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**VALUE STREAM MAPPING FOR PREFABRICATED PIPING IN
PROJECTS**

Master Thesis in
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ABBREVIATIONS

BoQ	Bill of quantity
CNC	Computer numerically controlled
CPE	Chief Project Engineer
DSM	Design structure matrix
EPC	Engineering, procurement and construction
FFM	Four field mapping
IC	Installation costing
KPI	Key performance indicators
NVA	Non-Value added
PC	Project Controller
PM	Project Manager
PO	Purchase order
PR	Purchase requisition
RFQ	Request for offer
SIPOC	Supplier-input-process-output-customer
VA	Value added
VS	Value stream
VSM	Value stream map
WoW	Way of Working

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ABSTRACT

Taking actions to fasten a project delivery will give an edge in large scale projects. By utilizing piping prefabrication a faster installation will be possible comparing to non-prefabricated pipes, which results in a quicker project delivery. The purpose of this Master thesis is to identify wastes and improvement suggestions resulting in a leaner process for prefabrication of piping.

Qualitative information has been gathered by using interviews and a workshop. Interviews were carried out with stakeholders, from the sub-processes, in the whole process flow from the sales stage all the way to the installation stage. By the use of Value Stream Mapping a current and a future state has been created. In the workshop stakeholders created a current state and listed issues and improvement suggestions for the processes. The future state was created based on the suggestions chosen for implementation. Prefabrication do require certain know-how of the process hence a process flow chart and a design structure matrix were created to allow for an easier understanding of the whole process.

The future state created results in a shorter delivery time for a project, with the chosen suggestions a decrease in project delivery time will be around 8 %. A goal of 20 % was set, this goal can be achieved by implementing more of the improvement suggestions that were given during the workshop. Besides a faster project delivery, the costs accumulating at site will be lower and will not require skilled labor at the same degree as a non-prefabricated solution. However, prefabrication is not applicable for all projects nor can the benefit of prefabrication be applied to all projects due to country specific variations and limits to the scope of deliverable.

Keywords: Value stream mapping, lean, process flow, prefabrication of pipes

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ABSTRAKT

Att handla så att projekt kan levereras snabbare skapar en fördel i storskaliga projekt. En snabbare installationstid är möjlig genom att använda prefabricerade rör jämfört med vanliga rör, vilket också resulterar i en snabbare leverans av projektet. Syftet med denna magisterhandling är att identifiera svinn och förbättringsförslag som resulterar i en mera slimmad process för prefabricerade rör.

Kvalitativ information samlats in med intervjuer och en workshop. Intervjuerna gjordes med intressenter inom process flödet från försäljningsstadiet hela vägen till installationsstadiet. Genom att använda värdeflödesanalys så har ett nuvarande stadie och ett framtida stadie skapats. Intressenterna i workshoppen skapade det nuvarande stadiet och listade problem samt förbättringsförslag för processerna. Det framtida stadiet skapades på basen av utvalda förbättringsförslag. Prefabricering kräver viss förhandskunskap så en processflödeskarta och en design structure matrix skapades för att kunna förstå processen bättre.

Det skapade framtida stadiet resulterar i en kortare leveranstid för projekt, på basen av de utvalda förbättringsförslagen uppstår det en 8 % kortare leveranstid för projektet. Ett mål på 20 % gjordes i början, detta mål kan nås genom att implementera flera av de givna förbättringsförslagen som listades under workshoppen. Förutom en snabbare projektleverans så kommer kostnaderna som ackumuleras på byggplatsen och mängden yrkeskunnig personal att vara lägre för att prefabricerade rör används. Däremot kan inte alla projekt nyttja prefabricerade rör därtill påverkar variationer mellan länder och leveransomfattning om det är lönsamt med prefabricerade rör.

Nyckelord: Värdeflödesanalys, lean, process flöde, prefabricering av rör

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TIIVISTELMÄ

Suurien projektien toimituksen nopeuttaminen voi luoda etulyöntiaseman markkinalla. Käyttämällä esivalmistettuja putkia saadaan nopeampi asennusaika kuin ei esivalmistetuilla putkilla, samalla saaden nopeamman toimitusajan projektille. Tämän lopputyön tarkoitus on tunnistaa ylimääräistä aikaa vievät vaiheet ja antaa parannusehdotuksia virtaviivaisemman prosessin luomiseksi esivalmistetuille putkille.

Laadullinen data on kerätty haastatteluilla ja yhdellä työpajalla. Haastattelut on toteutettu sidosryhmän kanssa johon kuuluu jäseniä kaikista prosessin kulun vaiheista myynnistä asennukseen. Arvovirtakuvia on luotu nykyisestä ja tulevasta prosessista. Työpajassa sidosryhmä tuotti arvovirtakuvan nykytilanteesta ja listasivat ongelmat ja parannusehdotukset prosessia varten. Tuleva prosessi luotiin viidellä valitulla parannusehdotuksella. Esivalmistelu vaatii tietyn tuntemuksen koko prosessista, siksi prosessin virtauskuva ja riippuvuusmatriisi tehtiin paremman ymmärryksen luomiseksi.

Tulevan vaiheen seuraus on lyhempi toimitusaika projektille, valituilla parannuksella projekti pystyy toimittamaan noin 8 % nopeammin. 20 % oli asetettu maalina, se voidaan saavuttaa jos useampi parannusehdotuksesta, joka oli listattu workshopissa, implementoidaan. Paitis nopeampaa toimitusaika projektille myös kustannukset työmaalla tulee alentumaan, yhtä ammattitaitoa vaativaa työvoimaa ei ole tarvetta. Mutta esivalmistelu ei pysty käyttämään jokaiseen projektiin; eri maiden vaatimukset, projektikohtaiset tekniset tiedot ja toimituslaajuus vaikuttavat.

Avainsanat: Arvovirtakuva, lean, prosessinvirtaus, putkien esivalmistelu

1 INTRODUCTION

In today's projects, there is a constant need to improve the delivery time for a project. In all projects and especially in EPC projects, proper planning and a proper way of working is required. In an EPC project where the company delivers the full scope of piping there is a decision to make whether to use standard piping solution or prefabricate a certain amount of that piping to speed up the installation and commissioning at site, this decision is currently done by the project team. This Master thesis is done on behalf of the Engineering department within that company.

1.1 Background

In thesis *Cost Comparison between Different Joining Options for Cooling Water Pipelines on On-site Installation* it was concluded that pipe prefabrication at the supplier will reduce the installation time at site hence reduce the overall time for that specific piping system. However, implementing the new piping design into the current way of working was not done in a suitable manner, issues with the way of working from the sales level all the way to installation and commissioning occurred.

Today's situation for piping installation works as follows; piping is sent to site and when they are installed they are welded together, for example joining one bend and two straight pipes requires two welds. For each welding seam that has been done, cleaning and pickling of the pipe must also be done. Proper pickling of the pipes must be done, otherwise there is a risk for contamination to occur in the pipes.

The new design options are either to use prebending of piping or use a coupling piping connection. Both methods are more expensive to procure and manufacture, but they do have a shorter installation time at site. By reducing the numbers of welds both the time and resources spent welding and pickling is decreased. The

piping sizes at a plant ranges from Ø10 to DN250. Joining piping by couplings are not exactly prefabrication since the work is done at site, but in this thesis the solution will be considered as a prefabrication method.

Fast track projects have become more common. If a prefabricated piping solution ensures that the company can supply a project in a fast track manner and that the delivery date will be achieved is important. By using prefabrication of pipes, a shorter total delivery time will be possible to achieve considering the whole plant and the quality of the piping is higher. Prefabrication is also an option at sites where the labor costs are high.

All the three options have a slightly different design when the design of piping is done for a plant. Decision on what piping to use is done latest in the design stage of the plant. Prefabrication will be used as a common term to refer to both systems in this thesis. (Lindholm, 2015)

1.2 Purpose

This master thesis will focus on mapping the whole piping process using VSM, aim is that the lead time will be lowered and process itself would be made leaner. Since there is no clear way of working when choosing prefabricated piping in an EPC project a general process flow chart has been requested. The master thesis will go through the process and its sub-processes for the piping system from sales to installation and commissioning. Problems in the process will be identified, process flow itself will be reworked with Lean-concept in mind. By optimizing the lead time for piping the project will be completed sooner and the return on investment will be increased. Knowledge gained through the gathered theory and data will be used to solve the improvement suggestions, these improvement suggestions are ranked

with reflection on how easy or hard they are to solve and what kind of impact on the lead time they have. Problem will be identified and a solution will be created. Research question to answer: *How to make the process leaner by identifying wastes and improvement suggestions?*

Within the company the focus on Lean has increased, operations carried out should be operated in such way that the amount of waste and non-value adding actions are at a minimum.

1.3 Delimitation

This thesis will focus on the piping system within the plant, other parts and systems delivered in a project are considered out of scope. The scope of the piping system starts in the sales phase and continues all the way to installation and commissioning, things occurring after the plant has been handed over are also considered out of scope. Schedule for this thesis is to aim for full completion in early 2018, this limits the amount of data gathered under a long period of time for example during the whole process of a new EPC project from start to hand over. Interviews and a workshop will be carried out, however with regards to time there are limitations to the availability of time to carry out all interviews, personnel working with projects have deadlines and other obligations to the projects they are involved in. Implementation of the future state will be carried out stepwise, suggestions on how to implement the improvements will be done during the time of the thesis. Project types other than turn-key deliveries, EPC, are considered out of scope. Furthermore, can be noted that two sub-processes for the major part are done outside of the company, these sub-processes can most likely be affected to the same degree as if they were done internally.

1.4 Confidentiality

Due to the level of detail several subchapters in this Master thesis will be confidential. The company, which this Master thesis is done for, delivers large industrial plants that require extensive project management, competition is though. Project deliveries are made around the globe. Background material will be provided for material that will not be publicly available. The name of the company will neither be given. The background material follows the same structure as this thesis, hence when referring to the background material the material will be under the same heading.

1.5 Disposition

This master thesis follows a scientific structure. First chapter will be an introduction of the thesis subject with background information. Second chapter will go through the theory for this thesis. Third chapter shows what method has been used in gathering the data. Fourth chapter will present the results when theory has been applied. Fifth and last chapter will summarize the master thesis and have suggestions for further research.

2 THEORY

In this section, theories supporting the thesis will be reviewed. The whole process of making something leaner can be done in numerous ways with several different methods. Value stream mapping was chosen as the primary philosophy to use because it is easy to adapt so that we can find out the answer to the research question based on where we are now. Besides Lean and VSM itself, research will include Kaizen and Design Structure Matrix. In the workshop the value stream mapping process will take use of Four Field Mapping, it has been used before within the company. The whole idea of value stream mapping is to find out steps that can be improved, that is make the process leaner, and how to implement the improvements into the way of working for that process.

2.1 Lean

Lean is described in The Lean Six Sigma Black Belt Handbook as follows:

The Lean methodology is an operational philosophy with a focus on identifying and eliminating waste in an organization. Lean principles include zero inventory, batch to flow, cutting batch size, line balancing, zero wait time, pull instead of push production control system, work area layout, time and motion studies and cutting cycle time. The concepts are applied to production, support and service applications. Lean focuses on eliminating waste from processes and increasing process speed by focusing on what the customer actually consider quality, and working backwards from that. (Voehl, Harrington, Mignosa, & Charron, 2014, p. 9)

Possible wastes will be identified, during the workshop, the interviews and when creating the process flow chart.

