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Project Bulk Materials Management Guide

for The Case Company's Co-owner in Finland

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The purpose of this study was to create a project bulk materials management guide for the case company's co-owner in Finland. The study was conducted in an engineering company working in various fields mostly related to Oil&Gas. Materials management is an important function for engineering and it will help the target company achieve better results on managing project costs.

The present study was accomplished using action research. The current state of the target company was analysed to determine current strengths and weaknesses as well as the stakeholders' needs. The current state analysis was carried out by conducting ten interviews with relevant personnel. The results showed that the lack of standardised process together with a lack of adequate enterprise resource planning software customisation, lead stakeholders to develop their own shortcuts and working ways. These stakeholders were mainly part of procurement, project management, project control, quality and construction management. A literature review was conducted on materials management practices in order to aid the proposal for the materials management process guide.

The result of this study was a project bulk materials management guide for the case company's co-owner in Finland including a process and a matrix chart to map the top layer process; and a basic checklist to determine a materials management plan. These tools would help the future implementation of a materials management function in the target organisation providing guidance and basic foundation to the materials management plan.

The recommendation of this study is that a well-defined materials management organisation supported by adequate enterprise resource planning software is critical for companies having materials management responsibilities. However, because of the uncertainty surrounding the process, further research will be required after the implementation phase, and proposed key performance indicators tested.

Keywords	Materials management, project management, enterprise resource planning

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Appendix 1. Interviews on the target organisation’s personnel

1 Introduction

1.1 Business Context

The target organisation of this thesis is an engineering company working in various fields mostly related to Oil&Gas. Also, it is co-owned by its biggest client. In addition to offices in Finland it is also present in Sweden, Netherlands, Singapore, UAE and Azerbaijan. They offer engineering, procurement and construction management (EPCM) projects and consulting services. Moreover, the target organisation has highly educated in house professionals from all necessary disciplines to carry out various scales projects mainly targeting full scale process facilities.
In addition, they decided to also offer vendor services for bulk materials. Consequently, Investment Material System (IMS) unit was created and target company's co-owner's site warehouse closed down. As a consequence, material management is a developing business that has a high priority since materials are expenses to have control of. Due to the fact, that keeping enough stock is as important as having the right kind. For instance, lead times of some items are long and prices of rarely used ones often high. Therefore, it is of most importance to have a good planning in place for delivering what is needed, when is needed at site projects in Finland.

Materials management topic was given by the target organisation for this thesis report. The thesis owner was part of the target organisation's project control group and it was decided by management that materials management was related to this department on some level. In addition, procurement department designed a supervisor for this study. Besides, this new service the target organisation was starting to run was in early developing stage and newly setup. Because of that, all the research that could yield implementation proposals and improvement ideas was welcomed and needed. Finally, the thesis owner was not too familiar with the old site warehouse system and could be more objective to the change in place.

1.2 Business Problem, Objective and Outcome

The closure of the site warehouse owned by the case company's co-owner in 2016 together with the creation of a new materials unit brought up some confusion to the target organisation. At the time, there was no separate guideline for bulk material management in projects commissioned by the co-owner. As a consequence, the lack of this guide had special impact because the target organisation had changed the way the bulk materials were handled to create a different unit called IMS (Investment Material System).

Before the closure, project bulk material needs were supplied from the available site warehouse to the contractors in commissioned co-owner's projects. For example, when there was a design change that resulted on materials additions to the original design, these were managed in the field. This meant that they would be taken from the stock available or even taken from other projects material depending on the urgency and stage of construction. Although, this flexibility allowed on demand fixes it also caused more difficult follow up of exact used bulk material quantities and real warehouse buffer needs. In turn, the quantity of left over material kept growing reaching certain ceiling value. As a result, multiple write offs were conducted during operational time.

After the warehouse closure, target company's management proposed that each project would have a warehouse exclusively for its materials needs. In practice, this meant that each project would have to log an accurate material list reservation. Therefore, bulk materials included in that list would be booked exclusively for the project. Thus, no material could be handed over unless it was part of the list logged. This measure was taken to avoid previously mentioned stock problem. After all, inventory is money invested that cannot be invested elsewhere; especially if it is expensive bulk material that may be difficult to use elsewhere and that with time can lose some properties or get damaged.

By contrast, newly created IMS unit did not support a warehouse per project idea, they supplied according to the orders they received. In essence, they did not reserve materials for projects in the same manner as proposed in the target organisation's project side. Unfortunately, this different logic was not noticed at once, causing some materials deliveries issues in those projects that were impacted.

There was an enterprise resource planning (ERP) system to create the purchase orders. However, there were many different places to fill information on requiring advanced training to do it correctly. Moreover, some of the process happened manually, especially when design changes occurred. In this case, it was left to the experience of the personnel and familiarity with the materials or the project to manoeuvre accordingly.
Furthermore, it appeared that in the IMS side, there was also some challenge to have a good follow up of the materials. For instance, the process in the warehouse from the moment bulk materials arrived until they left for delivery at the subcontractor's was rather long. This long process was due to the fact that, piping material and valves had to be tested individually and hand recorded to ensure quality before being added to shelves.

There were three main actors in average projects regarding material management. First, engineering disciplines; they started by designing the facilities and producing lists, specifications and data sheets of all equipment and materials. They finished by issuing all drawings required to erect the plant. Second, procurement department; took care of the purchases of all equipment and materials based on the lists and specifications prepared by engineering and expedited those materials. Third, construction management supervised the erection of all equipment and materials purchased by procurement as per drawings and in accordance with the specifications produced by engineering.

As a clarification for the reader, newly created IMS unit was part of the case company. However, in practice it was run separately from previously mentioned departments, it had its own interests and structure. This unit supplied all bulk materials needs to the projects commissioned by the case company's co-owner in Finland, but it was considered a separate business by the case company.

As a graphic summary, figure 1 below summarises the connection between the different departments regarding material management, according to the target organisation.

