29th Annual INCOSE international symposium
Orlando, FL, USA
July 20 - 25, 2019

Improving the information transfer between engineering and installation; case study at AS Nymo

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Abstract. Engineering, Procurement, Construction and Installation (EPCI) projects for the offshore oil and gas industry become more and more complex, with a reduced timeframe, and increased demand for cost savings in the industry. The result is reduced profit margins; therefore, the need for increased productivity is higher than ever. Some of the aspects important for productivity include material flow, information flow, sound planning, and organizational structure. This paper focuses on the information transfer between the engineering team and the installation phase of the fabrication at AS Nymo. Feedback from stakeholders, previous research and lessons learned from completed projects pinpoints that this handover has a potential for improvement. We analyzed historical data and involved key stakeholders in an iterative process to identify insignificant elements in the handover format. By removing this insignificant information, we found that it is possible to reduce the number of handover revisions by 60%. Additionally, we found that improving the handover could give a 67% reduction in time spent for the receiving stakeholders to find the specific information they seek. To verify our results, we suggest further testing for verification before validation through a full-scale project execution testing for future research.

Introduction

We performed the research in the oil and gas industry, for a company that specializes in the construction of drilling modules for offshore installations. Constructing offshore drilling modules consists mainly of design, fabrication, and outfitting of large modules with the typical weight of 1,000-4,000 ton. Typical modules from this industry are the Drilling Equipment Set and Drilling Support Module.

The research has specifically targeted content and shape of the handover from engineering to installation within the piping discipline for the target company. The handover consists of a wide range of drawings and specifications. The target for such a handover is to ensure that all required information for pipe installation is available for the operators to perform their work.

Company

AS Nymo is located at the south coast of Norway, with headquarter and main fabrication yard in Grimstad and additional fabrication facilities in Arendal. It began operations in 1946, and the Ugland family acquired it in 1956. The company specializes in Engineering, Procurement, Construction and

Installation (EPCI) of highly complex modules for the offshore oil and gas industry. The company also has extensive experience with accommodation modules, gas turbine exhaust and air inlet systems and subsea units.

Figure 1 visualizes the information flow for piping at the company during project execution. After the project has started, the design engineers develop a thoroughly detailed 3D model of the scope and prepare the requirements. Shop Engineering then produces the Piping Isometric (ISO) Drawings and work packages for fabrication. A Piping ISO Drawing is a detailed orthographic drawing that shows the details of the 3D structure of a pipe in the form of a 2D diagram. After the piping has been prefabricated, outfitting of the modules starts. For the installation team to outfit the module with piping, they require an extensive amount of documentation. The shop engineering team prepares this handover, consisting of information from several other departments. The installation team also requires the prefabricated spools from storage and a correct set of erection materials dedicated to performing the work. The Mechanical Completion team verifies the pipework after installation and pressure testing. Finally, the Commissioning team approves and completes pipe systems.