2.1.1 The nine types of waste (Muda)

In the Lean methodology the waste is something that is identified and eliminated. There are eight wastes listed in both the *Operations Management* book and *The Lean Six Sigma Black Belt Handbook*. The wastes presented can be sorted into the following categories:

- Overproduction
- Excess inventory
- Defects
- Extra processing
- Waiting
- Motion
- Transportation
- Underutilizing people

Lean has usually been classified into eight wastes but a ninth has been added that takes the individual and collective belief system into consideration and how they affect the daily behavior. Ninth waste:

- Employee behavior (Voehl, Harrington, Mignosa, & Charron, 2014, p. 67)

There are wastes that occur in several categories and wastes that are linked together.

Overproduction

When the item is manufactured before it is needed, high inventories and lead times, also results in difficulties in noticing defects. Overproduction is considered the worst kind of waste since some of the other wastes occur more frequently if production is higher than required. Common causes for overproduction are: Just-in-case logic, unlevelled scheduling, unbalanced workloads, and misuse of automation and long process setup times. In figure 1 the additional wastes also occurring during overproduction is shown.



Figure 1. Overproduction (Authors adaption from Voehl, Harrington, Mignosa, & Charron, 2014)

Excessive inventory

Stocking up with excess inventory leads to more people, more equipment and more storage required to manage the inventory. Excessive inventory is a way to cover up other processes that do not function properly. Those typical processes are: Poor market forecast, complex products, unlevelled scheduling, unbalanced workloads, bad quality or shipping from supplier, misinterpreted communication and reward system.

Defects

A defective product or service can occur anywhere along the value stream. Defects can occur both before and after it has been delivered to the customer. Regardless of who the customer is defects are something that the customer do not want. Common

causes for defects can be sorted in the following categories: The needs of the customer not understood correctly, poor practices in purchasing or poor-quality materials, insufficient education/training/instructions, product design of poor quality, weak process control or a lacking maintenance plan.

In an information or service based process the flow of faulty or inadequate information can be seen as a defect.

Extra processing

Processing that occurs which does not add value or processing a defective product several times before waste is identified is considered extra processing. Common causes for extra processing are: Updated product but no updated process, just-in-case logic, customer requirements unclear or undefined, over-processing to cover for downtime, poor communication, unnecessary approvals and extra copies or excessive information.

Waiting

The time that occurs while waiting for a process to complete. The process the user is waiting for could be a machining process, waiting for material to be processed or a slow computer. The waiting can be split into the following categories: Outage of raw material, unbalanced schedule or workload, downtime for unplanned maintenance, deficient equipment or facility layout, long process setup times, misuse of automation or problems in the quality upstream.

Motion

Movement of people or information that does not add value to the process. Common causes for waste in motion are: poor people, materials and machine effectiveness, working methods that are inconsistent, poor information

management, cell or facility layout not being favorable and workplace organization and housekeeping not being sufficient.

Transportation

Unnecessary movement of material, equipment and parts around the facility. Transportation of material does not add any kind of value to the product, the transportation should be kept at a minimum. Transportation wastes are: Poor purchasing practices, large batch sizes and storage areas, deficient facility layout and limited understanding of the process flow.

Underutilized employees

An organization that does not utilize the full mental, creative, innovative and physical skills or abilities of its employees. This occurs in almost every company. Common causes for this is: Old guard thinking, politics and business culture, poor hiring practices, in-service training not carried out or at a low level or a low pay high turnover strategy.

Behavior

The ninth waste. Waste that occurs from the result from human interactions, closely related to the underutilization of employees. Present in almost all organizations. This is considered as a root cause to the eight other wastes. Behavior waste can be split to two categories, personal and people. Personal waste is such waste that you can control by yourself, how you see your work, is it meaningful or meaningless? People waste is waste what occurs between the employees. Do managers hinder employees? Is there a can-do attitude? People waste can stagnate any process. (Voehl, Harrington, Mignosa, & Charron, 2014, pp. 67-97)

2.2 Value Stream Mapping

By using value stream mapping the flow of the process whether it is a product, process or information. Applying lean to an information heavy process is not that much different from a production process, some creativity is required. James P Womack and Daniel Jones defines three actions in the book *Lean Thinking*, they are:

- Problem solving (for example design)
- Information management (for example order processing, arranging logistics)
- Physical transformation (for example conversion of raw material into a product)

In this case the problem solving will be the planning and designing of the piping system. Physical transformation starts from the manufacturing of the piping to the installation and commissioning. Processes not fitting into these two mentioned will likely fit into the last action type, information management.

These three actions will help in grouping the sub-processes within the whole process. Problems and wastes occurring within the same action category might have solutions that are similar to each other. (Keyte & Locher, 2016, pp. 1-4)

A value stream mapping process can be split into four steps, each with its own objective. The following: *Preparation*, *Current state*, *Future state* and *Planning & Implementation*, see figure 2. (Locher, 2008, pp. 1-2)

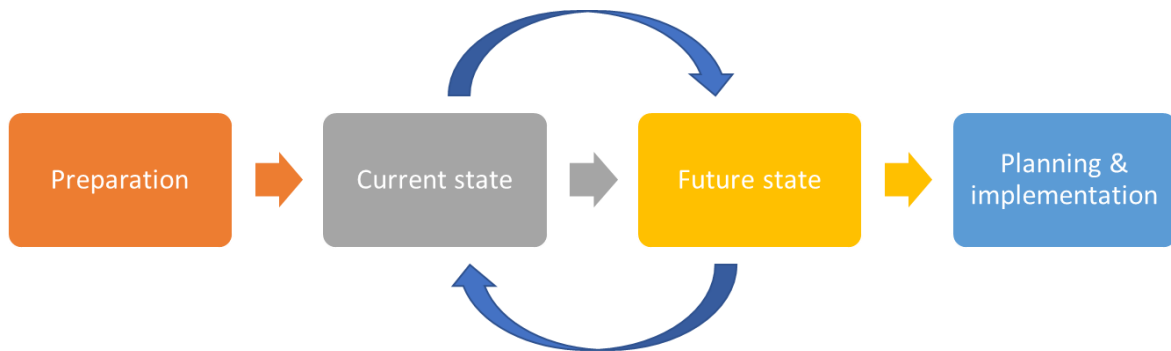


Figure 2. Value stream mapping process (Authors adaption from Locher, 2008)

The steps go under slightly different naming depending on the author and book. In Operations Management, they have used *Product Family* instead of *Preparation* since the book is more focused on products, the Preparation term will be used in this thesis. (Krajewski, Malhotra, & Ritzman, 2016, pp. 239-243)

2.2.1 Preparation

The preparation step takes place before the mapping of the value stream, the group that are to facilitate the value stream mapping is gathered. The team members in the VSM event should be cross functional so that the whole value stream is covered with members that have knowledge of one part of the whole process. Team members could be the managers of each functions or department that are within the value stream that is to be mapped.

According to Locher in *Value Stream Mapping for Lean Development* there are some key questions to answer before the mapping workshop takes place:

- What exactly will be mapped? What product, service or project? What activity?
- What process will be included? Where or when will the map start and where or when will it end?
- Who needs to be on the mapping team? Who will be the value stream manager?

- What are the business objectives? What will be the measure of the success?
- Who needs to support the effort? Who needs to be part of the decision process?
- What logistical plans need to be made to avoid difficulties that the mapping team may encounter?

By answering these questions, the scope is made clear. Appropriate mapping of the scope is critical for the mapping workshop to be successful.

Some guidelines for the value stream manager to successfully lead the implementation of the future state into the process itself are to identify families (for example plant deliveries based on: size, fuel, location and scope) and selecting a project from the chosen family.

Products or services that have a very similar process step can be grouped to one family. Goal is that by identifying the families the flow of information in the process can be mapped. Flow of information starts from the customer, goes through the processes and then ends up as a product, service or solution for the customer.

Following step, the value stream manager does, is choosing a project that can be worked on as an example. By having case projects estimations can be done, having more than one case allows for discussion on the differences identified between the projects. The projects should however be similar so that the process for each project does not differ too much from each other.

A supplier-input-process-output-customer figure can be made, otherwise called SIPOC. This figure shows clearly who the supplier and customer are. What the input and output is and what is done in the process itself.

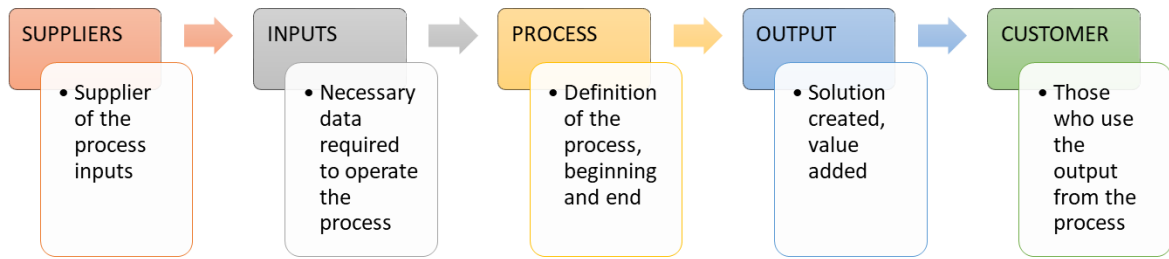


Figure 3. SIPOC (Authors adaption from Keyte & Locher, 2016, p. 15)

In figure 3 each step of the SIPOC is listed. A more detailed map of the SIPOC can also be made when preparing for the mapping, in such a map more details can be listed such as: the objective of the process stated; a problem statement, the goals, the suppliers with inputs from them, the issues and problems listed along with the benefits of a successful implementation, value stream manager, sponsor of the workshop and leadership decision, detailed process steps from start to full completion, what is in- and out-of-scope, the technology required for the processes, dates and location of the workshop, what output there will be and who the customer is, finally a participation list and list of data that is to be collected. (Locher, 2008, pp. 2-8)

2.2.2 Current state

By mapping the current state, the members in the value stream mapping group will be able to see the whole process. By visualizing the whole process for the team members, they will see how the current process works. Very few persons will understand the complete process with all its sub-processes, that's however not a prerequisite.

Locher identifies six following steps that should be done to complete the current state map.

1. Identify current customer needs.
2. Identify main processes (in order).
3. Select process attributes (or data attributes).
4. Perform value stream walk-through and fill in data boxes.
5. Establish how each process prioritizes work.
6. Calculate value stream summary metrics such as lead time, process time, first pass yield, cost, and other measures that the mapping team deems important.

Identify current customer needs

What does our end-customer want? Various customer requirements for that product, service or solution should be identified. Items that the customer finds interesting could be but not limited to: Lead time, quality, warranty, cost or new products and services.

Identify main processes

Identifying of and recording of key-processes takes place in the correct order that they occur. Splitting the process up into suitable sub-processes, the split-up should be done in a logical way, each time a person hands the task forward to another person could mark the beginning of a new process. But if a process is very long, several months, it could be split up to several smaller steps. A process that takes up less than a couple of minutes could be merged with another process to keep the number of sub-process boxes at a number that is manageable. There is a risk that by having too many small sub-processes the team will lose track of the big picture.

Select process metrics

There are numerous different ways to measure a process. The most basic one being the time taken to complete the process. Depending on who the participants in a value stream mapping process is they might have a more hands on experience or a balcony view with less knowledge of the detailed process but. For the value stream

mapping good estimates are good enough that can be used. Metrics that can be used to measure are:

- Process or lead time
- Available time
- Number of people involved
- Typical batch size
- Quality output
- Rework required
- Inventory
- Demand rate
- Sources of information

All metrics do not need to be used when measuring. The metrics can be chosen based on what waste is to be eliminated, for example if we would like to create a shorter lead time we would use those metrics that in any way measure time.