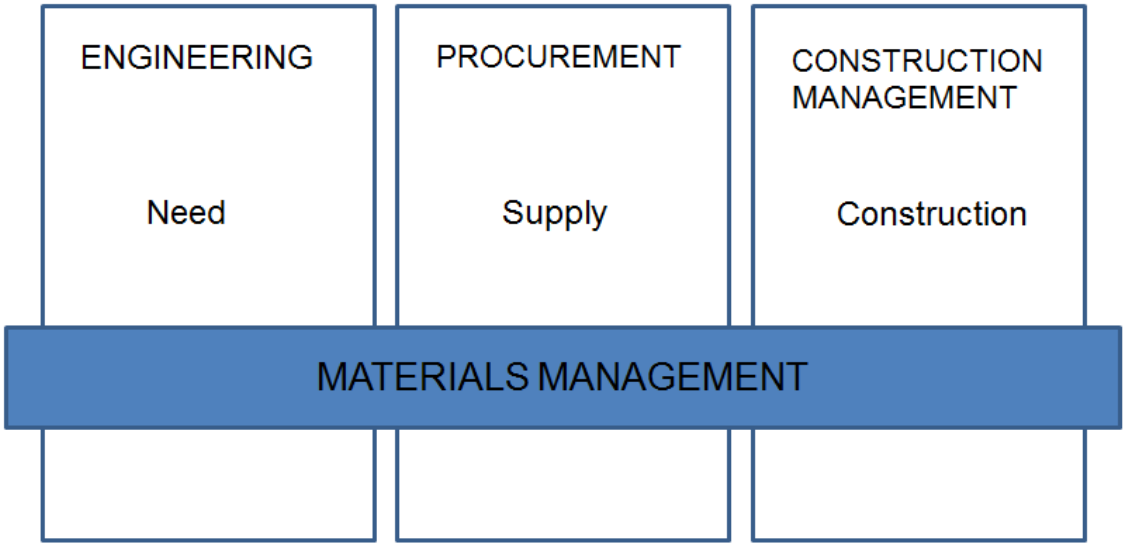

Figure 1. Materials Management process definition by the target organisation.

At the beginning of the research, there was no integration between above three blocks regarding material management. This implied that deliverables were produced in each block according to the procedures defined, but there was not a continuous common process. This lack of continuous common process was raised by assigned company supervisor as the main contributor to slight chaos on materials management. Accordingly, the **objective** of the thesis is to create a project bulk materials management guide for the case company's co-owner in Finland. Consequently, the **output** of the thesis being the project bulk materials management guide for the case company's co-owner in Finland (key requirements, IT tools, strategy and leadership).

1.3 Structure of the Thesis Report

This study was conducted to create a project materials management guide for bulk materials in Finland related to co-owners projects. These projects were engineering projects mostly related to oil&gas. Bulk materials were those materials regularly used in big quantities, where there was a need to have a constant stock. More detailed introduction is given in the previous subchapter.

In chapter two, the project plan of the study is defined. In the project plan, the research design and the data collection plan are detailed. This research design, discusses the method used and why it was chosen. On the other hand, the data collection plan specifies how the data was collected.

In order to understand the impact of the warehouse change and describe what the main challenges were, a current state analysis was carried out. The analysis results and interpretations are outlined in chapter three. This analysis was carried out, to understand the strength and weaknesses of the situation at the target organisation. In addition, conducted interviews can be found from appendix 1.

Then, in chapter four, literature review concerning material management is done in order to create a conceptual framework of materials management process. Here, materials management process is described and best practices discussed.

Next, in chapter five, how project bulk materials management guide for the case company's co-owner in Finland is co-created is discussed. This co-creation was based on their feedback about the findings yielded by current state analysis together with literature review and the status of the internal materials management development project.

Finally, in chapter six, discussion and conclusions explain the significance and implications of the conducted research in the target organisation. Also, personal thesis owner's reflection is described and future steps are outlined.

2 Project plan

2.1 Research Design

What the closure of the site warehouse left behind was difficult to grasp. Apparently, those involved in the decision were scarce, and the reason behind it somewhat uncertain. In addition, there was a general feeling of surprise and unpreparedness as it looked like a smooth transition period had not taken place. Therefore, materials management concept felt abstract and undefined at the start of the research. Materials management is a very wide topic, and different companies have varying customisations based on their materials needs. While much research has been done in inventory efficiency and Lean production, there seem to be less on bulk material processes in EPCM projects related to oil&gas. Nevertheless, in the case company developing an efficient bulk materials handling process seemed to be at critical point, due to the site warehouse close out. Moreover, bulk materials constituted a very big part of a typical project. As a simple graphical idea for the reader; for example, take a pipeline carrying oil from one point to another, this tends to be long and require many steel parts that are precisely connected to each other and have certain characteristics to withstand weather elements, corrosion, etc.

In particular, bulk materials management was chosen due to the local case company's co-owner's projects needs for the target organisation. Besides, bulk materials were the ones affected most by the site warehouse closure. After all, these were materials partially in stock that project managers had better visibility over and suddenly they could not. In addition, these materials were handled locally mostly by the newly created IMS unit. Therefore, the thesis owner envisioned a better access of information to conduct this research.

By contrast, setting the scope was rather time consuming because there was not much of a foundation. In short, there was an idea of how materials management should be handled with the new setup, but this was also modified and adapted constantly. Moreover, only those working closely within the circle of construction, IMS unit and procurement had a deeper understanding.

The steps taken to define the scope and find out what was working and what was not were the following. First, there was a need to get familiar with the current situation of the practices and the status of materials management. For that purpose interviews

were scheduled with those actors that were involved with the materials flow. After, internal documentation was studied to determine whether there was anything that could be used as a base for the project material management guide. Moreover, an internal project for materials management development was launched by the target organisation. Unfortunately, direct personal involvement to the thesis owner was not granted and access to updates on decisions was not available.