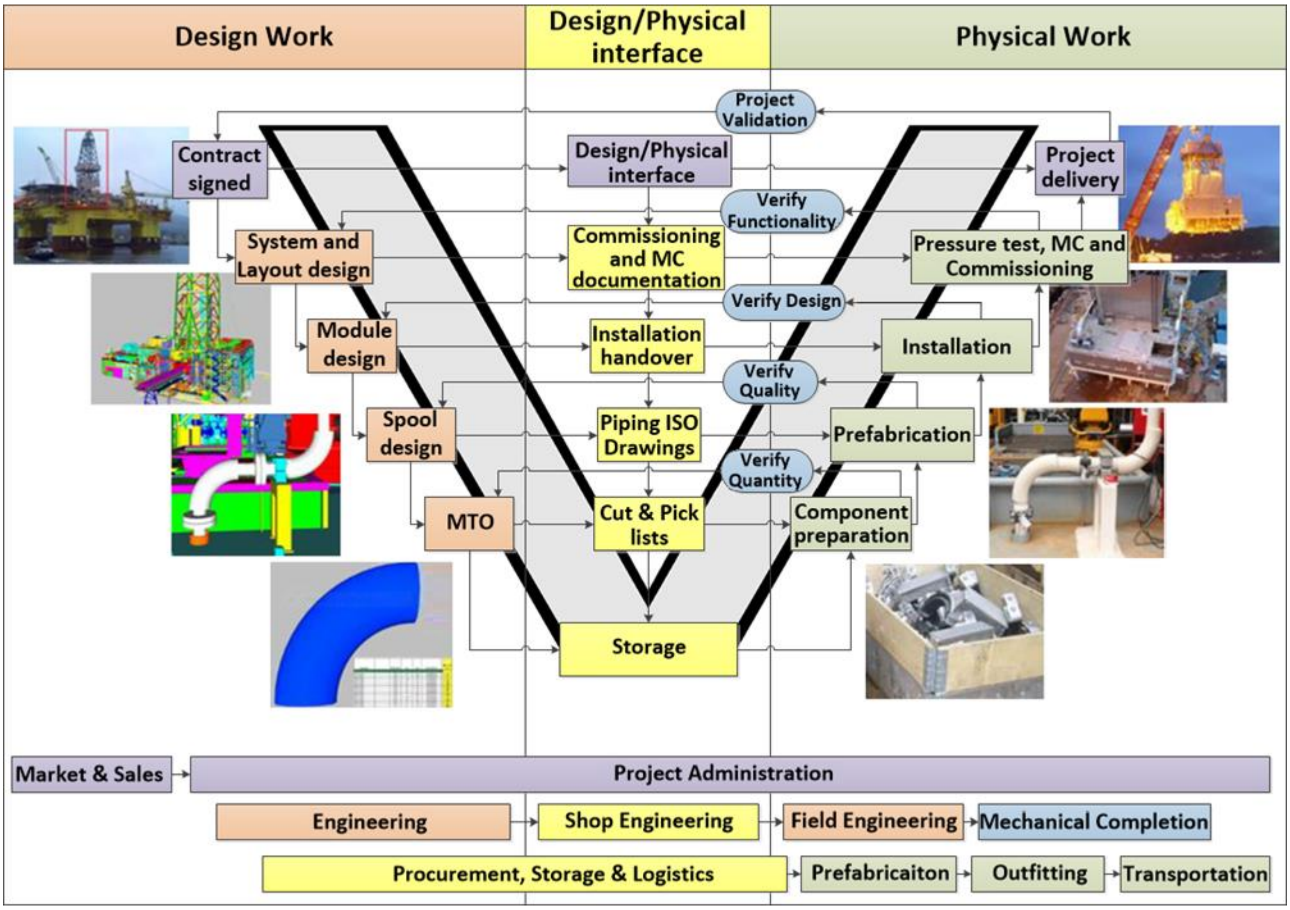

Figure 1. Information flow for piping during project execution

Problem Statement

Progress reports during project execution and lessons learned reports prepared after project completion indicate that the actual progress compared to planned progress is less than satisfactory during the installation phase. Additional staffing and overtime in this phase caused hour consumption to exceed the planned estimates, creating a mismatch between the planned progress per hour and the actual spending of hours needed to meet the required progress. The indications are that as this phase progresses, the deviation between estimated units installed each hour and actual units installed increases. This phenomenon results in a delayed handover from installation to the next phase. Company processes and several academic studies (Ellingsen et al. 2013, Homeland 2013, Lande et al. 2013, Throndsen et al. 2015, Kalsaas 2016, Bijl et al. 2014, Bredesen et al. 2014, Bentsen et al. 2013) have investigated this phenomenon to identify the causes. One of the causes found is that the handover from shop engineering to installation can contain obsolete, confusing, or faulty information. The installation team receives this documentation from shop engineering. However, the root causes of the faulty documentation are unknown.

Research Question

This research aims to get a deeper understanding of the main impact factors causing confusion and misinformation related to the installation handover format. Furthermore, this paper seeks to identify a way to improve the flow of knowledge between design and installation by reducing these impact factors. The specific research questions are therefore as follows:

- What are the main impact factors causing confusion and misinformation in the installation handover format?
- How can the new knowledge about the main impact factors contribute to make the handover format more correct, intuitive, and usable for the receiving stakeholders?

Literature

The Company conducted earlier studies under the paradigm of Lean philosophies with a particular focus on Lean Construction. The paradigm of this paper is System Engineering. As a result, the content of this paper involves both paradigms, and uses both Lean and System Engineering literature and tools. The System Engineering Body of Knowledge (BKCASE Editorial Board 2017) describes the field of System Engineering, and the applications for System Engineering. Any application from System Engineering used in this paper has its basis in the SEBoK. The search for literature used in this article follows the five steps described by Bloomberg (2014).

Lean, Lean Production, and Lean Construction

Lean and Lean Production. The concept of Lean originates from the production methods developed by Toyota in the 1950s. Since then, diverse areas of operation have applied the Lean philosophies. Lean development is a way of thinking and a system of management used to create customer value (Ward 2002). Lean is a practice that considers the use of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination (Gustavsson 2011). The term waste indicates time spent performing unproductive work (Womack et al. 1991). It is common to define seven types of waste (Morgan et al. 2006), and value stream mapping is one method to identify this waste.

Lean Construction. The International Group for Lean Construction views lean production as a theoretical inspiration for the formulation of a new, theory-based methodology for construction, called lean construction (Koskela et al. 2002, Koskela 2000). Therefore, they state that this is not a question of how to apply Lean Production into Lean Construction, but rather applying the methods whenever they are justified. The introduction of the concept *flow* is probably the most significant contribution to the understanding of the construction process made by Lean Construction (Bertelsen 2004, p. 13). The Transformation-Flow-Value model embeds this concept (Koskela et al 2002, p. 215). Lean Construction suggests achieving flow through working on sound activities. To make an activity sound, Lean Construction suggests managing seven factors: previous work, space, crew, equipment, information, materials, and external conditions such as considering the weather (Alazim et al. 2009, p 8).

In common Lean Construction terminology, the information flow refers to the complex flow of decisions (Bertelsen 2004, p. 17). However, we argue that this is also valid for the value and quality of this information as well. This means that in making the information in the handover more accurate, usable, and absorbable for the receiver should increase the flow of the project execution.

The Germ Theory of Management

In his paper about The Germ Theory of Management, Tribus (Tribus 1992, p 5) states that if the variability of material (or information) to a system is not dampened by the system; the variability passed on the next system will be increased. This variability will continue to increase as it passes through the following systems. The result may then be that the final variability becomes unacceptable, which can lead to missed schedules, product failure, or failure to meet specifications.

Case Study

We research AS Nymo as a single case study. The first part of the research focuses on getting a deeper understanding of the challenges related to the handover format between design and installation departments. The second part focuses on how to improve this handover to make it more efficient and usable for its receiving stakeholders. Figure 1 illustrates the location and interfaces of this handover in the project execution method at AS Nymo.

Background

In 2012, AS Nymo decided that their five-year goal was to cut the overall project execution cost by 40% to improve their competitiveness in the market. This goal set in motion several activities, such as:

- Adapting Lean Construction philosophies.
- Hiring a Professor from the University of Agder as a part-time employee.
- Opening the company for several master projects.
- Implementing a new tool for progress and quality control.

The activities to reach this goal experienced some success, and to further Nymo's vision in 2017, AS Nymo has stated a new four-year goal. This goal is that AS Nymo should reduce overall project hour consumption by 30%, reduce project execution time by 30%, and increase company turnover by 30%. With basis in experience from the last five years and this new goal, the company initiated three internal improvement projects in 2017:

- Improve the flow of materials to and within the company.
- Improve the usability of the plan during the project execution.
- Improve the content and format of the handovers from design to construction.

This research is a part of the latter internal improvement project.