Perform value stream walk-through

Important when mapping the processes is to have a walk-through of each process step and follow the process itself when it is carried out. There could be several steps that are overlooked when it is explained to another person during the value stream workshop. Some steps might not be physically possible to follow up since the process itself spans over a long time, in this case qualified estimations are good enough. A virtual tour could be done also to simulate each sub-process with the help of access to documentation concerning that subject, issue or problem.

Establish how each process prioritizes work

Asking the persons carrying out the process how they prioritize their task can shed light on how each person prioritizes their tasks. Participants are most likely working on several different projects at any given point so knowing how they prioritize their work is essential to optimize the process and cut down on the lead time.

Calculate value stream summary metrics

When the walk-throughs have been done the team can review the performance of the current state. Measuring the current state of the value stream can be done in several ways, most common are using the total lead time, total process time and total cost. When estimating the total cost everything that goes into the process should be taken into consideration, process time, information, material, quality and warranty costs. Using a range for the lead time is something also to keep in mind, the same sub-process might have the same task, but input and output might differ, a task or project might be completed successful or not-so-successful. (Locher, 2008, pp. 23-34)

2.2.3 Future state

When planning for the future state, there are seven questions that should be answered before starting to map out it. Locher lists them as follows:

- What does the customer really need?
- How often will we check our performance to customer needs?
- Which steps create value and which steps are waste?
- How can we flow work with fewer interruptions?
- How do we work between interruptions, and how will work be triggered and prioritized?
- How will we level the workload and/or different activities?
- What process improvements will be necessary?

Brainstorming for new ideas for the future state could be a viable option but the risk is that the sole concept of the mapping, making the process leaner, would be overlooked, limit the brainstorming to encompass the seven questions.

What does the customer want?

The first question to be answered. If possible, involve the customer in the making of the future state. Making assumptions of what the customer wants can lead to the

future state ending up with wrong results. The service level that the customer requires that is lead time, quality and cost.

How often will we check our performance to customer needs?

At what rate to check the performance, if it is done too often it is a waste of resources and if it is too seldom the problems will be bigger when they are found. For each sub-process, a review meeting could be held each day/week/month depending on the need, that way when a sub-process takes too long management can respond quicker or more resources can be allocated to that sub-process. When a problem occurs, identifying the root cause is the top priority so corrective actions can be carried out to prevent that the same problem would occur in the future.

Which steps create value and which steps are waste?

Identifying the waste can be done according to the nine types of waste that were mentioned in 2.1.1.; Overproduction, excess inventory, defects, extra processing, waiting, motion, transportation, underutilizing people and employee behavior.

Some other questions that can help are also: Are there items that are reinvented again? Are there different WoW causing different lead times for the same sub-process? What kind of interruptions in the process do we have, where do they occur? Are there too many handovers of the process, could we make do with a lower number of handovers, do each process participant add value to the process?

How can we flow work with fewer interruptions?

Moving from a functional, batch and queue processing flow process to a more cross functional flow process will lead to minimization of queues lead time shrinks to 50 to 90 percent. Quality of the process is increased by 30 to 90 percent and process time reduced by up to 40 percent. Moving personnel around into new groups might

not be possible so periodically moving the cross functional team together to handle the tasks at hand could be an option.

Whether the personnel are moved around or choosing to have temporary sessions, the key is to have the information flow to flow uninterrupted between the sub-processes and teams.

How do we work between interruptions, and how will work be triggered and prioritized?

Watching from a birds view on the complete process pockets of flow will be seen, maybe even several. With the pocket flow queues will occur, usually items are prioritized as first-in-first-out but in some cases, that is not optimal. Work can be triggered in pull, push or a combination of them. Correct number of resources that will be allocated to a sub-process to complete it within time should be clear.

Interruptions can be of varying degree and some are more critical than others. Having an unscheduled brake-down of a machining equipment can cause serious issues with the production, while another interruption could be a blue screen on the computer which is usually solved after a restart of the computer. There are of course interruptions that take time that cannot be affected within the company, for example an approval process from the customer's side might take longer time than anticipated or a power outage causing shutdown of equipment.

How will we level the workload and/or different activities?

An unlevelled workload causes difficulties. A sub-process often having queues forming might need attention from the management so that the issue can be reviewed and possibly fixed. Adding resources is one option, either by relocating from another sub-process or using sourced external resources. Redesigning the

process is another option, for example could a sub-process more upstream be partly released so that the sub-process that takes long time can start sooner?

Limiting the number of projects in the whole process is an option to consider, however that could result in turning down business opportunities. Nevertheless, projects might occur that are too good to pass on. Working towards identifying root causes for an unlevelled workload is beneficial.

What process improvements will be necessary?

Quality before quantity, a well implemented minor improvement in a process is better than several half-hearted improvements. Before deciding on which one to choose to take a step back and see the whole process, what improvement will the process benefit the most from? (Locher, 2008, pp. 55-76)

2.2.4 Planning & Implementation

There is no clear way when implementing the future state into the process. Nevertheless, there are some guidelines that can be used and adapted to fit that specific need. Improving the first pass yield of information flow is a key to make sure that other improvements do get implemented correctly, improving the information quality does not require that much effort. By using checklists for each step in the future state the process of implementing will be carried out easier. These checklists can be done relatively quickly and easily for a specific sub-process after the VSM event by the sub-process owner.

Developing an implementation plan

To do a successful implementation of the future state the organization can identify loops. A loop is a pocket of flow for certain steps of sub-processes. One loop should be easy to understand and comprehend, within each loop the future state for those sub-processes in that loop can be seen and the improvements listed. As an example,

loops could be split into engineering and procurement loop, internal and external loops. Key for the loop is that those that have tasks within that loop are aware of the rest of those within the same loop, and what the future state within that loop is and how it is implemented.

Ending the event

After the VSM event the participants in the event should reach out to those that did not attend the event and share with them what was done during the event. What the current state was, what the future state is and specifically how the implementation of the future state will be carried out. The process flow chart, SIPOC or other visualization chart can be used to visualize the VSM event. The visualization chart can be made visible at different areas in the organizations, so the employees can be made aware of it.

Value stream management

For the VSM event to be successful and have the future state implemented requires that the management is onboard, value stream manager and the VSM team are also required. Having key people ignoring the implementation will hinder the implementation. Follow-ups of the implementation can be done at suitable intervals.

“Change will not come easily, but the rewards for the organization can be great” (Locher, 2008, p. 95)

There are high requirements on the value stream manager, she or he should have strong project management and interpersonal skills. Since the future state involves changing how people work there are bound to be conflicts occurring, these conflicts must be solved. The participants in the VSM event are also required to be willing to support the effort. (Locher, 2008, pp. 89-96)

2.2.5 Value-added and non-value-added activities

A VA-activity is something that the external customer is willing to pay for and a NVA-activity is something that does not add any kind of value to the process. When mapping out the VS it is very important that all VA- and NVA-activities are accounted for. VA-activity could be the conversion of raw material to a processed product, for example taking flour and baking a bread out of it. For an NVA activity there are two different kinds, they are:

- Poor-process design activities. An activity in a process that occurs that is unnecessary, waiting, setting up, storing or reworking something are examples of such activities
- Unrequired activities that does not add to the process or add value for the customer, logging in a document could be an example

There are estimations that as much as 65% of organizational activities and 95% of the lead time are consumed by NVA-activities. Activities that also could be regarded as NVA are safety, accounts receivable, accounts payable, processing, payroll, environmental, legal, taxes, marketing, quality control and other similar activities not adding directly to the value of the product. These are however very much needed for the whole company to function. (Voehl, Harrington, Mignosa, & Charron, 2014, pp. 107-112)

2.3 Kaizen

The Kaizen improvement method stands for continuous improvement of the process by the personnel. With the Kaizen mindset, it's seen as almost any process can be improved, and those most suitable to improve the process are those working with the process. By having the people carrying out the process improve it they will more likely take it to heart and maintain the achieved WoW and quality. To achieve

the continuous improvement flow, the Deming cycle can be used, see figure 4. *Plan-do-study-act*; **plan**, choose the process to improve and comes up with improvements, **do**, implements the improvements, **study**, analyzes the result and data gathered from the do-step, go or no-go decision is made, **act**, successful result means implementing it as standard WoW. (Krajewski, Malhotra, & Ritzman, 2016, p. 121)

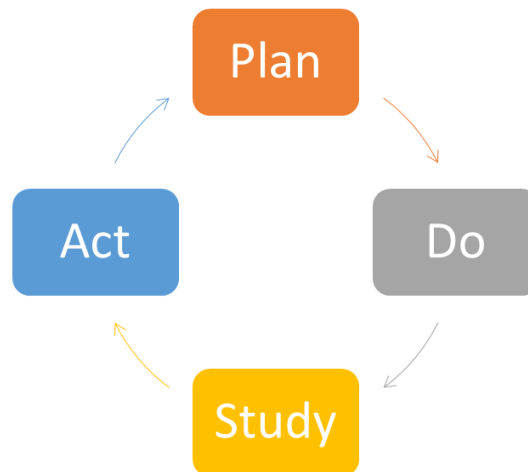


Figure 4. Plan-do-act-study cycle (Authors adaption from Krajewski, Malhotra, & Ritzman, 2016)

The term *Kaizen Tian* are small scale improvements that are quick to execute. By carrying out these improvements continuously big savings can be accumulated after a while, improving small tasks each day, every day.

This Kaizen method can be carried out both in teams and alone. When done in a team it is important that they are gathered voluntarily, regularly, during normal working hours and supervised by their manager/supervisor. They then identify, analyses and solves problems that they have encountered in their daily work. The solutions that they come up with are then suggested to management. Participation in these teams are built on free will.

A Kaizen team consists of four different categories of people. They are: members, leaders, facilitators and management.

Members are the core of this and have basic knowledge of the concepts used. Leaders are the members' direct foremen and supervisors, they have the capability to lead and develop ideas within a group of members. Facilitators are managers with excellent knowledge of the Kaizen methodology, the facilitator do the coordination of the whole process from small meetings to the whole organization. Management only task is to support and commit to the Kaizen methodology, they are also the ones that chooses which ideas are go and which are no-go. (Oakland, 2014, pp. 348-352)

An effective way to identify problems in a production process is to cut the safety stocks, to a low level or all the way down to zero. Having none-existing safety stock levels will cause problems in the production, however this way the problems with the production will be exposed. This methodology can also be applied to service/information processes such as scheduling, billing, order taking, accounting and planning. Reducing number of resources available to accomplish a certain task is a common way to add stress to the system. (Krajewski, Malhotra, & Ritzman, 2016, p. 230)

2.4 Design Structure Matrix

A DSM helps in assisting to visualize with graphs the dependencies between each sub-process. The DSM is an $N \times N$ square matrix where N represents the number of sub-processes. This method can be applied on products, organizations and processes, additionally it can be applied on multiple domains where all the mentioned areas are joined.

The DSM approach consists of five steps that are taken to model and analyze the whole process. These steps are: *decompose*, *identify*, *analyze*, *display* and *improve*.

Decompose, breaking the system down into basic elements with several hierarchy levels if needed.

Identify, documentation of dependencies between the elements.

Analyze, rearrange the dependencies and elements to see how the system behaves and acquiring understanding to the patterns.

Display, visualizing the findings in the DSM, special features or interest that require more attention.

Improve, applying DSM results in a better understanding of the system and possible improvements visualized by the DSM analysis.

In table 1 a design structure example can be seen. An X in the table indicates a dependency between the tasks.