After an initial temperature check, it appeared that the integration of the input generated in each project phase with the next was not in place. This none existing integration posed a threat for benefiting a common goal on project material management follow up. In short, there was no process integrating different departments. In practice, it meant that each discipline had procedures to follow in order to produce certain deliverables, but their involvement would end when these deliverables were passed forward. However, procedures from other disciplines to produce their deliverables will not be questioned in this research, it will be assumed that those in place are correct. After all, questioning every other procedure in the company would prove a never ending process and would not help clarify materials management function in described scenario. In addition, previously mentioned IMS unit is not part of the scope as the perspective of the study is framed from the case company's project site. In other words, how a project is impacted regarding bulk materials will be researched. For finding those impacting issues some of IMS unit's processes will be described. However, this study will not propose solutions for internal IMS complications.

In figure 2, the graphical summary of the research design is represented in detail.

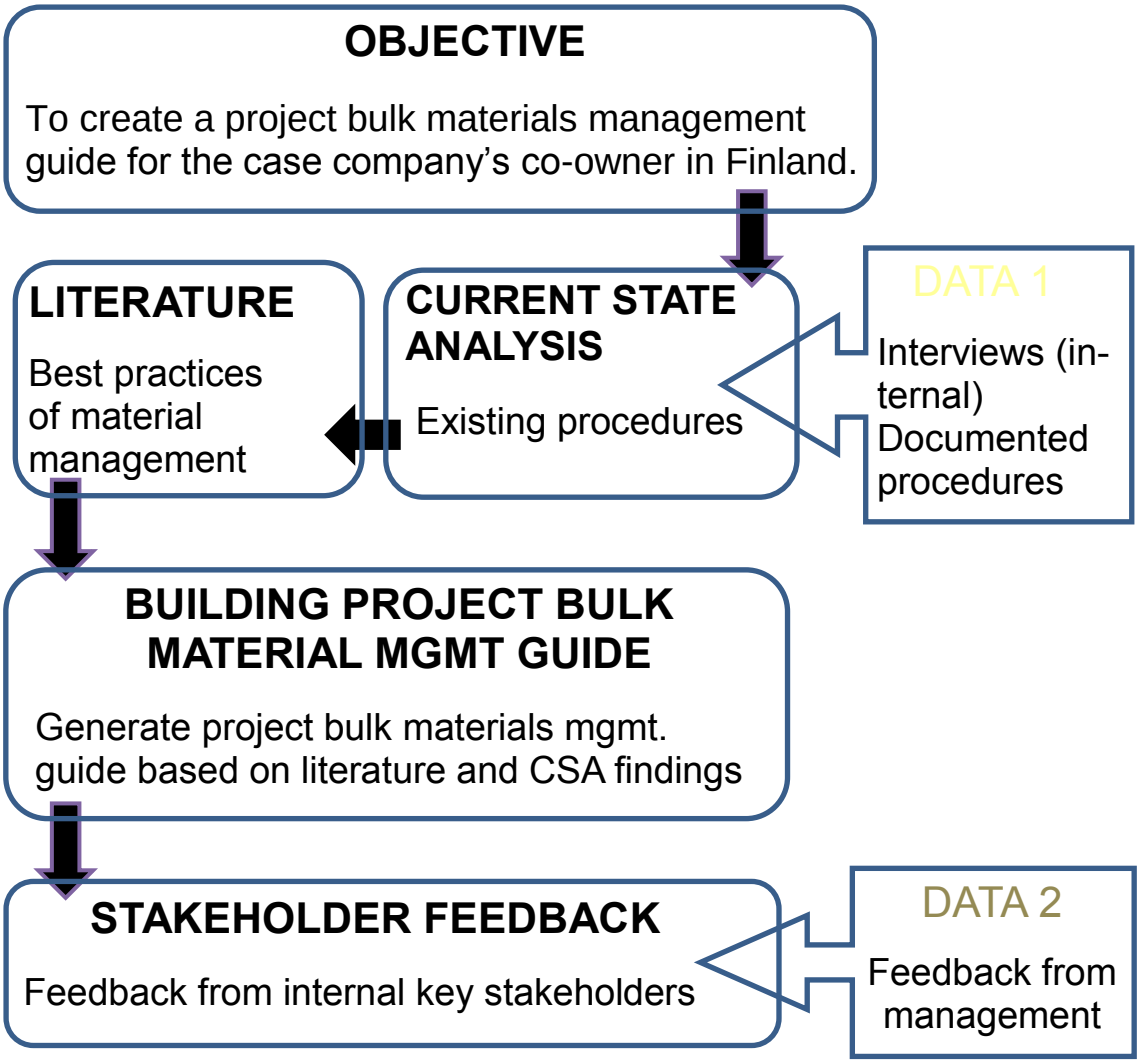

Figure 2: Summary of the research design.

2.2 Data Collection Plan

In order to propose a solution for material management of bulk materials after the site warehouse closure, it was a must to collect data and analyse it. Otherwise it would be difficult to realistically know about the issues and why they were a problem. In order to carry out the current state analysis in the target organisation it was mandatory to gather data from the personnel in the target organisation. The reason behind relaying on company personnel was the fact that there was not much written data to research. Data was collected from 10 different individual interviews conducted on project related colleagues. These interviews were conducted from January until March 2017 with varying durations, but with 1h on average, more detail information can be found from appendix 1. They were recorded and carried out face to face based on informal conversational interview approach and are attached in appendix 1. With regards to the interview style, informal approach was decided because the scope was still somehow uncertain. The uncertainty lied on not having worked with materials before and not having knowledge on how processes related to these happened. Based on that starting point, informal approach granted the opportunity for the interviewees to share their knowledge and ideas freely. Moreover, it was a fitting approach to gradually become familiar with the weak points and define the scope. Furthermore, in every interview new perspectives were discovered and these posed further questions and ideas. For that reason it was so important to keep a relaxed and conversation like style.