Current Situation

AS Nymo has recognized that improved productivity during outfitting of the large modules is required to increase their competitiveness. The installation of pipework into the modules is an example of an opportunity to improve productivity. Historical data provided by the company indicates substantial overrun of installation hours spent compared to plan on the four largest EPCI projects executed over the past eleven years. We can argue that the severity of this overrun indicates underestimated hours in the plan, especially on the latest project. However, due to the current five-year strategy, our research has focused on the effectiveness of the handover.

Financial motivation for the research

Three Master projects (Ellingsen et al. 2013, Homeland 2013, Lande et al. 2013) and three bachelor projects (Bijl et al. 2014, Bredesen et al. 2014, Bentsen et al. 2013) conducted at AS Nymo from 2012 to 2014 measured waste in the piping installation department. This research builds further on these projects. We analyzed these project reports and observed that the average waste measured in these studies was 31%.

Through our analysis, we observed that Homeland et al. and Lande et al. combined their findings to broaden their sample hours for analysis (Homeland 2013, Lande et al. 2013). Their research consisted of 272 sampled hours that accounted for 53% of the total hours observed in all the studies. In addition, their research had verified the results through additional qualitative research. They divided their observations into four separate teams of installation operators, and their studies indicated the following leading causes for unproductivity:

- Inaccurate and flawed information causing uncertainty or rework.
- Misunderstanding in the handover causing confusion.

Homeland et al. and Lande et al. related 11% of the wasted hours in the installation phase to the handover format. Assuming this is true for all the four largest EPCI projects over the past eleven years, the sum of wasted hours concerning the handover for these four projects is about 4,800. With the typical hourly cost of one installation operator at approx. 650 NOK, this amounts to a total loss of more than 3.1 million NOK. We have not studied the impact that this overrun has on its surroundings. With a basis in the Transformation-Flow-Value model (Koskela et al 2002, p. 215) and the germ theory of management (Tribus 1992), we assert that the repercussions for other departments are substantial.

Research Methodology

Figure 2 illustrates the specific steps performed in this research and uses Muller's modeling and analysis approach as a basis for partitioning the research (Muller 2017, p. 3). This research is a case study at AS Nymo. Yin (Yin 1994) and Blumberg (Blumberg 2014) provided the basis for the methodology and methods used in this research. The research uses mixed methods and contains both quantitative and qualitative research to get a deeper understanding of the challenges to the handover and ways to improve it.

The main author of this paper is an employee of this company as an experienced Piping Engineering Lead. The personal involvement in the company gives relevance to action research methodologies (McNiff 2016).

Understanding. We started the research by performing a stakeholder analysis (Figure 3) to map the stakeholders, and their interests and influence. With a basis in this stakeholder analysis, we gathered data through qualitative research by interviewing the relevant stakeholders. We decided to keep these interviews informal, and with open-ended questions with the thought that this would make a good foundation for an open dialog in the iterative process to come. We selected the subjects for the interviews based on their relevance defined in the stakeholder analysis. After the interviews, we analyzed the results to identify what the subjects regarded as the main impact factors.

We performed three separate quantitative studies by performing the following historical analysis on the most significant project over the previous eleven years:

- Identify the content of each handover.
  - Executed by evaluation each handover individually.
- Identify the value of each element of information in the handovers.

- Executed by using the results from content analyzes and information elements from a single handover.
  - Analyze each element and conclude through review with involved stakeholders and specific representatives from feedback stakeholders.
- Identify the cause of revisions to the handovers.
  - Executed by selecting 100 handovers at random and made an inventory of causes of hand-over revisions (Walpole et at. 2013).

Exploration. We analyzed the collected data. We then reviewed the analysis in cooperation with both the involved and feedback stakeholders and agreed on the main impact factors causing confusion and misinformation in the handover format.

Optimization. We used the answers from the exploration phase to assume the potential for improvement by further analysis of the earlier findings. We engage in an iterative process with involved stakeholders and specific feedback stakeholders to suggest how the new knowledge about the main impact factors can improve the handover format. We then prepared and distributed a questionnaire among the involved personnel to map the current opinion on the suggested improvement. Finally, we analyzed the results and calculated the Net Promoter Score (NPS). The NPS is a management tool used to measure the loyalty of a firm's customer relationships introduce by Reichheld in his 2003 (Reichheld 2004). We used NPS as a tool to measure the stakeholder's loyalty to the new handover layout to determine if the stakeholder would promote or detract the solution.

Verification. We formulated a hypothesis stating that the new handover layout would make the handover more correct, intuitive, and usable for the receiving stakeholders. We then executed an experiment among the receiving stakeholders and analyzed the findings to verify our hypothesis. Finally, we adjusted the handover in accordance with the results, gathered final feedback, and concluded with suggestions for future research.