Table 1. DSM example (Authors adaption from Eppinger & Browning, 2012)

		Output / Supplies						
		A	B	C	D	E	F	G
Input / Receives	A		X					
	B				X			
	C	X						X
	D	X	X					
	E			X			X	
	F		X	X		X		
	G					X		

In table 1 the sub-processes go from A to G; some processes are lined in both the x and y axis. Diagonally in the middle goes a separating line. X's under the line are subsequent tasks (inputs), X's above the line require information from a task that is done later in the process (outputs). Here is an example: Task B supplies

information to task A, D and F. Supplying information to a sub-process more upstream, A, might cause issues while supplying information to a more downstream process, D and F, does not cause any issues. Supply of information going upstream, in the table above task G affects how task C is carried out, for example choosing the piping design in a plant based on how long the piping installation is permitted to take at site.

Another way to mark the dependencies can be with a value reflecting on how much the task depend on another task, for example 1-10, where 1 means that there are some small dependencies and 10 means the dependency level is very high. If a DSM analyze results in several X's towards the upper right corner a rearranging of the sub-processes might be needed to be done. (Eppinger & Browning, 2012, pp. 2-12)

The different types of tasks can be split into four categories depending on where the X is in the table: sequential, parallel, coupled and conditional.

Sequential

A sequential task is a task having dependents that are more upstream or downstream. As an example, task A supplies information to C and D or task G supplying information to C. If a task supplies information to a more upstream process the parameters supplied should be frozen so that those can't be changed.

Parallel

Parallel tasks are those that are independent of each other, they can be done in any preferred order or simultaneously. For example, Task D and G does not have any dependency between each other.

Coupled

Coupled tasks are interdependent with each other, meaning that they require to be worked on simultaneously, information is exchanged between them while the task progresses, for example E and F.

Conditional

A conditional task affects which of the two tasks are done, could be that depending on the outcome in a sub-process there are two different tasks that are done. Such an example is not present in the table. (Eppinger & Browning, 2012, pp. 133-134)

2.5 Four Field Mapping

By using a four field map wastes can be identified in an information and administration type process. Process is visualized, a current and future state is mapped. The four fields in a four field mapping process are according to Richard Smith et al. in *The Effective Change Manager's Handbook*:

- Phases
- Participants and stakeholders
- Timeline activities
- Standards and Criteria

Phases are a family of activities.

Participants, those performing within the sub-process.

Stakeholders, those that provides input or receives output from a phase.

Timeline activities, passing of info, performing tasks, meetings or decision making.

Standards, the minimum required quality of what is required in a process.

Criteria, items that must be met before moving forward. For example, approving a drawing before manufacturing starts.

Furthermore, there is a *time line* and a *resource line* also that helps in visualizing the process. Everything is ordered chronologically in a time line of the elapsed time. Resource line is the number of man hours consumed for each process.

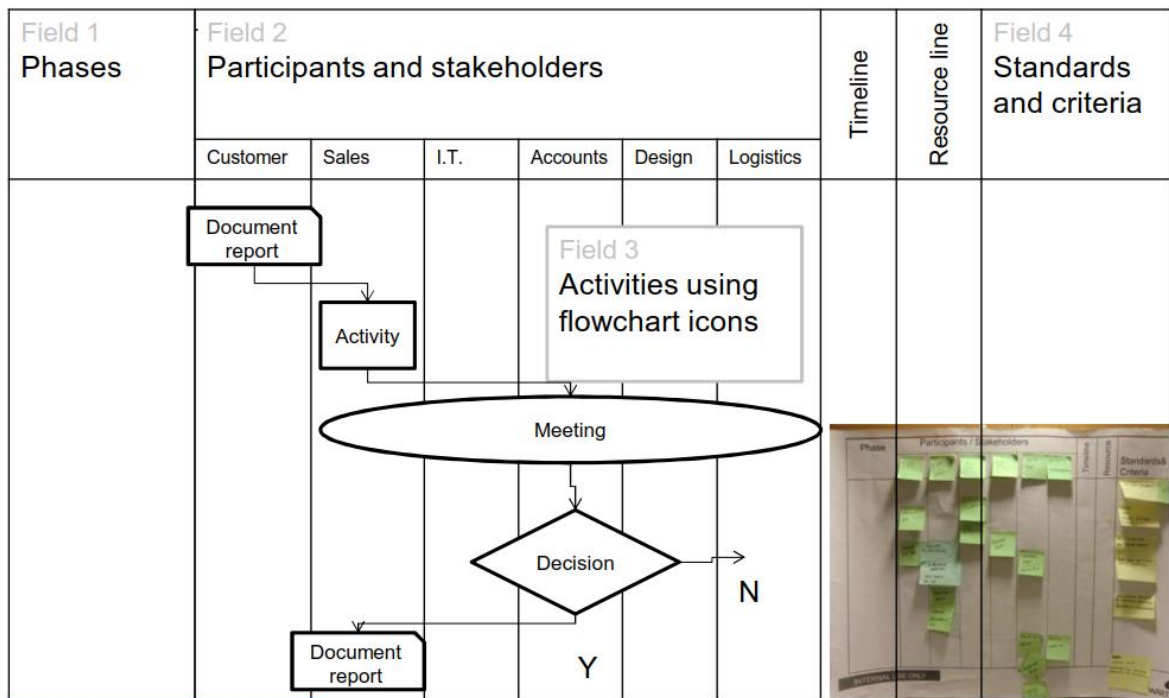


Figure 5. Four field mapping example (Company source material)

In figure 5 the fields are shown and how the process has been mapped out can be seen. The figure has a vertical orientation but can also be horizontally oriented to allow for a longer time span with more details. The horizontal version will be used in this thesis.

3 RESEARCH METHOD AND DATA COLLECTION

In this chapter, it will be shown what measures were taken to collect data and information. Interviews and inquiries will be conducted both by email and face to face meetings.

Splitting of the full process into sub-processes is done to make it more comprehensive and manageable. The sub-processes are split into logical parts, aim is that when a person hands the information over to another it will mark the end and beginning of a sub-process, meetings and decisions are also considered to be a sub-process.

3.1 Workshop

In the workshop, the process from start to finish will be gone through. Those participating in the workshop will be people that have knowledge of the sub-processes, depending on the sub-process several persons from the same sub-process area will be chosen, aim is to choose persons with varying degree of experience and knowledge in the subject. In the VSM workshop, current state of the prefabricated piping WoW is mapped out. In the workshop issues and improvements are also gathered. Since there will be numerous issues and improvement suggestions only a part of them will be selected to be included in the future stage, selection is done by having the workshop participants rank the issues and improvements. Based on the rankings data is gathered and a future state created.

Before the workshop a SIPOC will be made that will be handed out to the participants in the workshop and during the interviews to give them an overview of why the mapping is done and what goals there are with the mapping. Motivating the participants to actively participate in the mapping minimizes behavioral waste.

A DSM will be made of the future stage with key persons to gather important data after the workshop has been carried out. The key persons will be chosen after the workshop based on the general process knowledge for that person. The DSM will help in visualizing the complete process and where there can be challenges when information required are taken from a sub-process more upstream in the process. This DSM will also help to visualize the tasks that receives information from a sub-process more downstream of the flow.

While mapping out the sub-process in the workshop Kaizen method will be taken into consideration to enhance the process and make way for small and effective improvements.

3.1.1 Case study

The data in the workshop will use data from a case project delivered during 2017. Current and future state will be created by the use of case project data.

A plant delivery is made to order, this means that very little is done before a contract has been awarded and a down payment has been received. Designing might be done in fast track projects but material is never bought before the deal is sealed. This can result in a pocket of flow, when the go-ahead is received there is a lot of procurement to be done. Standard material with a high value and long delivery time is top priority at that time. Material that is plant specific like the piping is designed, when design is completed material is procured.

3.2 Interviews

Interviews are conducted either by face to face meetings, emails or by direct messaging. Persons participating in the workshop will be interviewed. Interviews

will be carried out both before and after the workshop. Goal with the interview is to achieve qualitative hands on data that will be used before, during and after the workshop. The interviews before the workshop will be aimed at gathering general knowledge about that sub-process. Pre-workshop data is gathered to have a better knowledge of the sub-process itself during the workshop and seeing the point of activity. Example questions are:

- From who the sub-process is received
- From where information is accessed to accomplish the sub-process
- What information is created
- What information is given to next sub-process and to whom
- How long it takes to complete the sub-process
 - o Time spent waiting
 - o Time spent working

Interviews done after the workshop will focus on receiving more details and issues that came up during the workshop and questions regarding the implementation. The interviews were carried out in an unstructured manner to gather as much information as possible.

3.3 Implementation plan

The implementation plan will be created after the workshop. The implementation of the future state will take place after the initial thesis, implementation will be split into stages. By applying the future state to a case study, estimations can be done both with and without the future state applied and measure the impact prefabricated piping has on the process.

3.4 Key performance indicators

To measure the progress made in the VSM event and the other improvements that will affect the process lead time some KPIs are needed. KPIs decided to be used are:

- Lead time for a sub-process
- Total lead time for the complete process
- First time right (flow of information)

By measuring the lead time on sub-process level and for the complete level differences in lead time between non-prefabricated and prefabricated piping will be seen. First time right will focus on the flow of information, making sure that when an activity is completed correct and sufficient information is passed onwards, for example sending out an email without sufficient information to carry out the task given.

3.5 Improvement suggestions

Improvement suggestions will be identified based the knowledge of the sub-process owners and supported by the theories. Definition of an improvement suggestion is something in a sub-process that does not work optimally or does not add any value to the process. This improvement suggestions will be identified in the workshop. When all the sub-processes have been gone through and improvement suggestions listed, the improvement suggestions will be ranked. Ranking will be done based on how they affect the process and how easy they are to fix, an improvement suggestion with high impact on cost or lead time and easy to fix will rank high while an improvement suggestion with a low impact on cost or lead time and hard to fix will rank low.

4 RESULTS AND DISCUSSION

For the following chapter, the theory and the data gathered in the previous chapters will be taken into use and the deliverable will be created. The theory behind VSMS four stages *preparation, current state, future state* and *planning & implementation* will be adapted to suit the needs of the chosen method, four field mapping.

Within the company the lean methodology has been implemented with five guiding principles, which are:

- Leadership and continuous improvement
- Value for customers
- First time right
- Make it visual
- Demand drive flow

These five principles do correspond well to a lean methodology, waste is minimized, visually easy to interpret and value-added activities are in focus.

At start a rough process flow was created, this was just adding each step that is involved in the process and sorting them in the correct order to have some basic starting point, from this point a more detailed chart can be made. This can be seen in figure 6.