In short, the facts were blurry and different people had a different idea about what the focus of the research should be and what the problems were with bulk materials management in company's co-owner's projects in Finland. Above all, the aim was to get a better idea about what was not working and the difficulty that different stakeholders were facing. These different stakeholders were chosen from procurement department, project management, project control, quality, construction department and IMS unit. Nevertheless, engineering department was also consulted for understanding their connection to materials management. The reason behind excluding engineers was that they were not directly impacted as much by the warehouse closure. After all, engineers are in charge of the designs that lead to material lists, they were not in charge of purchasing nor receiving bulk materials.

Each participant was chosen, on the basis of both their participation in the internal development project for defining the material management flow and their hierarchical level in the projects. Also, the availability and predisposition to dedicate time to the thesis were considered. Materials management development projects teams were filled by personnel having other responsibilities. In other words, these persons were not dedicated to materials management development solely. In fact, these development projects came on top of their general duties. This time scarcity also was somewhat responsible for the interviews to spread over a period of three months. For the purpose of clarity interviews have been dated and numbered. Furthermore, starting and ending the interviews round with site materials coordinators. These coordinators were the most affected and overloaded resources because of the warehouse closure.

The biggest starting challenge was the difficulty to get any official instruction to form the overall frame. Apparently, there were no procedures on material management recorded. To put it more simply, some tasks were part of the construction management plan, some others part of the procurement plan and even it was mentioned a section in the project plan regarding materials. However, the materials management responsibilities with the old site warehouse were different from the ones with the new IMS unit. As a result, there was not much that could be used for building the new model anyhow. Also, the target company seemed to be more interested in forgetting old ways and building new ones. In any case, due to the change of practices regarding material management no documentation existed. Summarising, it was a process that needed to be built from scratch. In addition, materials management development projects had a later deadline than this thesis to define their processes and responsibilities.
Therefore, proposing best practices for bulk materials management to aid the materials management process for projects commissioned by the case company's co-owner seemed appropriate. Why the focus was set in company's co-owner's projects in Finland answered to the fact that these projects were the most affected ones by the new model. And, IMS was supplying bulk materials solely to these projects.

Finally, 4 workshops for sharing results and proposal building were carried out during April and May 2017. At this point, still the materials management development was running parallel to this thesis and ideas were being discussed but not that many conclusions shared. Once again, it was a challenge to get a collaborative process for proposal building, stakeholders were busy and availability of time was a limiting factor. Moreover, from previously interviewed personnel, solely materials coordinators, project

management and procurement management were considered. The reason for this selection is that these stakeholders were the ones most involved with proposing implementation options for materials management function in detail. They were all highly involved with the materials management development projects. Ultimately, the thesis was commissioned by the procurement department.

These workshops were conducted face to face by commenting on printed proposals and power point slides created summarising thesis content. First workshop included both material coordinators and lasted one hour. Next workshop was carried out with newly appointed project manager, former project procurement manger, and lasted 30 min. Then, technical services purchasing manager and project procurement manager were included in the third workshop and lasted 45 min. And, last workshop was conducted again with the technical services purchasing manager and the project manager to discuss the final proposal, this lasted one hour. Unfortunately, due to the confidentiality of the data, these workshops content has not been added as appendix, but was made available to the university thesis instructor.
For further clarification to the reader, the technical services purchasing manager was the target organisation’s assigned thesis supervisor.

The following table describes in more detail, the plan for the data collected.

Data collection point	**Data source**	**Content of data collection**	**Outcome of data collection**	**Participants**	**Date**
Current State Analysis					
Data 1a	Interview	Procurement procedures	Current state of the procedures	Procurement management	2)26.01.17 5)15.02.17 8)02.03.17
Data 1b	Interview	IMS function related to procurement	Current state of the collaboration	IMS team	3)30.01.17
Data 1c	Interview	Material management ongoing changes	Current state of the changes	Project management Quality Construction management	4)06.02.17 6)15.02.17 7)15.02.17 9)06.03.17
Data 1d	Interview	Warehouse procedures	Current state of the procedures	Material co-ordinators	1)26.01.17 10)07.03.17
Feedback round					
Data 2	Workshop	Evaluation of final pro-posal	Feedback for initial proposal	Materials coordinators Project manager Procurement management	1)24.04.17 2)26.04.17 4)05.05.17 3)27.07.17 4)05.05.17

Table 1: Data Collection Plan.

3 Analysis of the current materials management documentation practices

3.1 Overview of the analysis on documentation practices

In the previous chapter, it was explained how the data will be collected to understand the current state of bulk materials after the warehouse closure. In this chapter, the focus will be on collecting the data by interviewing relevant target organisation's personnel and analysing the findings based on the interviews. This analysis was hoped to unveil the main weak points of the materials management situation in the target organisation. Also, it was important to understand the problems each disciplined was experiencing and why.

During the current state analysis it was discovered that there were many issues from the point engineering disciplines released their designs to the point when materials arrived at the site. For instance, the need date of materials at site appeared to be one of the weakest points. The reason for its criticality was that it caused big difficulties on planning construction schedule. Hence, this need date inaccuracy could lead to downtown time at construction site when materials arrived late or storage problems when materials arrived early.

Downtime at construction site meant that, for example, if a pipeline needed to be erected and not all required materials were available, it could not be carried out. However, it is not as simple as shifting the attention elsewhere. Often, some processes on adjacent sites are stopped to carry out the intended work. Furthermore, scheduling a new process stop in the same location may be difficult. Obviously, economic impact also played a role when downtime occurred. Besides, the work will need to be performed in any case, requiring more resources to make up for the time lost or delaying the project. Unfortunately, foreseen and avoiding this scenario was not always easy, that is why it was important to adapt and find best solutions at all times.
Regarding early materials delivery, this could become a problem if space in the field was not allocated to the project. Despite of thinking that in a refinery there must be plenty of space to leave material, this is far from reality. On one hand, for safety reason only specific places are marked and intended for storage use. This is because a refinery is a process area with dangerous and hazardous chemicals. For that reason every construction site requires a field plan and strict supervision. On the other hand, some

materials have specific storage requirements, related to temperature and reactivity on the presence of other materials. Therefore, it may not always be possible to store it at site or reproducing those conditions could prove expensive and difficult. In addition, it is good to bear in mind that once materials were received and confirmed the responsibility lied on the receiver. This responsibility implied that in case of storage damage the guarantee would not be usable and the material could not be returned. Obviously, a material not fulfilling design requirements could not be used either. So, it would be a cost that would need to be written to the project. In short, planning carefully the need date of materials at site was critical for the overall success of the construction.