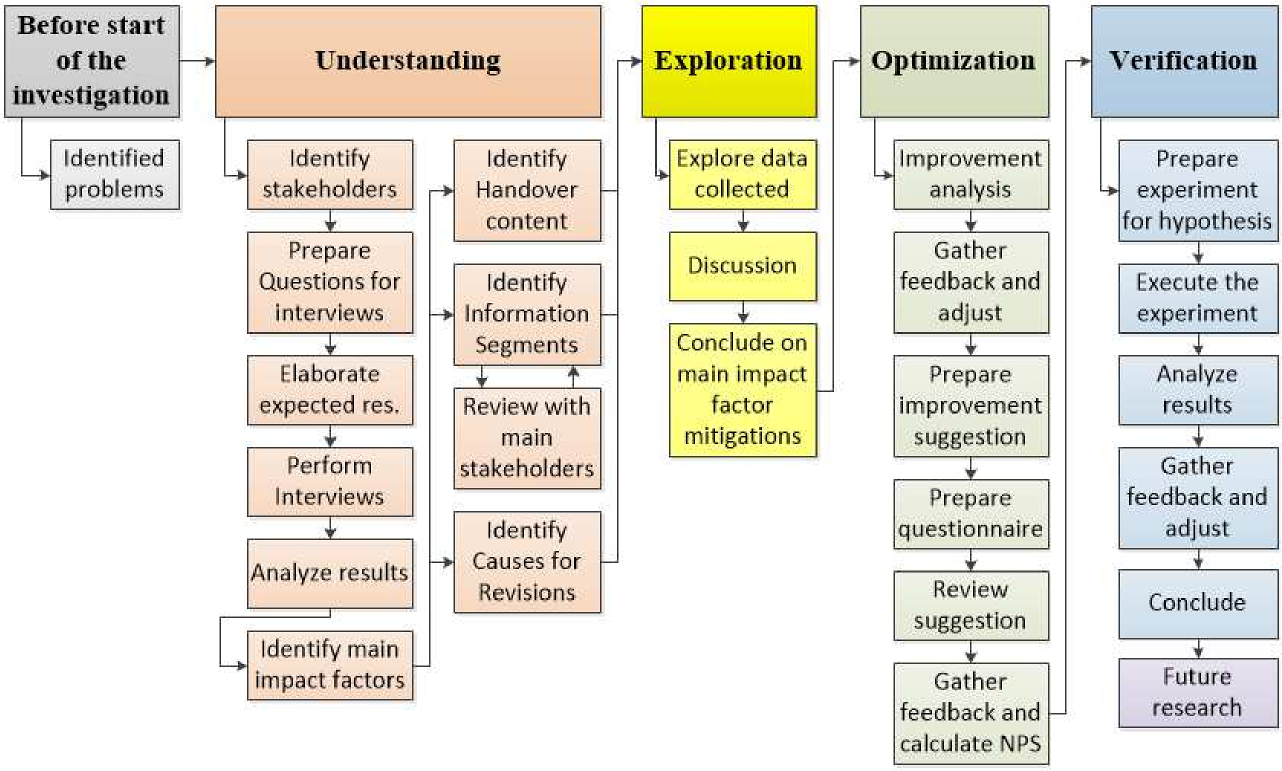

Figure 2. The specific steps preformed in this research.

Research Findings

Understanding. We used Christensen et al. (Christensen et al. 2004) as a basis for our terminology when we performed the stakeholder analysis. Figure 3 illustrates these results, and the stakeholders' interest and influence in this research.

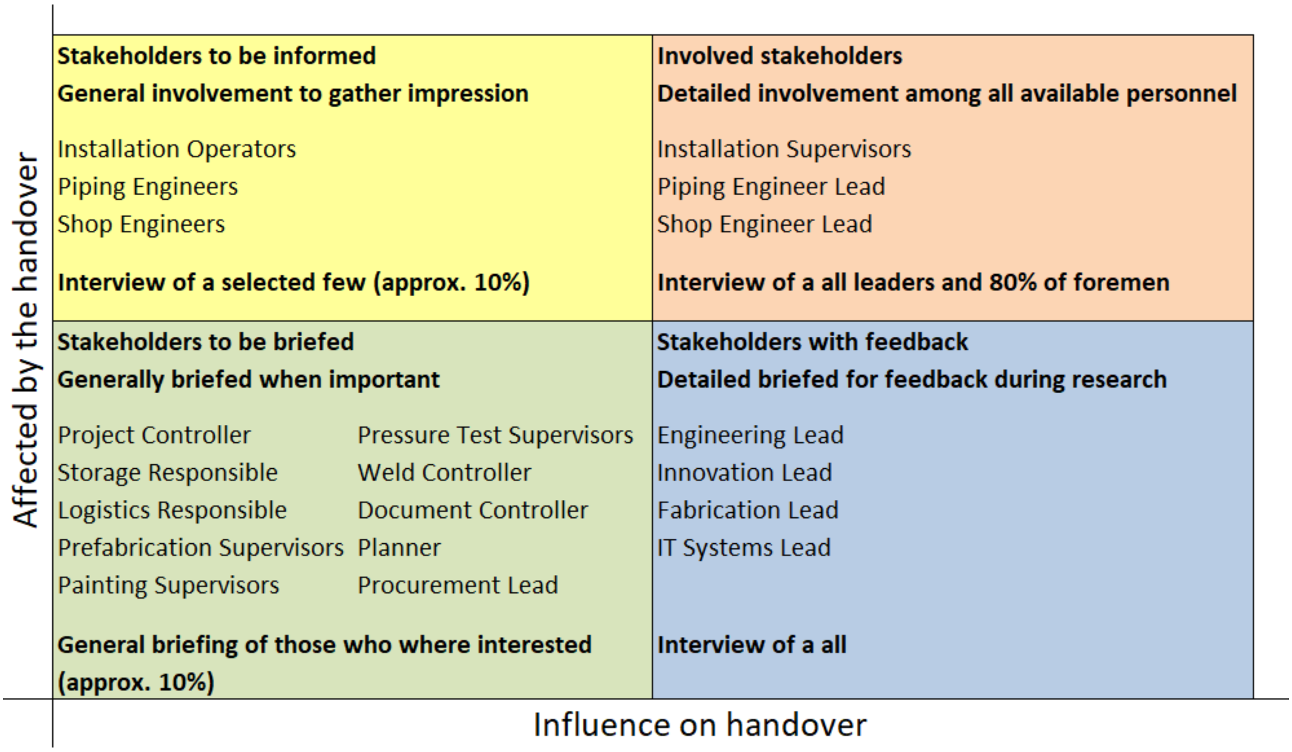

Figure 3. The stakeholder analysis including interest and involvement.