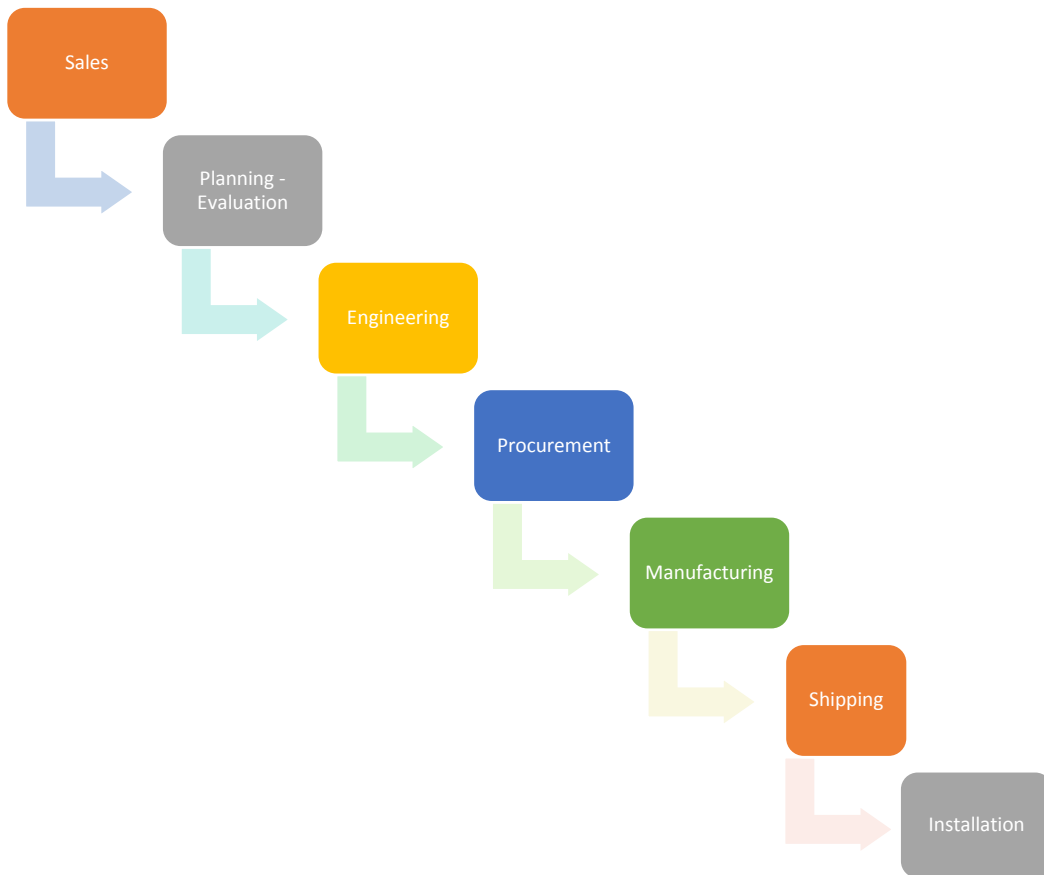


Figure 6. Rough process flow (Author)

Before the workshop a SIPOC was made, as a basis for the ones facilitating the workshop to have something to fall back on if needed. The problem statement for the workshop is to improve the way of working, target for the workshop is to decrease the delivery time of a project with 20%. In the SIPOC the following things are listed: suppliers, inputs, outputs, metrics, customers, what is within the scope of the workshop, problems and stakeholders.

Project name: Value stream mapping for prefabricated pipes				
Problem statement:		Targets:		
Improve way of working		Lead time decrease of 20% for total project time		
Suppliers:	Start	Current state: value stream of process steps		End
Engineering department		Sales		Project team
		Planning and scheduling		Sales team
Main Inputs		Project Management		Main outputs
Design choice		Engineering		Process mapped
Schedule		Procurement		Improvements
Process knowledge of participants		Manufacturing		In scope
Issues and opportunities		Shipping		EPC projects
		Installation and Commissioning		Four field map
Current Metrics				
Project Schedule				
Issues and opportunities solved				
Claims related to prefabrication				
Issues and problems			Stakeholders	
Previous project cases			Complete process chain	
Manufacturer of prefabricated piping			Workshop participants	

Figure 7. SIPOC of the workshop (Author)

When comparing the process steps in figure 6 and 7 a *Project Management* step has been added, this to separate the management of the project from the planning and engineering since the management process in a project is significant and connects to all the other sub-processes.

4.1 Case project

The chosen case project is an EPC project which utilized prefabrication of piping due to a tight schedule. As earlier mentioned there are some projects where prefabrication has previously been utilized. The case project utilized prefabricated piping in the installation. Installation went well, reasons for this are several, this was a similar project to other projects within the destination country, and country specific requirements such as customs clearance were handled well thanks to past knowledge. The site team and the contractors functioned well together. Subcontractor had the resources and the economy to cope with the site conditions. Both the site and project team were experienced. There were a lot of preparations

before the project started, the procurement of material in the project was completed very early in the project schedule.

4.2 Pre-workshop interviews

To receive some preliminary data before the workshop and to have information to use as a basis for the workshop, interviews were carried out with different stakeholders in the process for piping. However, they were not specifically aimed at prefabrication but to achieve a better general picture of that process. Also, a preliminary process flow chart was created of the workflow for piping with the input from the interviewees. Here below is a short review of the persons interviewed, more details of the interviews can be found in the background material.

Installation costing estimator

In the sales phase of a potential project there are cost estimations done for the whole plant. The estimations are done by a team each specialized in a certain discipline. To have accurate estimates the estimator receives inputs from the sales team concerning project specific data. The level of detail of the inputs received from the sales team might vary.

There are two main inputs that the estimations start out from, scope of supply and plant site layout. The scope of supply contains all the equipment needed for the whole plant. Plant site layout show where the equipment in the scope of supply is placed out as a preliminary plan, this is something that can change as the project continues. A preliminary Bill of Quantity is also used to estimate the work.

The sales tool used have ready-made templates for the estimations where the details of the inputs can be specified for example distance of piping and number of welds. Currently there are no specific way to estimate costs if the piping is prefabricated, an option used is just to decrease the number of welds based on previous design data of how much welds can be removed thanks to prefabrication. In the future when more data is available the possibility to choose the prefabricated option in the program can be added. (Installation Costing Estimator, 2017)

Scheduler

Planning and scheduling starts in the sales phase, a baseline is created with deliverable dates, for example start of site work or hand-over date. The work does not end with the project being signed, it ends when the project is handed over, that is installation and commissioning are completed or even later, after warranty or after some steps of service provided. Planning for a project differs depending on the deliverables, an EPC project requires much more planning than an EEQ. Schedulers work can be split up into two parts, preparation and upkeep.

In the preparation phase each stage is planned, how long it will take and what resources are needed and at what point. The level of detail early in the phase is very basic and gets more detailed as the sales phase progresses and furthermore when the project is signed.

The upkeep phase is when the schedule is followed up and updated according to how the project progresses. Upkeep phase starts at the site, the work progression is followed up to check that work is done according to schedule, this phase is usually handed over to a site engineer who does the work, however sometimes the scheduler and site engineer works together to keep the schedule up to date, there are also cases where the scheduler has continued alone with a remote follow up.

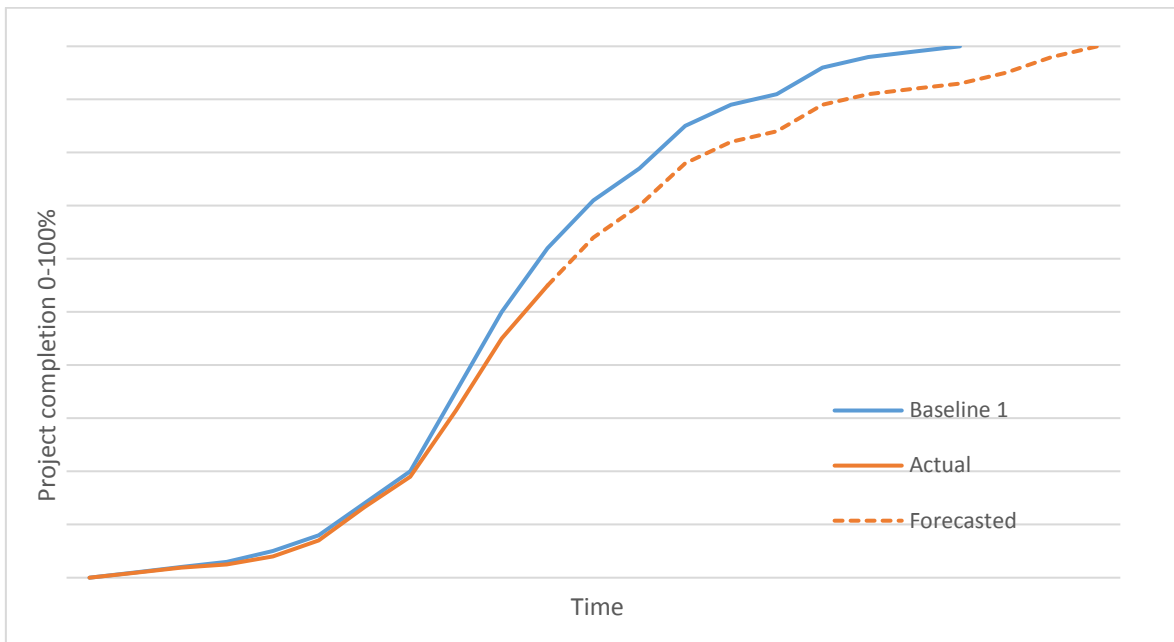


Figure 8. S-curve example (Author)

The initial schedule usually serves as a baseline, with signed milestones. From that same baseline an initial S-Curve is generated for reference purposes. As the Project evolves, the actual progress curve is created as is a forecasted progress curve on a weekly and monthly basis. In figure 8 an example s-curve can be seen how project progress is visualized. The blue line is the baseline, the original schedule, the orange line is the actual progress in the project and the dotted orange curve is the forecasted progress. This forecast is important because it helps anticipate any future problems and delays. (Scheduler, 2017)

Chief Project Engineer

In an EPC project there are usually one Project Manager and one Chief Project Engineer for each discipline. The CPEs work might start already in the sales phase, usually the project team is involved when the project is awarded. The CPE is one of the key person involved in a project, for prefabrication this is the person that needs to know how the process flow goes.

Latest in the design kickoff meeting with engineering the decision regarding prefabrication is done, this can be a request from customer, a demand based on the schedule or a cost factor, if site labor pay rate is high. The level of prefabrication can be decided, if all pipe sizes are prefabricated and to what extent or if just some bigger sized piping is chosen. All sizes are not bent, however they can be prefabricated to correct length with fitting allowance and coupling options can also be utilized.

When procurement starts after design is done it is important that when doing the technical evaluation of the offers received that every detail and all the work requested in the RFQ are included in the offer, the technical evaluation the offer is checked that all the requested material is offered in the offer or if there is another substitute it is checked that it can be used. When procurement has been accomplished and a supplier has been chosen, proper follow ups must be done to check that manufacturing of the piping is according to schedule. (Senior Chief Project Engineer, Mechanical, 2017)

Purchaser

While the CPE is responsible for the technical evaluation of the offer, the purchaser does the commercial evaluation, which is choosing the supplier that has the best offer with the commercial aspect in mind.

When the technical evaluation is complete for the prefabricated offers a purchase requisition is created. In this requisition there are details of what is to be bought and what offers are eligible for commercial evaluation. In the commercial evaluation several things besides the price are negotiated, delivery date, payment terms, and other terms and conditions also affect the evaluation and who is awarded the deal. Following inputs should be included in the purchase requisition; delivery date/s, specification of the scope, delivery location, type of packing and

details for documentation. The commercial evaluation includes the negotiation of pricing or creating a favorable deal with the supplier. (Purchasing Manager, 2017)

Logistics coordinator

Logistic Coordinator arranges the transportation of material according to the shipments agreed upon, additional shipments can also be added later if needed. Shipment plan is reviewed several times during the project.

Usually the material is sent to a port where several orders are packed into a container. The container is then sent to site according to the shipment plan. Usually shipments are sent by sea freight, in urgent cases material can be air freighted. In the contract certain milestones can state that specific material shall be at site to complete the milestone. (Senior Logistic Coordinator, 2017)

Own comments

The IC estimator does not currently affect the project deliver management, accurate estimations are of course important. Accurate estimations will allow for a better base to start from for the project team. In the future it might be possible to offer prefabrication as a standard option or an option to the customer already in the sales phase.

Scheduler provides vital input to follow up what work is required and when, also that the work is completed in time, if not measures can be taken to stick to the schedule and important milestones.

The project management work that the CPE carries out is not easily measured in time. The focus would rather be on the quality of the work, first time right, rework creates unnecessary work.