Also, around this need date of materials at site, design maturity level was brought up as a troublemaker. It was not always easy to estimate at which point to start the purchasing process. Ideally, no purchases would be made until the piping drawings were at final stage, commonly called approved for construction (AFC). Nonetheless, that would require a very long project timeline, which it was never the case in engineering. The piping drawings, also called isometrics, were the ones showing all the lines that a project would need and contained all the bulk materials required.
As an illustration for the reader, an example of an isometric is included. On the picture, the central part is the detailed drawings of a pipe and on the site different tables present details on the materials needed for that pipe. These material details give for example the exact volume and type of material needed among others. Although, the drawing is not important in itself it was included to understand the connection between drawings, material lists and purchase orders. The connection was a conversion from below model by a middle step to the ERP, in order to produce bulk materials lines. This middle step was another database the target company customised. However no further details will be discussed on this database as it does not have further significance for the study.

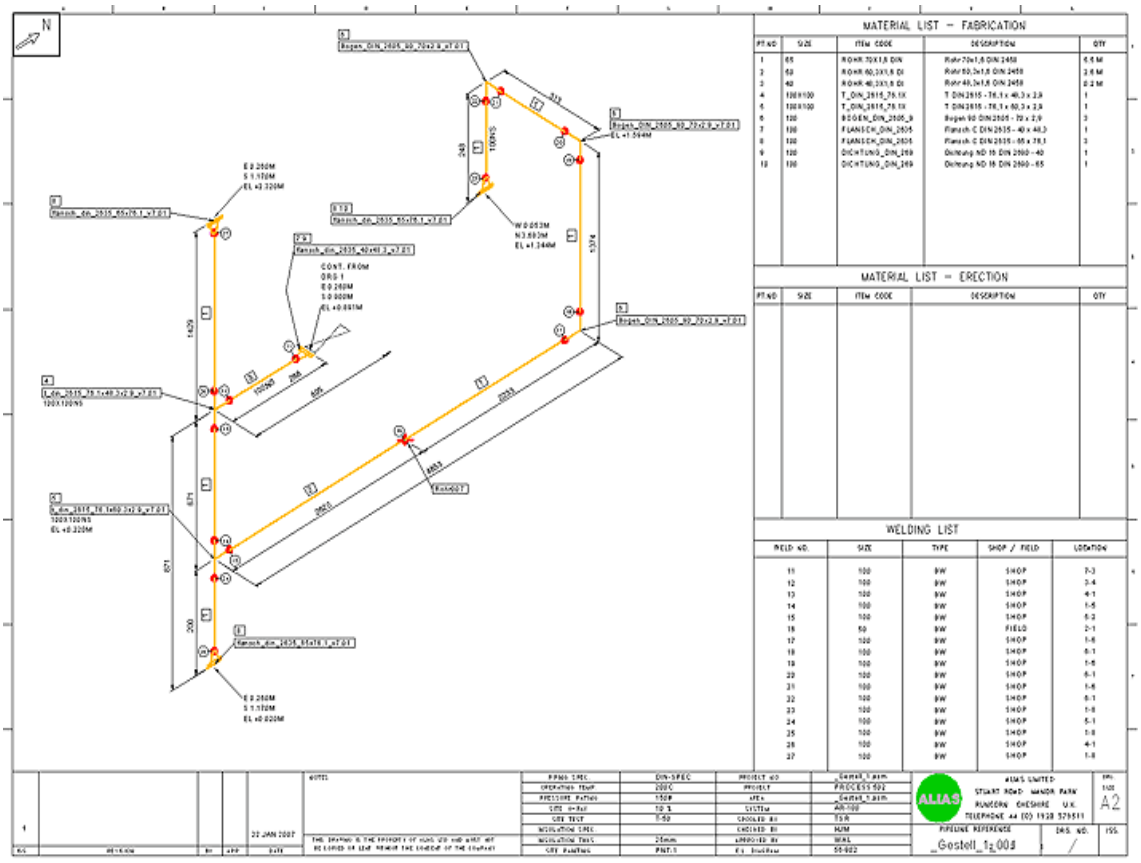

Figure 3: Plumbing water isometric (3D-CAD-Software for pipeline planning taken from company data).

Overall, it seemed that the target organisation was in transition state regarding materials management. Thus, the lack of standard instructions contributed to different project specialists' to decide about the materials schedule on their best guess. This transition has to be understood in the frame of a company getting by materials management handled by a very flexible site warehouse. This site warehouse was owned by the case company's co-owner. By contrast, at the start of this research, the case company was fully responsible for the materials management via their newly created IMS unit. In other words, the change was massive but the structure and tools to support it were not adapted fast enough.

There are differences in procedures depending on the customer and location of the projects. Therefore, the focus will be on procedures applicable to Finland and the customer will be solely the co-owner of the case company. Also, there are different types of materials, and accordingly different ways to handle it, as a result the target has been set to include only bulk materials. Moreover, this bulk material was handled by the newly established IMS unit.

3.2 Description of the projects related bulk materials practices

As previously mentioned, the target organisation took ownership of the bulk materials and created a new business unit called Investment Material System (IMS). As a result, the old process where a site warehouse existed for all projects was deemed obsolete and an unstable period followed with numerous issues arousing. Next, these issues will be analysed in detail.