We interviewed a selection of the stakeholders based on their level of interest and involvement as indicated in Figure 3. We expected that the first qualitative research would give us the following stakeholder requirements:

- The handover should only contain relevant info
- The system should be set up to reduce the number of revisions
- The handover should be mainly digitized
- The content of each handover should be visualized instead of using printed pictures from 3D

Figure 4 shows the results of the analysis of the qualitative research. We observed that the results mostly revolved around the extensive amount of insignificant information and revisions. We therefore concluded to regard the following as the main impact factors:

- Amount of insignificant information
- Amount of pages in the handover
- Number of revisions

We observed that the interviews showed opposing interests in regards to the level of digitizing. We discussed this observation and concluded to elaborate this further in the optimizing stage of the research. The reason for our conclusion is that we believe that concrete examples could solve the issues through an iterative process.

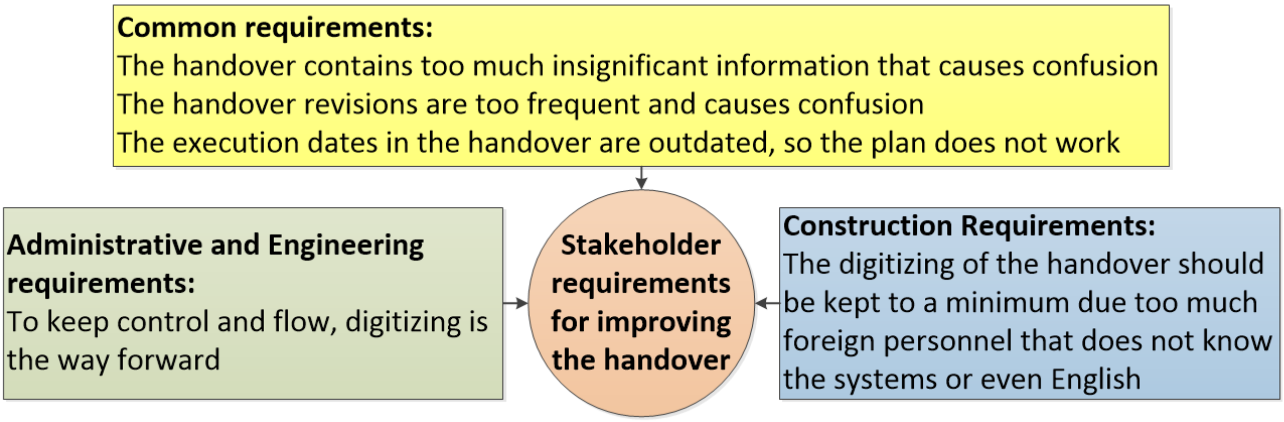

Figure 4. Common and opposing Stakeholder Requirements.

To identify the content of the handovers, we recognized that there were 196 unique handovers for the piping installation with 318 additional revisions. We examined the content of the last revisions of each handover manually and categorized the results as illustrated in Figure 5 as the zero measurement for content. We also observed that the zero measurement for the number of pages including revisions were 28,582. In the context of this research, the term *zero measurement* means the status of the company at the start of the case study.

Handover Categories	Pages on last revision	In percent
1. FrontPage & Content overview	1 187	14 %
2. Piping ISO drawings	1 082	12 %
3. Pipe Support drawings	3 038	34 %
4. 3D Model pictures	1 254	14 %
5. Welding Procedures	450	5 %
6. Torque & thread seal requirements	284	3 %
7. Piping & Instrument Diagrams	307	4 %
8. Material Take Offs	210	2 %
9. Standard support details	552	6 %
10. Structural and Mechanical Layout	286	3 %
11. Other	229	3 %
Total pages	8 879	100 %

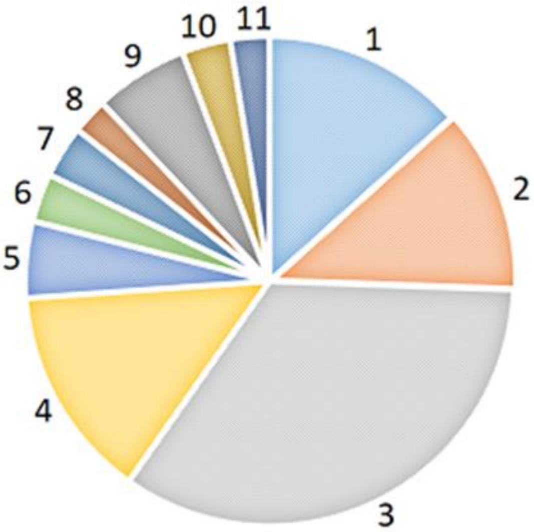

Figure 5. The content of each handover categorized.

We identified each element of information in each of the categories from Figure 5. An information element is one piece of information contained within the handover format. When there were several elements of information in the same category, we multiplied the amount of elements. Based on our understanding of the stakeholder requirements, we identified the zero measurement and categorized the elements into three information value categories (Table 1). Through a review with the installation supervisors and other involved stakeholders, we received feedback on the value of the categories and adjusted accordingly. The result of this review for each category was:

1. FrontPage & Content overview is important due to the size and complexity of the physical handover. A reduction of the handover may make this category obsolete.
2. Piping ISO drawings are the core of the physical handover, and all relevant information within this category must remain at least equally accessible and understandable.
3. Pipe Support Drawings is only required in the physical handover when they are large and complicated.

4. 3D model pictures are the basis for understanding the handover and has to be included in the physical format until a truly valid alternative is in place (with basis in approval from the supervisors).
5. The Welding Procedures are not required in the physical handover as long as it clearly states what procedure to use. This is because the welders physically carry the welding procedures on them at all times due to requirements.
6. Torque & thread seal requirements relevant for the handover must be included in the physical handover.
7. The Piping & Instrument Diagrams is the "process map" that guides the operators and has to be included in the physical format.
8. Material Take Offs of support clamps is equally important as other erection materials when performing the piping installation.
9. The standard support details have to be included in the physical format.
10. The structural layouts are the main tool for measuring beginning and end of a pipe, and has to be included in the physical format. The mechanical layout might be important in special cases.
11. Other attachments have to be included in the physical handover when required. Digitization of the CPI form for valves is acceptable.