From the basis of the interviews a preliminary process flow was created, in Appendix I a simplified process flow chart can be seen, see background material for

the full process chart. This flow chart allows for better understanding of the whole process before and during the workshop. The process starts with the project being signed from there the process continues with designing, procurement, manufacturing, shipping, installation and in the end project handover to the customer.

Common for the work done by the Purchaser and Logistic Coordinator is that their work should not take long if background data is in order, then on the other hand if there are changes or delays the work load increases. For the Purchaser the evaluation phase can extend for a longer time and for the Logistic Coordinator if rescheduling of containers and shipments are needed.

4.3 Four field mapping workshop

4.3.1 Workshop preparation

Before the initial workshop there were six questions that were to be answered that are a part of the preparation phase.

What exactly will be mapped? What product, service or project? What activity?

Prefabricated piping process from the sales phase to the commissioning phase of the plant. Activities that occur within the sub-processes in the piping process. Mapping of the piping will take place with information gathered from projects where the piping has been within the scope of supply of the company, meaning that the project to be an EPC project.

What process will be included? Where or when will the map start and where or when will it end?

Mapping will take place from when the contract has been awarded all the way through to the installation and commissioning phase. Process from contract signed, planning, project management, procurement, shipping, installation and commissioning. The sales phase is also researched but not included in the mapping. The engineering and manufacturing process is done by external firms, nevertheless affecting the engineering and manufacturing processes are possible. Mapping will start with individual interviews to prepare for the mapping event. Mapping event will be done in one workshop, this workshop will be split into two stages. In the first stage all the sub-processes will be mapped out, in the second stage; time and improvement suggestions will be listed.

Who needs to be on the mapping team? Who will be the value stream manager?

Personnel carrying out the sub-process, from start to finish, will be the one mapping it out, that way the most hands-on approach will be achieved. Employees with experience from working with prefabrication of piping will also be involved.

What are the business objectives? What will be the measure of the success?

Process mapped, suggestions for improvements resulting in a lead time decrease by 20%. Personnel more aware of each other's processes. A general process flow chart created resulting in a clear WoW.

Who needs to support the effort? Who needs to be part of the decision process?

Managers need to support this activity, allow personnel to participate in the mapping. By involving all the sub-processes in the mapping everybody will be part of the decision hopefully resulting in everybody supporting the effort and implementation of new WoW.

follows phase and sub-process detailed data that is filled in horizontally under each process. The data is split into the following categories: Resource time MIN/MAX, Elapsed time MIN/MAX, Timeline MIN/MAX, CTQ (criteria, template and quality), Standards and criteria, Issues and challenges, Improvement ideas and opportunities. This sheet is filled in during the workshop and so the current state is created. The improvement ideas and opportunities stand for the future state, things that can be implemented almost directly into the WoW. However, in the workshop we ended up using a slightly simplified version, where we joined the time rows into one row and *CTQ and standards and criteria* were also merged.

4.3.2 Current state – Workshop

In the workshop mapping of the whole value stream took place, the process from the point that the contract has been signed to project handover was overviewed. The event itself had very good participation and those that were hindered had a stand-in that took their place ensuring that all the aspects were covered. Some of the stakeholders represented the same process, this to create discussion and have different views on the same issue. In the workshop we had the following participants:

- Project Planner
- 3x Senior Chief Project Engineer, Mechanical
- Strategic Purchaser
- Purchasing Manager
- Senior Development Manager
- Inspection Manager
- General Manager, Mechanical Engineering
- Senior Logistic Coordinator
- Chief Design Manager, Mechanical
- Engineering Manager, Mechanical
- Operations Excellence representative

Initially all the activities were listed and sorted according to each stakeholder as can be seen in figure 10.



Figure 10. VSM event activities (Author)

From this point the activities were sorted into a timeline for better overview of the whole process. This timeline can be seen in figure 11. During the re-modelling the discussions flourished and both ideas of improvements and issues came up. These were noted and added under an activity or to the right which can be seen in figure 11. Due to time limitations all the opportunities and issues were not added to an activity, during the documentation they were placed under correct activity. Another aspect that also got left out from the workshop was the prioritizing the issues and improvements that were listed.

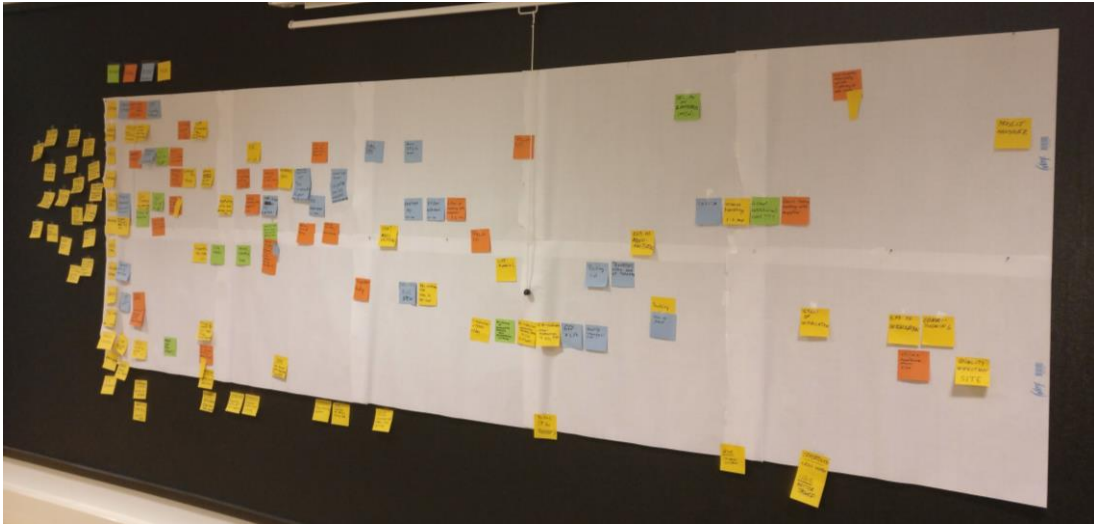


Figure 11. VSM event activities (Author)

After the mapping it was confirmed that there are three activities that take up more time than the rest. These three tasks are: engineering, manufacturing and installation. A fourth task is also quite time consuming, transportation, however this activity is something that cannot be affected in the similar fashion as the other three. Affecting the transportation by shortening the transport time is out of scope, nevertheless there is always an option to freight the material by air, but due to costs this should be considered only as a last resort when everything else has failed.

Considering the preliminary process flow chart there were activities that had not been listed that were mapped during the workshop. The participants did actively participate in the discussion that concerned their activities, also the facilitators assume that the stakeholders became more aware of the different processes there are in the whole process.

Improvement suggestions

Here under follows a list of a couple of challenges that were brought up during the workshop, the suggestions can be split into two categories, challenges and improvements. The issues, are items that does not work optimally, things that could

be improved for a clearer WoW. The solutions to the issue and improvements are described in the future state. See more details in the background material.

- Issue: Economically feasible for the suppliers
- Issue: Engineering phase requires more resources
- Issue: Are the prefabrication methods approved in destination country
- Issue: Tagging of piping
- Issue: Unclear scope and requirements
- Issue: Civil works late
- Issue/Opportunity: Educate the subcontractor on prefabrication

Current state

A current state map was created during the workshop and documented in Excel, in this chart the data gathered in the workshop is collected. The current state map and timeline can be seen in background material.

4.3.3 After workshop interviews

After the initial workshop there was a need for some further interviews. The interviews were to find out information concerning customs clearance and site feedback from the case project, these two topics that weren't covered fully in the workshop. The project controller and the superintendent for the case project were interviewed. See more details of the interviews in the background material.

Project Controller

The Project Controller functions as the Project Managers right hand. Monthly financial reporting, documentation, shipment value arrangements and other project related tasks. To do the customs clearance it is important that the documentation is in order, material will get stuck at customs if proper documentation is not provided. Close communication with the customer is required concerning shipments since the customer is usually the one responsible to clear customs. (Project Controller, 2017)

Senior Superintendent Mechanical

The Superintendent supervises the site work, depending on their discipline they focus on different areas. Along with supervision they also report and communicate with the project team about the progress of the site.

Means of following up on the amount of installed piping should differ from regular installation and prefabricated piping. In a regular installation the number of welds are used as a measurement of how much is installed. However, for prefabrication the weight of the installed piping could be used as a measure for progression, counting the number of welds is not as accurate since the number of welds are less. (Senior Superintendent Mechanical, 2017)

4.3.4 Future state – Workshop

Due to time limitations the future state was not completely mapped in the workshop. Issues and improvements were listed, and some were mapped under corresponding activities. The improvements are listed and ranked according to how they are executable, impact on delivery or ease of implementation. In this case the future state will be the map created after the chosen issues and improvements have been solved and added to the process flow. See an overview of the solutions in the background material.

Overview of solutions

The mentioned suggestion for improvements do have different challenges that need to be solved. Opportunities are items that can improve the process further allowing for a better overall process. Here under follows a list of the solutions (in no particular order), in the background material a more detailed list can be seen.

- Issue: Economically feasible for the suppliers
- Issue: Engineering phase requires more resources
- Issue: Are the prefabrication methods approved in destination country

- Issue: Tagging of piping
- Issue: Unclear scope and requirements
- Issue: Civil works late
- Issue/Opportunity: Educate the subcontractor on prefabrication
- Opportunity: CNC table from design straight to pipe bending machine
- Opportunity: Using prefabrication in the sales phase
- Opportunity: Utilizing several different prefabrication options
- Opportunity: Standard prefabricated parts
- Opportunity: Annual agreements
- Opportunity: Reduce amount of pickling needed at site
- Opportunity: Releasing part of the design for manufacturing
- Opportunity: Automated packing plans

The issues and opportunities suggested are spread out wide throughout the whole project timeline, where the first ones are concerning the sales phase and the last ones are about the installation.

Ranking of the issues and opportunities

By ranking the mentioned issues and opportunities it can be decided which ones to focus on solving within the scope of the thesis. Issues and improvements were slightly rewritten to allow for easier understanding and evaluation, similar issues or improvement suggestions were also merged into one. The ranking aims at finding low hanging fruit, tasks that are easy to implement and have a big impact ranks high. The ranking is done by sending out a questionnaire to the participants that then rank the above-mentioned issues and improvements. The questionnaire tool used is Google Forms. In figure 12 it can be seen how ranking a question is structured, confidential part is blurred. Two rows for each item, ranking the ease of implementation and the impact on delivery on a scale from 1-5, where 1 indicates easy implementation and low impact, 5 indicates a difficult implementation and high impact. Best option would be an issue easy to implement (1) with high impact on delivery (5).

1. Increase capacity at the supplier

The respondent is asked to rate each item on a scale from 1 to 5 based on the effort required to implement the change and the impact on delivery. The scale is as follows: 1 Easy/Low, 2, 3, 4, 5 Hard/High.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 12. Screenshot from the questionnaire (Google Forms)

The categories were ranked according to where the average value for each answer. Then the items received points from 1-14 depending on where they ranked. Better ranking resulted in lower points. The results of the ranking can be seen in table 2. The full form can be seen in Appendix II. Complete un-blurred form can be seen in Appendix II in the background material. There were items that ranked high in one category but lower in the other. Goal with the ranking was to find the low hanging fruit, finding those that are easy to implement and still have an impact on the delivery.