The decision to change the working principle of the bulk material management was mostly due to the following challenges:

- There was neither total ownership nor total responsibility of bulk material management
- Contractual structure was complex
- Customer ”Wholesaler” and projects’ site warehouse operations were blended
- Clients had difficulties to identify total costs of materials
- Non-currant materials accrued to warehouse continuously => Economical losses (write-offs)
- Some projects were considering site warehouse as a ”hardware store” => Some other projects had lost materials which they had reserved properly in advance
- Material deliveries to prefabrication site had circulated via site warehouse=> Increased shipping costs and risks, time losses
- Bulk materials to other site in Finland had typically circulated via the site warehouse

Material management was firstly defined briefly in the project plan at the beginning of the project. There, the responsibilities regarding the bulk materials were described:

- The customer was in charge of the biggest part of the purchases
- Materials arriving in the field warehouse went through the receiving process, materials had to be tested and hand marked according to their properties before being stored.
- Quality assured materials were handed over to subcontractors.

These materials being delivered to the field directly had to be agreed separately with the delivery inspector and the warehouse. Multiple interviews were conducted in the target organisation with representatives of those three main actors mentioned before, Engineering, Procurement and Construction. Relevant interviews can be found from appendix 1.

The expectations for the resulting materials management procedures were to improve numerous situations:

- to have better visibility from engineering to construction
- to have the requisition initiation and approval in system
- To have actual costs, lead time and vendor data collected and managed from engineering to construction
- to have inspection/Shipping release, OSD register, material issue to fabrication
- to have a better analysis of contractor's work front
- to have material status, shortage and surplus reporting
- to have material traceability and installation log
- to have document control register

In figure 4, it is described the process diagram of how the procurement was handled in an average project. The figure is taken from the target organisation's internal developing material. The need was entered from the input coming from engineering, next, was processed and appropriate authorization for purchase given; then, purchasing happened if enough requirements were filled. Finally, when the material was received and inspected the invoice would arrive at the target organisation and payment authorization granted.

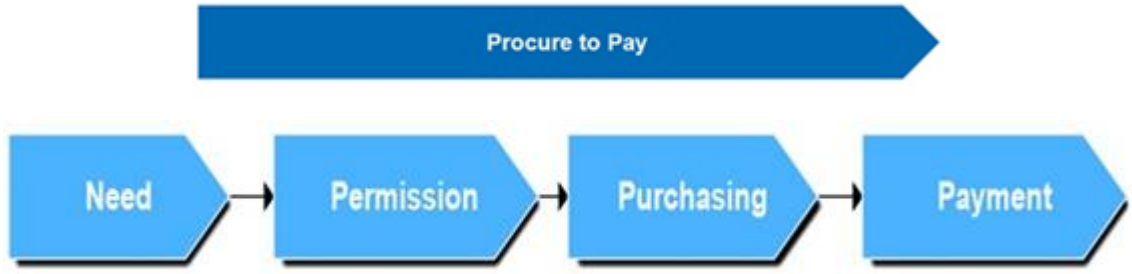

Figure 4: Project Procurement (Target organization's internal data).

Figure 5, shows the overview of the internal development of the material management process in the target organisation; in this case all materials are taken into account. Hence, the goal is to handle above mentioned expectations.

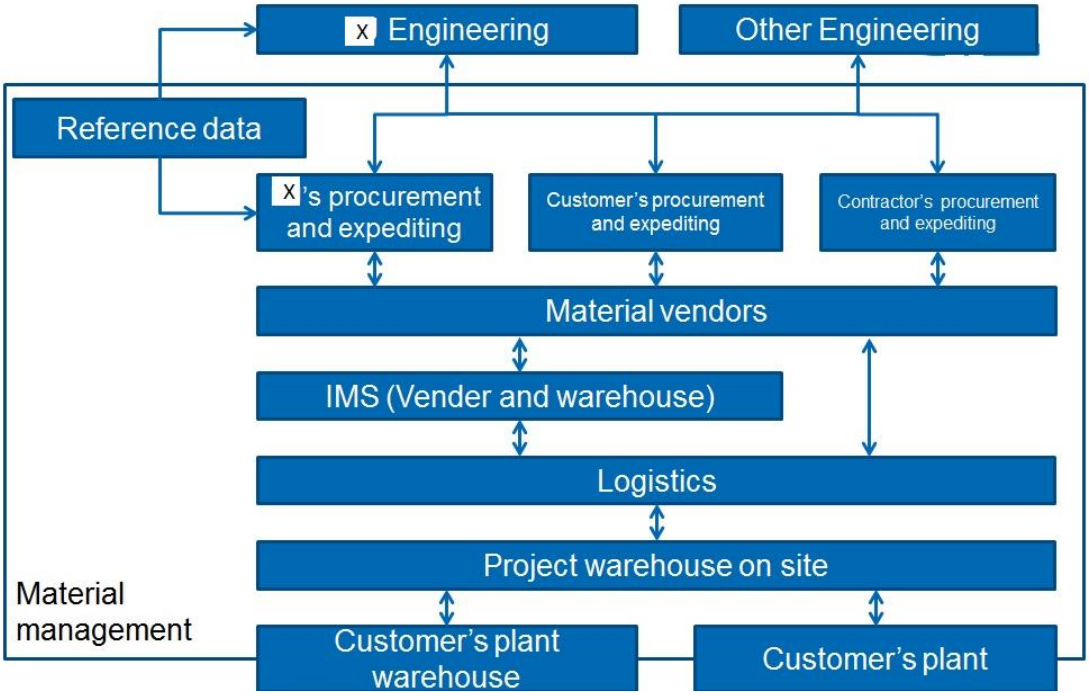

Figure 5: Material management process in the target organisation (Target organization's internal data).

In the figure above, a wide view of materials management process is taken. This wide view can be seen by not only including the target organisation's engineering team but also external engineering. The scenario of having an external engineering could be defined by customer requirement. This scenario could be related to the magnitude of the project. If for instance, a new refinery would be constructed a bigger engineering company could be entrusted with part of the project instead of relying solely on the case organisation. Nevertheless, the case organisation would be expected to continue with the project after, therefore, needing defined procedures for it.