Table 1: The amount of information elements in each category and their value

Content category	The zero measurement for number of information elements	Information elements required in a paper format	Information elements that may be digitized	Information elements that are not required
1. FrontPage & Content overview	17,640	196	16,072	1,372
2. Piping ISO drawings	129,840	83,334	19,476	27,050
3. Pipe Support drawings	133,672	3,038	106,330	24,304
4. 3D Model pictures	10,032	10,032	0	0
5. Welding Procedures	8,100	450	0	7,650
6. Torque & thread seal requirements	24,992	3,408	3,408	18,176
7. Piping & Instrument Diagrams	23,946	23,946	0	0
8. Material Take Offs	6,048	5,640	408	0
9. Standard support details	3,312	3,312	0	0
10. Structural and Mechanical Layout	2,288	2,072	216	0
11. Other	3,378	2,383	900	95
Total amount	**363,248**	**137,791**	**146,810**	**78,647**
Each category in percentage	**100%**	**38%**	**40%**	**22%**

To increase our understanding of the underlying reasons for the handover revisions, we analyzed 100 of the 318 revisions at random and categorized them into to four main causes. If there was more than one main cause for revision, we categorized the reason into the main cause with the highest priority.

Table 2 shows the results of this analysis, its estimated standard variations, and categories with priority. In Table 2, *external* refers to a change initiated by the client that is out of AS Nymo's control and usually commercially compensated by this client.

During our examination of the handovers, we observed that a majority did not have any revision history explaining the reason for the change. We manually compared the revision examined with the previous revision to identify the main cause for revision. Due to the extensiveness of this analysis, and the priority of the main cause for the revisions, we halted the examination when we identified an external cause and moved on to next handover. We noted that the feedback we got from other stakeholders did not include any comments in regards to missing revision history. Therefore, we engaged in a new discussion with the receiving stakeholders to understand their experience. The receiving stakeholders provided us with the following feedback:

- The supervisor contacted the shop engineering through verbal communication or mail if there were doubts in regards to any specific revision.
  - This method worked but was not preferred as it put extra stress on the key personnel.
- Revision history was more and more implemented later in the project and is the preferred solution.

Based on this information, we concluded that the revision history should be a natural part of the handover regardless of the handover format.

For the sake of further analysis, we assume that the selection of 100 handovers is representative for all the revisions. Hence, it can serve as the zero measurements of main revision causes. Based on this assumption, it would have been possible to avoid 105 revisions and to digitize 86 revisions. Changes caused by digitized information do not trigger a revision change to the handover itself. This is because it is an update of reference documents or a data transfer exercise in the project control system. Of the remaining 127 revisions, the client would commercially compensate for 51 of these. The remaining 76 should be a target for future research to improve AS Nymo's project execution.

Table 2. The result of main revision cause analysis

Main Cause Priority	Categories	Sample results	Standard deviation
First Priority	Has to be in paper format (External)	16	± 4,0
Second Priority	Has to be in paper format (Internal)	24	± 4,9
Third Priority	May be digitized	27	± 5,2
Fourth Priority	May be avoided	33	± 5,7

Evaluation and improvement

Exploration. For our research, we identified the three main impact factors: The *amount of insignificant information, the amount of pages in the handover, and the number of revisions.* From our analysis of the information contained in the handover, we observed that it is possible to digitize or remove 62% of the data. Furthermore, we also found that this could result in a potential reduction of the physical revisions by 60%. Based on these findings we assume a substantial decrease in the total amount of pages in the handovers. Figure 6 illustrates the interconnection between the main mitigating actions, the research done, and the impact factors.

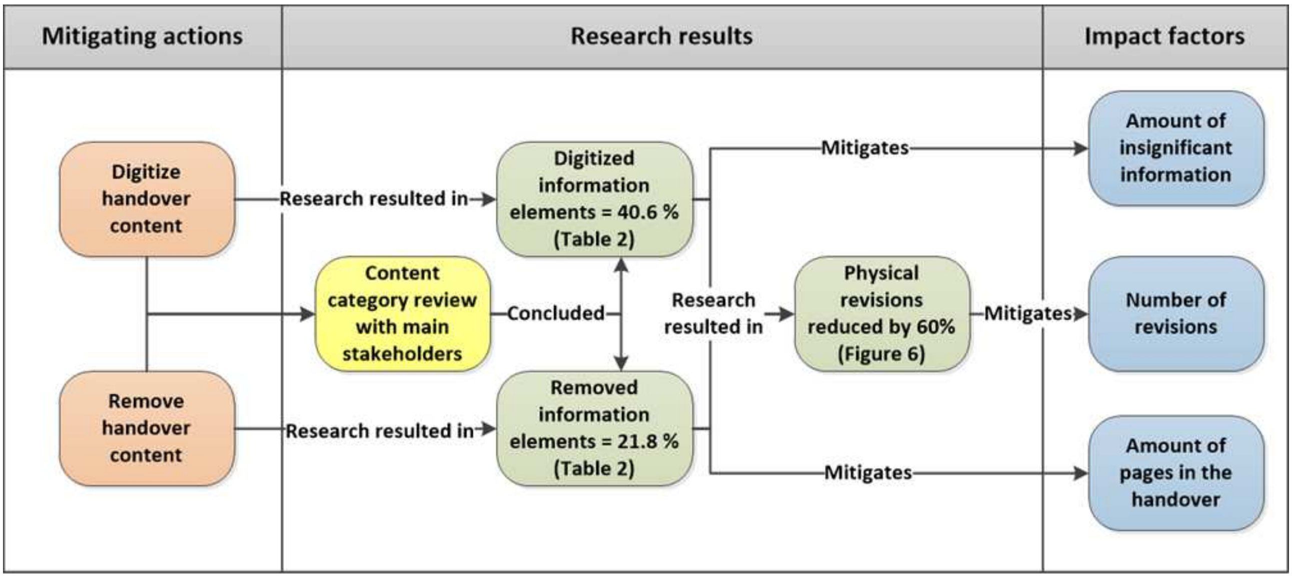

Figure 6. Interconnection between the main impact factors and mitigating actions.