Table 2. Ranking of the results (Author)

Name	Implement	Implement rank	Impact	Impact rank	Total sum
Making the scope clear for the prefabricator of piping	2,45	2	3,73	1	3
Annual agreements with suppliers of prefabricated p	2,45	3	3,45	4	7
Releasing certain parts of the piping design to manuf	2,40	1	3,20	7	8
Tagging the pipes so the tags remain on the pipe unti	2,50	4	3,30	5	9
Standard prefabricated design parts, e.g. piping from	2,70	8	3,70	2	10
NC table straight from design team to the bending m	2,60	5	3,20	8	13
Approve prefabrication methods at destination coun	3,50	13	3,50	3	16
Automated packing lists created for prebent piping	3,20	11	3,27	6	17
Educating the subcontractor on what prefabrication n	2,64	7	2,91	10	17
Utilizing several different prefabrication options, pre	2,60	6	2,70	11	17
Making sure other delays don't affect delivery, i.e. Ci	2,80	9	2,60	12	21
Increase capacity at the supplier	3,64	14	3,09	9	23
Decreasing amount of design hours for piping system	3,10	10	2,60	13	23
Sales phase to use prefabrication in their offers	3,30	12	2,50	14	26

From the ranking the following options placed in top five in the table:

- Making the scope clear for the prefabricator of piping or coupling supplier
- Annual agreements with suppliers of prefabricated parts
- Releasing certain parts of the piping design to manufacturing
- Tagging the pipes so the tags remain on the pipe until installation
- Standard prefabricated design parts, for example piping from radiators always have the same design

Furthermore, in the after workshop interviews there is also feedback from site resources, those are concerning the installation of the piping, so it is considered very important, that feedback will also be included in the chosen solutions.

4.3.5 Suggestions for implementation

The improvements that were chosen in the ranking and used in the future state will be implemented into the WoW. The things that will be implemented are based on the feedback from the workshop and the case project site, some of these implementations are already partly implemented. The site feedback is considered to have a high value so attending to those issues that came up there is very important. The site focused more on the installation of the material while the

workshop besides focusing on installation also included improvement suggestions to the current way of working within the whole project.

From the workshop the following things were ranked in top five:

- Making the scope clear for the prefabricator of piping or coupling supplier
- Annual agreements with suppliers of prefabricated parts
- Releasing certain parts of the piping design to manufacturing
- Tagging the pipes so the tags remain on the pipe until installation
- Standard prefabricated design parts, for example piping from radiators always have the same design

From site the following things were mentioned:

- Tagging of piping
- Quality of manufactured piping
- Late deliveries of material

Based on these above-mentioned items, further research is done to see how they could be implemented into the WoW and how the issues from site can be dealt with.

The tagging of piping system was mentioned both during the workshop and from site feedback. *Late deliveries of material* and *Quality of manufactured piping* can be merged with *Making the scope clear for the prefabricator of piping or coupling supplier*.

From a meeting with a Senior Project Chief Engineer and an Engineering Manager (2017a) suggestions for the implementation were made. Here under follows a short list of how the suggestions can be implemented. Background material contains further details.

Making the scope clear for the prefabricator of piping or coupling supplier

Implementation is done by having meetings where the specifications for the piping, requirements of the machines doing the prefabrication, scheduling and details of the drawings.

Annual agreements with suppliers of prefabricated parts

First meeting where the technical and commercial details are drawn up and a follow up meeting where the final details are agreed and agreement signed.

Releasing certain parts of the piping design to manufacturing

Implemented by prioritizing the design so parts can be approved for manufacturing. Standard prefabricated pipe parts can also be used.

Tagging the pipes so the tags remain on the pipe until installation

Implemented by having a short meeting where material for the tags and location of the tags on a pipe is chosen. Feedback from site where the tag should be placed required.

Standard prefabricated design parts, for example piping from radiators always have the same design

Implemented by researching for parts that use the same specifications over and over again, standard prefabricated pipes are then chosen based on the research.

4.4 Process flow chart

With the process flow chart, each step from the sales phase to the installation is shown and every task needed to be carried out is shown in correct order. In Appendix III a new simplified process flow chart can be seen. Comparing this chart to the one first one the biggest difference is with the implementation of the annual agreement and the use of standard prefabricated piping, these two removes the major part of time consumed for the technical and commercial evaluations, hence they are removed from the new chart. Quality inspection has also been added to emphasize the importance of that the manufactured pipes corresponds to the

design at the supplier. The full process flow chart can be seen in the background material.

4.5 Design structure matrix from a project management point of view

This DSM was created from discussions with a Senior Chief Project Engineer and an Engineering Manager (2017a), the project management phase is the singular most important task that must function for the flow to work. There is a lot of work that the project team, for prefabricated pipes the CPE, handles and fulfilling those tasks or following up of those tasks are necessary for a successful delivery. Based on the tasks mapped out during the workshop a DSM was made. The process flow chart and future VSM is used to create the DSM. In Appendix IV the DSM can be seen. The DSM will be given as it is, it will show if there are items in the flow that requires special attention or for example if there is a decision that should be made earlier. See background material for the full DSM and more details.

4.6 Results

As the time comparison was compared to the case project, which used prefabricated piping, the time difference will be bigger compared to a project utilizing standard piping. The site costs will also decrease due to shorter installation time of the plant also resulting in an economic impact on the budget.

For the 20% decrease to be possible some but not all improvement suggestions must be implemented. By implementing the top five items in the ranking and ensuring that the quality of the prefabricated pipes are met a decrease of around 8% in delivery time will occur compared to the case project. If a similar comparison would

be done to a project where no prefabrication is used the author assumes the difference would be even bigger. Important to keep in mind is also that there are differences in both between areas and countries, not to forget the projects themselves can have major variations.

The results are not only focused on decreasing the delivery time directly with improvements in the process such as the annual agreement but also by ensuring that the work at site shall function as smoothly as possible. By taking actions in ensuring that the quality is met everywhere along the supply chain, changes made earlier will not come as a surprise resulting in rework when the piping is installed at site.

Of the five chosen improvement suggestions only one shortens a step in the process, the annual agreement, the procurement time will be shorter. The process of releasing parts for manufacturing means that the manufacturing itself is split up under a longer time span allowing for a potential faster delivery. The rest of the suggestions are regarding the quality of the work. Educating of the subcontractor and the tagging of piping items does not remove any process step, they are more to ensure that the quality of the piping is met, resulting in less work required at site in finding the right pipe while working, a correct WoW also simplifies the work done at the supplier. Neither does the standard prefabrication design parts add or remove a step in the process. It is a one-time process, when done projects utilizing it will benefit from it and as a result the design time for the piping will be shorter.

4.7 Further actions

Before starting the thesis, there were already ideas of things that could either be improved or implemented into the way of working. Along with digitalization an

idea of implementing traceability, visualized in figure 13, with the help of a Quick Response code emerged.

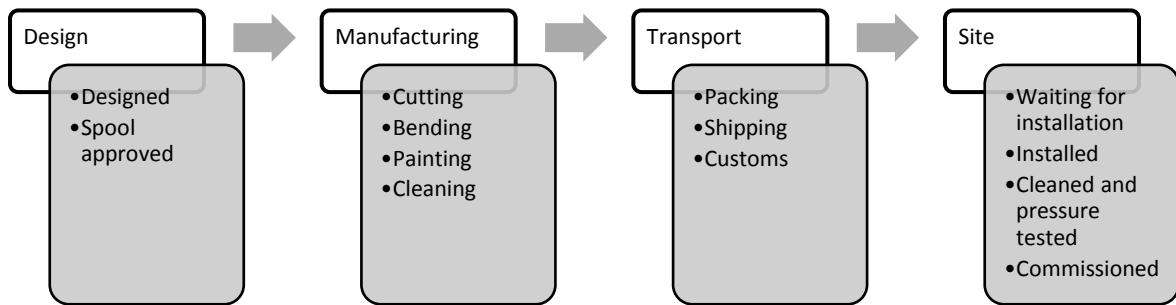


Figure 13. Traceability in the process (Author)

This would be applied to a spool pipe in the design phase. This code would follow the spool pipe through the whole process. The process-steps are only indicative. The scan-able code would be read and signed off at each step in the manufacturing process. When packed it would be merged into a case or container with several parts and later at site the scan-able code could then be used to identify cases and to sign off that the piping has been installed, cleaned and commissioned, allowing for easy follow up at site. The use of a scan-able code would allow for the design to go digital. If taken into use, a spool pipe anywhere in the whole supply chain could be tracked and seen where in the process it is allowing for easy follow-up. Implementing it so that every stakeholder in the process will use it can be a challenge, within the supply chain internet accessibility can be of varying quality.

4.8 Own comments

From the beginning the scope was quite clear and the deliverable was understandable for me. The whole idea of going through the whole process from the sales phase to the installation felt very extensive in the beginning, but by

splitting it into small chunks and a schedule to follow it became more manageable. Analysing the gathered information from interviews and the workshop was an extensive effort. Searching for specific data for a project takes time, there is so much information within a project, deciding on what to include and what to exclude required background knowledge. To keep in mind for a site installation is that completion of the installation does not merely rely on the installation of piping, other installation work can also be delayed, be on the critical path.

Even though the thesis was focused on prefabricated piping the lean theories and VSM method can be applied to any process flow. Analysing the current process and improving is something that should be done again and again. The writer sees the VSM method as a good way of working to improve the process. With benefit it can be used again and again to improve the process. Ranking of the improvement suggestions with the stakeholders is a good way to find the low hanging fruits. However it is important to keep in mind that a democratic vote does not necessary rank the suggestions correctly, it can be used as an indication. Finding the same improvement suggestions in a new mapping session might be hard, however similar suggestions are very likely to occur.

While creating the process flow chart and DSM there were always information or sub-processes that could be added to the chart or matrix, the goal was to have all the major processes listed and most of the minor ones, which was achieved. There is always room for project specific adaptations. Most of the improvement suggestions indicate that either standardization or moving the decision more upstream in the process will make the process leaner. The responsibility of the decision is either moved to a standardized template or a person more upstream in the process. People will react differently on the change of responsibility, there are both those that want to take responsibility and those who prefer someone else to take it.

In the DSM, the current and future state the transportation and the manufacturing related processes are placed as one sub-process each, however the manufacturing and transporting can take place numerous times. If batches are utilized the first batch of material is first designed, manufactured, shipped and installed. The design of the following batch starts when the previous batch has its design completed, batches can of course overlap each other to some amount in all sub-processes. Batches close to each other can of course be joined together to save in on costs, for example during shipping.

Another aspect to keep in mind is the location of funds in the budget. For each project the costs are split into offshore and onshore costs. Onshore budget are costs that are accumulated in the destination country, offshore budget are those costs accumulated in home country and other areas. The issue to keep in mind here is that if prefabrication is used the onshore costs at site will most likely be lower if we are comparing to a project without prefabrication. Likewise, the offshore costs, those that accumulate in home country, will be higher compared to those projects without prefabrication.

Even though the implementation itself were out of the scope of the thesis, signs of implementation starting for some of the suggestions were seen at end of the thesis. One annual agreement is soon in place, education of the suppliers are well underway and tagging of piping has been reviewed during the research for the QR code.

5 CONCLUSION

Before this Master thesis started there were already improvements planned for the prefabrication of piping. This thesis has functioned as documentation and confirmation of the ideas. Some of those ideas were further explored in this Master thesis.

The Master thesis itself is just a small piece in the continuous work that is underway in order to make the whole plant delivery faster. The goal of decreasing the lead time by 20% for the whole project cannot be confirmed with empirical data, however the results clearly shows that if the prefabrication is implemented according to the improvements the delivery of the plant will be shorter. More empirical data is needed. During the research the same or very similar improvements were mentioned by different persons in the process, this indicates that there is a common understanding on some key issues that do need improvement.

So how has the research question *How to make the process leaner by identifying wastes and improvement suggestions* been answered? Numerous improvement ideas have been identified, some of them have been further researched to investigate how they affect the process and suggestions on how they can be implemented into the process.