Bulk materials were the ones that were purchase via ERP system; they were inputted to the system by the engineers after filling the material reservation template. Material reservations included detailed type of material, material take-off (MTO) quantities and need dates. Engineers came up with these material needs in the course of their designs.

Typically, projects had two phases as described in figure 4. On one hand basic engineering phase and on the other hand execution engineering phase. In basic engineering phase designers produced all required data to define material needs. Generally, this required data included; process data, piping data, instrumentation and automation data, electrical data, mechanical data and civil data. Usually, at the end of basic engineering of a project, information regarding material purchases was logged in the material reservation template and purchase requisition template.

Basic engineering in a project leaded to a final investment decision on constructing a new unit for example. In this phase overall estimations were made on the possible complications and challenges and the cost of those. In short, investment risks were assessed according to engineering results. However, not all basic engineering projects continued to the next phase, the execution phase. Often, costs could be too high or proposed solutions not satisfactory. In any case, in execution phase; construction and installation was carried out based on the engineering designs with materials purchased. In execution phase, procurement, expediting and construction management worked together around the materials management. During execution phase, procurement was negotiating construction contractors and all specified materials were bought by purchasers. After, expediting did the follow up of the materials until they arrived at site. Then, construction management would take over materials and forward them to subcontractors as needed. Nevertheless, engineers kept detailing their designs and as a consequence changes could happen. Sometimes, engineering changes had a major impact in materials already purchased. For instance, if it was found that a pipe diameter had to be bigger or smaller, then, not only the pipe parts but also valves and instruments in that line needed to be revised. In the following page, figure 6 is used to describe graphically the complete project material process in more detail.

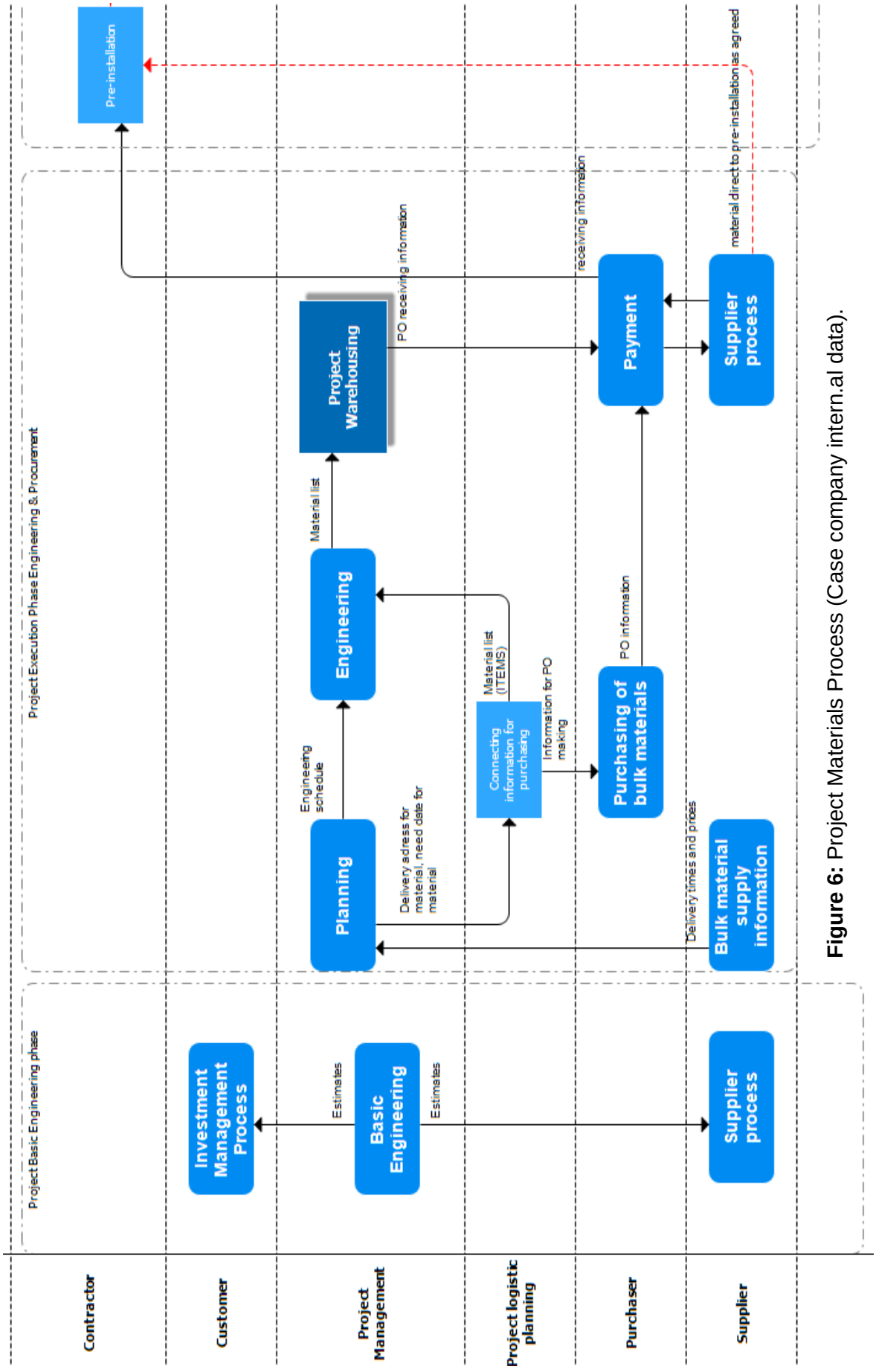

Figure 6: Project Materials Process (Case company intern.al data).