Optimization. We observe that several of the categories of the handovers contain information not required in the physical handover format. The categories 1, 3, 5, 6 and 8 in Table 1 contain mostly information that is not required. The remaining number of elements of information in these five categories are 12,732, while the overall reduction of elements on category 2 are 46,526. With this observation as a basis, we started an iterative process with high influence stakeholders and concluded to look at the option of combining the relevant information from all these categories into a piping installation isometric as mitigating action to the amount of pages in the handover.

By reducing the amount of information on each piping ISO, we assume a reduction of the total amount of installation ISOs compared to piping ISOs. To gather evidence for this assumption and further analysis, we calculated the amount of required installation ISOs. First, we decided that the typical installation ISO (including the categories 1, 3, 5, 6, and 8) contains the same amount of information elements as the original piping ISO to avoid too crowded isometrics. Secondly, we observed that only information elements related to a pipe spool scaled when combining the drawings. Finally, and based on the first two actions, we calculated the amount of installation ISOs to be 737 since this was the point where the amount of information elements on one standard installation ISO equals that of a piping ISO. Based on the main author’s experience, this seems to be a conservative calculation and sufficient for further analysis. Figure 7 illustrates the new categories with the amount of physical pages and information elements.

Updated Handover Categories	Information elements in first revision	Pages in revi: revision	Pages in percent
1. Piping installation ISOs	88 456	737	23 %
2. 3D Model pictures	10 032	1 254	39 %
3. Piping & Instrument Diagrams	23 946	307	9 %
4. Standard support details	3 312	551	17 %
5. Structural Layout Drawings	2 072	259	8 %
6. Other	2 383	134	4 %
Total pages	**130 201**	**3242**	**100 %**

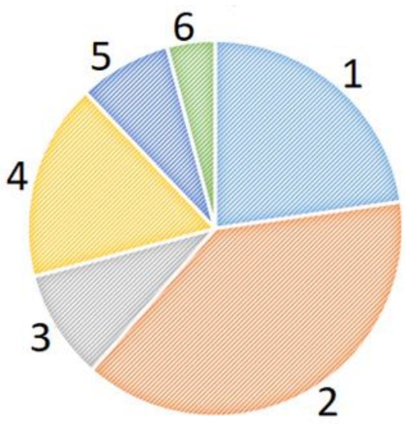

Figure 7. Estimated information elements and number of pages in new handover format.

We selected a medium sized handover and prepared a new version based on our findings so far. We calculated that with this new layout, there should be a potential for reducing the number of pages from 8,879 to 3,242 when excluding revisions, and from 28,582 to 7,203 when including revisions. We engaged in an iterative process making adjustments, before presenting the new handover to eight high influence stakeholders from both construction, design, and innovation. We discussed the layout and content of the handover and finalized the review with a questionnaire to each of the participants. Figure 8 presents the results of this questionnaire with calculated NPS. Since a typical NPS questionnaire ranges from 0-10, while our questionnaire ranges from 1-9, we defined our categories as follows:

- Detractors: Stakeholder score in the range of one to five
- Weak Detractors: Stakeholder score of six (*Weak* counts as half of a *Detractors* score)
- Passives: Stakeholder score of seven
- Weak Promoters: Stakeholder score of eight (*Weak* counts as half of a *Promoters* score)
- Promoters: Stakeholder score of nine

Although the question regarding the reduction of the overall work gave an NPS of zero, the average result for these five questions is 18.3. An NPS between one and fifty is a good result and gives a clear indication that the general opinion is promoting the idea of the new layout for the handover.

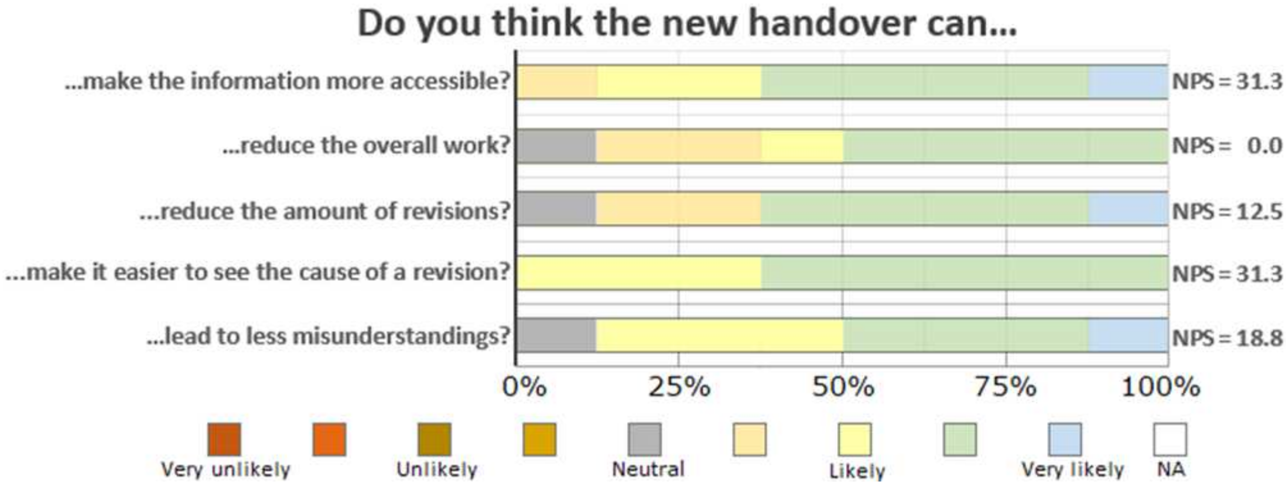

Figure 8. Results of the questionnaire on the assumed value of the new handover format.

What impact will the mitigations of the main impact factors have on the handover?