A big impact of prefabrication would be the implementation of the prefabrication knowledge and schedule for it to the sales team. This would result in projects allowing for a faster delivery time currently possible, giving an edge in the sales process.

Affecting the suppliers of prefabricated piping directly wasn't within the scope of this thesis, however making sure that the suppliers receives all the support needed

to manufacture as fast as possible has been looked upon. Having the design directly transferred to a CNC machine will to some degree save time and decrease the risk of human error in the process. Additionally, the use of standard prefabricated design parts would allow for faster designing. The implementation of annual agreements will save time, the whole procurement process will be shortened. Standard prefabricated design piping parts and annual agreements allows the supplier to have key parts in stock, if the demand for prefabricated piping increases the suppliers will be more willing to invest in both machinery and may even stock up on frequently used material. Today the number of suppliers being able to manufacture the prefabricated piping is low, finding new suppliers able to prefabricate piping should be emphasized.

Even though the design of the systems and manufacturing at the supplier would be efficient. The final hurdle would be to make sure that the installation at site works well. This also means that prefabricated pipes arrive to site according to schedule. The scheduling must be done so that the work required before the installation of piping can start is completed latest by the time the prefabricated piping arrives. This can be done by having continuous follow-ups with the site. The schedule and updates to it must be communicated with all the involved parties so they are aware of the situation.

If prefabrication is utilized, it is very important at site that the material sent there is properly tagged. If a pipe is without tag at site it will be very hard to find out where it belongs, size and shape can of course allow for some guestimates. Imagine building a puzzle in the beginning, it is very hard to place a certain piece of the puzzle at the correct spot when starting.

From the basis of this Master thesis there are four things that should receive the main focus, they are:

- Tagging of the piping
- Quality control of drawings and manufactured piping
- Standard design piping and annual agreement with prefabricated piping manufacturer
- Ensuring the delivery is on time to site if delays occur they are to be communicated to all stakeholders

Further there are three things that should be implemented in the near future, they are:

- Traceability of piping from the design phase to installation using a scannable code
- Prefabricated piping implemented in the sales phase allowing for faster project delivery times
- New suppliers for prefabricated piping

Lastly there are two minor things that should be taken into use:

- Prefabricated piping to have fitting allowances at suitable spot in the piping
- CNC codes to be received from the design to the manufacturer

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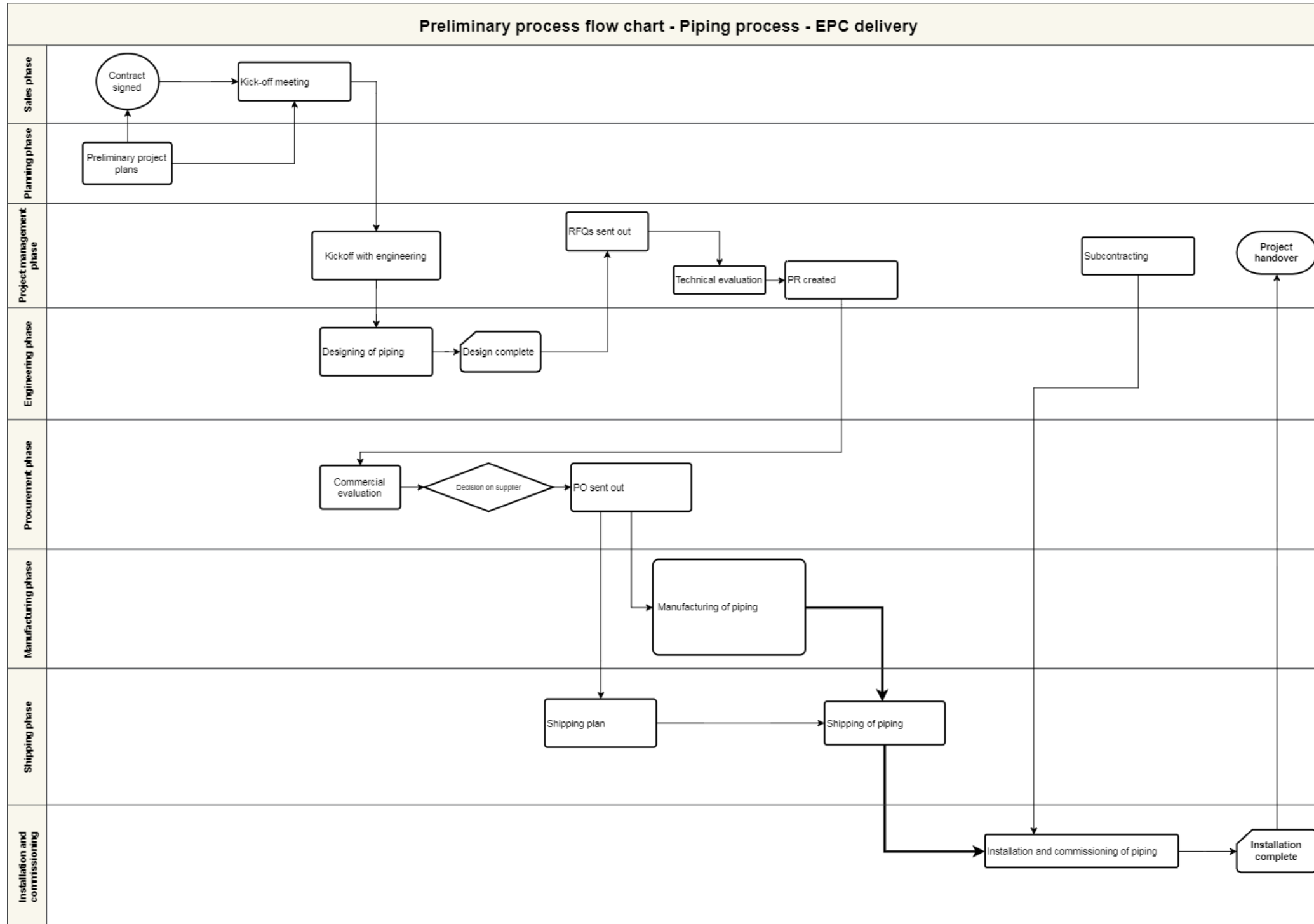
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APPENDICIES

APPENDIX I: Preliminary Process Flow Chart



APPENDIX II: Ranking Questionnaire

VSM for Prefabricated Piping

During the workshop several issues and improvement ideas came up, here below you can find some of them. Filling in should not take that much time.

For each question there is two factors affecting. How easy the solution is to implement and what kind of impact the solution has on the delivery. In case there are questions that you don't have any knowledge on, you can leave them blank.

The scale goes from 1 to 5. 1 indicates that it is easy or low impact, 5 indicates that it is hard or high impact.

1. 1. Increase capacity at the supplier

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. 2. Decreasing amount of design hours for piping system

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. 3. Approve prefabrication methods at destination country

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

4. 4. Tagging the pipes so the tags remain on the pipe until installation

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5. 5. Making the scope clear for the prefabricator of piping or coupling supplier

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. 6. Making sure other delays don't affect delivery, i.e. Civil works are late or similar.

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. 7. Educating the subcontractor on what prefabrication means/what kind of work is required at site

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. 8. NC table straight from design team to the bending machine

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

9. 9. Sales phase to use prefabrication in their offers

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. 10. Utilizing several different prefabrication options, prebending and different type of couplings

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. 11. Standard prefabricated design parts, e.g. piping from radiators always have the same design (roof and field radiator piping different of course)

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

12. 12. Annual agreements with suppliers of prefabricated parts (Prebent piping and couplings parts)

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

13. 13. Releasing certain parts of the piping design to manufacturing

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

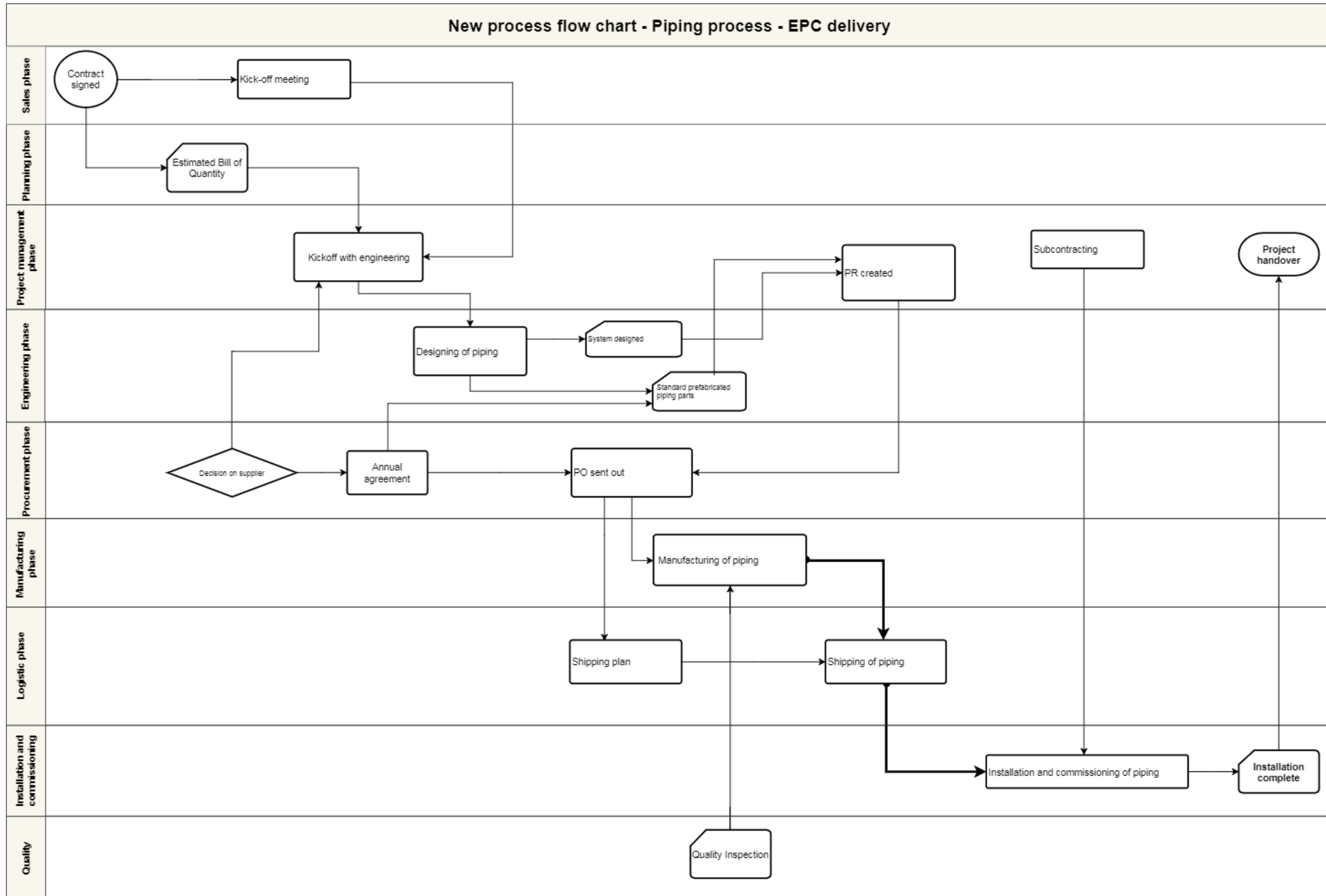
14. 14. Automated packing lists created for prebent piping

Mark only one oval per row.

	1 Easy/Low	2	3	4	5 Hard/High
Easy to implement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Impact on delivery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

15. Own comments if any:

APPENDIX III: New Process Flow Chart



APPENDIX IV: Design Structure Matrix

