabrication steps that WeBuild mainly could affect. The log data also lacks information about when processes start, e.g., the welding of pipe spools. All in all, these factors make it hard to discern whether the work process has become more efficient.

Related to RQ2, the main issue found in the development of WeBuild was that prefab piping was not included in the initial design phase. This led to a disconnect between the functionality of WeBuild and the users' needs at the department. Due to the disconnect, the integration of WeBuild at prefab piping was limited to progress reporting. A more holistic approach targeting the entire prefabrication process of pipe spools is required to fully be able to move away from work packages on paper. Since the work at different departments varies greatly, it is recommended to include the departments that are intended to use the application.

Chapter 6

Summary

Digitalization is widespread in today's society, and many companies are trying to take advantage of its opportunities. It is vital to measure the results of digitalization against the expanded resources to assess whether the effort has been successful. In this regard, finding ways to describe the effects of digitalization is necessary. Understanding how digitalization affects a company's processes and procedures also helps guide further development in CSE.

The direction of the thesis was chosen based on an initial literature review and discussions with representatives at AKSO around relevant issues they are experiencing. A case study was carried out focused on determining whether log data related to progress reporting could yield meaningful insights into the effects of digitalization. Five interviews were conducted with employees related to the process at prefab piping to gain insights into developing and implementing the mobile application WeBuild. This information was used to assess whether the log data provided sufficient grounding to analyze the effects of digitalization.

In the development phase, prefab piping was not included in the initial requirement gathering. The result is that the application does not reflect the department's needs. As of today, it does not seem to be a push towards extending the areas in which WeBuild is used. Although WeBuild only had a minor impact on the work process at prefab piping, the lead time varies significantly between projects. The analyzed data related to progress reporting was simplistic and could not account for influential factors such as the work package's extent or the workforce's fluctuating size. An attempt was made to explain factors that influence the lead time of the processes.

People who want to measure the effect of digitalization can use this thesis's findings to guide the process. It could prove helpful to understand the underlying work process that the log data describes instead of doing it the other way around. Determining factors influencing the lead time in this thesis could have guided the data gathering to produce a better analysis. Also, the importance of requirement gathering prior to the development is evident.

6.1 Limitations

1. A different set of data related to WeBuild was originally intended for this thesis. However, it was discovered over halfway through that the data did not exist. This to the thesis has a different.

2. The information in MIPS related to a work package contains estimates for workload for cutting, beveling, and welding. Combining these estimates and how many working hours the department uses with the analysis in this thesis could be interesting. A conclusion to RQ2 cannot be drawn without more comprehensive data than was available in this thesis.

3. The author was relatively inexperienced in doing interviews. The interviewees had different personalities, and it was sometimes challenging to keep the conversation flowing. Listening through the transcripts made it clear that some questions might have led. Another concern about the setting is whether the interviewees felt comfortable speaking their minds.

4. The sampling size for the interviews was five people associated with the work process at prefab piping. One person represented each role in the department, and only one of them was a super user for WeBuild. The super user did not actively use WeBuild. One should therefore be careful not to generalize without additional substantiation.

5. The prepared questions for the interviews were partly based on an initial evaluation of the log data. At that point, the author thought that all functionalities in WeBuild were implemented in the department. Also, the initial

evaluation was done without the knowledge of the work process at prefab piping. Doing another round of interviews with the latest lead time analysis could have led to a more meaningful discussion with employees regarding how much various factors influence the results in the thesis.

6.2 Future work

Adding the information related to the estimated workload of work packages and the workforce size could be of interest in determining whether the data generated through progress reporting can grant insights into the effects of digitalization at AKSO. Even if the effects seen by implementing WeBuild are minor, refining the method can be of value. If it is shown to work, it can be used to assess the effects of other measures initiated in the department. For researchers examining how to use system data, it would be helpful to determine the data required for the analysis based on an initial exploration of the underlying work process.

6.3 Conclusion

RQ1: The findings from the log data related to lead time showed significant differences between the projects. When looking at the whole picture, WeBuild could not have had too much of an impact on the lead time found in the analysis. Overall, it is unlikely that WeBuild had more than a minor impact at best. The progress reporting for cutting and beveling is made by a saw operator instead of the facilitator. This could reduce the lead time seen in the data. However, since work packages are always available for welding operators, it does not reduce the time fabricating pipe spools overall. A welding operator does the reporting for welding. Even though the operator reports the progress earlier, this is offset by the reporting of cutting and beveling.

The log data related to progress reporting could not account for integral factors that affect the lead time. The most obvious limitations of the data are the lack of information regarding how many work hours are estimated for the work packages and how large the workforce at the department is. The log data in this thesis does not provide sufficient grounding to analyze the effects of digitalization. Caution must be exercised when looking at a single data source. Understanding how the data came about and the factors influencing the process is necessary in this regard.

RQ2: The disconnect between WeBuild's functionality and the users' needs at prefab piping seems to stem from the initial requirement gathering. Due to this disconnect, the drive to fully integrate the application into prefab piping is absent. The use of WeBuild has been more or less the same since it was first implemented, and the implementation has not granted the desired results. The work packages are still printed on paper, and most of WeBuild's users only use the application when required. Even if the data quality is improved, at least concerning reporting the cutting and beveling of pipes, the data is not used actively in the company. A more holistic approach targeting all stages of the work process at prefab piping might be necessary to achieve the goal of moving away from paper.

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