Verification. Through feedback from high influence stakeholders, we have found that the majority would promote the suggested layout of the new handover. This indicates that the newly acquired knowledge about the mitigations of the main impact factors could increase the handover correctness, intuitiveness, and usability for the receiving stakeholders. To expand our empirical data, we initiated an experiment to measure what impact these mitigations had on the handover. We assumed that if there were any positive impacts due to these mitigations of the main impact factors, the receiving stakeholder would use less time locating information in the new format, than in the old format. Based on this assumption, we formulated a hypothesis as the basis for our experiment:

- The increased intuitiveness and usability of new handover layout will decrease the time the receiving stakeholders use to locate the information element they seek.

To test our hypothesis, we selected two handovers with similar size and complexity and prepared one with the new layout, and one with the old. We also prepared a set of questions relevant for both handovers. We gathered a selection of receiving stakeholders and divided them into two groups: Group A and group B. We presented the new handover layout to both groups before the experiment.

In our experiment, group A was presented with the old layout and the questions first, and then the same questions for the new layout. Group B did the same in reversed order. We measured the time it took each receiving stakeholder to answer the questions for both tasks.

For our verification method, we followed a predefined set of rules:

- We note down the time for every individual
- Each wrong answer was noted down separately for every individual
- If the time spent on the old handover is less or equal than the new handover, the hypothesis is assumed false
- If the time spent on the old handover is between 0 and 10% more than the new handover, the hypothesis is inconclusive
- If the time spent on the old handover is greater than 10% of the new handover, the hypothesis is assumed true

Figure 9 illustrates the results of the experiment. The results shows that the time spent on new handover layout was 33% of the time spent on the original handover layout. Of the 13 questions on each layout, 78% of answers was correct on the original layout, and 94% on the new. Feedback gathered through an open discussion with the participants after the experiment provided us with the following comments:

- "We think that the new layout is significantly easier to follow that the original"
- "We would like to see more examples of the new layout, preferable of completely different packages of higher complexity"
- "Since we now have some experience, the questions will be even quicker to answer on the new layout if another experiment is ever conducted"

Operator #1 spent less time on the original layout, then on the new. We discussed this observation with the operator, and he informed us that he had been working with this specific package in the previous project and was very familiar with its content.

The results show that 5 out of 6 spent more than 10% additional time on the original layout with higher or equal grade of correctness. Based on these results, we assume that our hypothesis is true for the selection of the participants. Therefore, we conclude that we have gathered additional evidence supporting that the new layout can make the handover format more correct, intuitive, and usable for the receiving stakeholders.

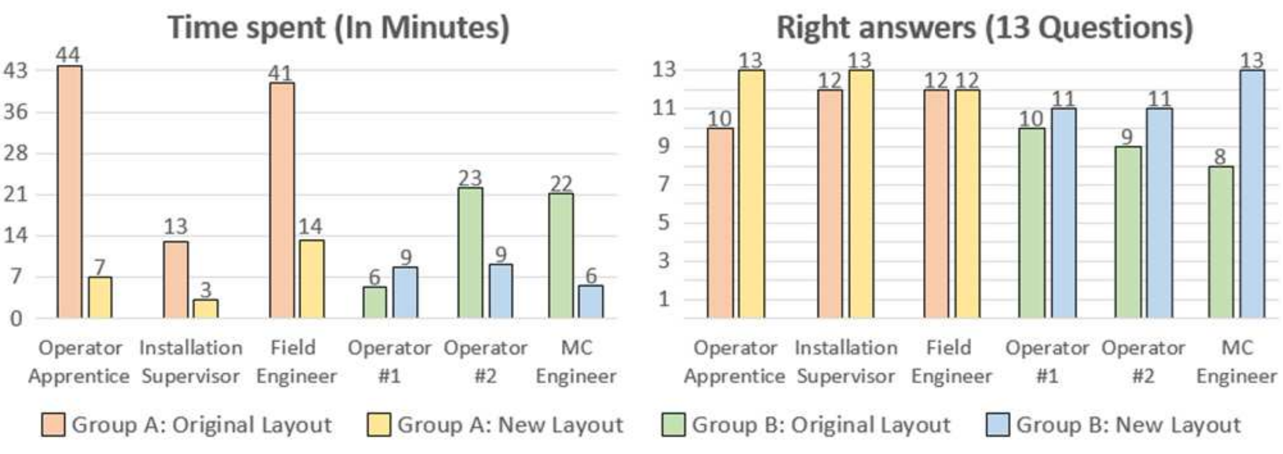

Figure 9. Results of the verification experiment comparing original and new handover layout.

Conclusion

In this this paper, we have gathered data to support that the following impact factors are the main cause for confusion and misinformation in the installation handovers: *Amount of insignificant information, the amount of pages in the handover*, and the number of revisions. Furthermore, we have gathered data indicating that removing and digitizing information not required in the physical handover format, could reduce these impact factors by as much as 60%. With this newly gained knowledge about the impact factors, we prepared a new layout for the installation handover and gathered empirical evidence to support that these mitigating factors can make the handover format more correct, intuitive, and usable for the receiving stakeholders. Additionally, we found that improving the handover could give a 67% reduction in time spent for the receiving stakeholders to find the specific information they seek.

Future Research

We recommend expanding the scope of the experimental hypothesis to gather additional empirical evidence. By increasing the number of test subjects, the number of questions, and the number of different handovers the foundation for the empirical evidence would improve significantly. To expand the empirical evidence even further, we would also suggest repeating a similar analysis in a manufacturing company of a different domain. If the results provided through this research supports the current findings, we recommend implementing the new layout of the handover as part of the project execution in a small or medium-sized project in both companies. During this project execution, we recommend gathering data of the performance through mixed methods to enable for continuous improvements in the installation handover format.

Acknowledgments

Raymond Omnes has assisted in gathering valuable quantitative data for this paper and provided the author with a second opinion throughout the research. The people in the construction, engineering and innovation departments at AS Nymo have served as discussion partners and test subjects and has provided valuable input.

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Biography

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