3.3 Analysis of the current strength and weaknesses on bulk materials flow

In order to determine the strengths and weaknesses of the bulk materials management flow in the target organisation, ten interviews were conducted in relevant target organisation's personnel. The reader can find these interviews from attached appendix. Consequently, in the following lines, the analysis resulting from these interviews will be described.

There was a change on project materials management flow due to a closure of the site warehouse. Unfortunately, according to the interviewees, the impact of the change was not understood by the different parties, as information flow went rather slow. Moreover, the change seemed to have been implemented in a rather tight schedule and without time for the project teams to discuss alternative plans. Furthermore, it appeared that it caught by surprise the contractors and the project teams. Basically, it seemed that the existing system did not have detailed enough procedures in place and was not fully understood. Then, it looked as if it had been replaced without transition by a new model. However, this model pointed at a scenario where it was not planned thoroughly enough beforehand. In addition, old procedures were based on the work way developed over 30 years ago and were highly manual. In other words, automation was not widely used. Therefore, with the change, no process existed causing appointed material coordinators to process big amount of orders one by one and having limited follow up control.

On one hand, newly created IMS unit's warehouse was located over 100km away from the projects related to Porvoo refinery and even further for those in Naantali refinery. This location was not always handy from the project perspective. Also, it was not always clear if all the project equipment had to be shipped there, to the project site or to the subcontractor's own warehouse. The reason for the location to be important lied on the costs that storage and receiving materials caused together with the time and personnel that were needed to do so. For instance, bulk materials were first shipped from a vendor to IMS warehouse in Kotka. Once in IMS, they had to be inspected first by the logistics team there and prepare them for further shipping. In addition, when they were shipped from IMS warehouse to the project site, they had to be inspected again at site by case company's personnel. To give the reader a better perspective on the lengthiness of the receiving process with bulk materials at IMS warehouse, we could take a valve as an example. This valve would require manual testing to assure the properties

required by the design, it will have to withstand certain characteristics depending on which liquid would be carrying and at which temperature will be put under. After the test, in the case it was successful; the valve would be hand marked and stored at the defined location in the warehouse, or packed following required quality and safety protocol. Usually, few valves together with other bulk materials would be included in a single receiving. Therefore, time and costs resulting from receiving were significant. By contrast, none bulk materials followed a different receiving process, still it was preferred by the target organisation for these to be delivered from the vendor to directly to contractors at site. However, this later case falls outside of the scope of this study, so no further details will be explained. Above all, in the target organisation, materials required defined receiving processes, accurate planning and big coordination. It is important to understand that refinery related projects have very high safety requirements and failing to assure correct quality control could lead to a fatal incident and legal proceedings.

On the other hand, the working principle of IMS regarding purchase orders was based on lots of materials while projects at the case company linked materials to isometrics. This different working principle caused difficulties tracking the orders at IMS side. The reason for the difficulty lied on the fact that orders could not always be delivered fully. In practice, this meant that when partial deliveries were made, those materials left to be delivered were not highlighted in any way by the system in IMS. The reason why partial deliveries happened was related mostly to IMS not having in stock the full amount ordered, it was mentioned by IMS management that defining stock buffer level was slow process. Obviously, because of the costs that having a large inventory causes, limiting the stock was on the case company's best interest.

However, partial deliveries could be also related to design change by the target organisation and requiring more materials. In other words, each order of bulk materials that was not fully delivered had to be manually tracked by IMS warehouse personnel in some way so the remaining materials would be delivered. Of course, this manual tracking was far from optimal and deliveries were forgotten quite often. In addition, the system at IMS did not support multiple pickings due to stock buffer comparison only working for one picking at the time. As an illustration for the reader, this meant that one warehouse worker with a list of items from a single order could pick items and mark them in the system at the time.

Even more, when deliveries were ready for shipping, there was no procedure at IMS followed to inform about the imminent delivery to the contractor or the target organisa-

tion. Moreover, the information about the delivery happened, according to interviewed site coordinators, once the tracks were on the road. But, because often delivery details were not confirmed the truck driver was awaiting instructions as it went on the road. Furthermore, awaiting instructions meant, site materials coordinators being contacted urgently to find out how to proceed. Nevertheless, as previously mentioned, receiving materials required few important steps. So, there were cases recorded of materials arriving at wrong location, in wrong quantity, wrong materials or even all of the above. In short, the system at IMS needed improvement supporting multiple pickings, partial deliveries and shipping requirements needed to be defined and enforced.

In addition, according to project control, the function of the schedule was not widely understood or even taken into use efficiently. By customer requirement, at the end of basic phase of a project, the schedule for execution phase was created with the existing information available, this had to be reviewed when the execution phase would start. However, it seem that quite often still at that point contractor's contracts for construction were not awarded yet, as the information from engineering disciplines was not comprehensive enough to do so, consequently, the construction part was guessed. As a clarification for the reader, basic engineering phase is the stage to make the decision on investing to execute a project. As a result, at the end of this phase, engineering disciplines had to produce accurate enough designs for project control department to create the project cost estimate and the schedule for the execution of the project. Moreover, the project cost estimate included both engineering hours expenses and materials expenses. Concerning the last one both bulk and none bulk materials.
Nevertheless, according to project engineers, participation of responsible persons of each department together to create the schedule in an interactive way was not always carried out. It appeared that, not all relevant leads or even project managers could see the advantage. As a clarification for the reader, interactive planning meant booking few sessions with all engineering disciplined leads, procurement leads and construction management leads involved in the project and discussing the milestones to be achieved within the timeline given by the customer. At the same time, the project planner would be drafting the project schedule by assigning sets of activities for each discipline to be performed in the timeframe discussed. Due to this step being missing, procurement management pointed out that relations on limitations between the parties were not well understood. Therefore, it seemed that materials risks were not always identified early enough; consequently, making decisions relying on assumptions.

In any case, project control management mentioned that it was not possible to have all the items to be bought listed on the schedule due to resources limitations. Especially, in smaller projects the required manpower would be too great. As a result, need date of bulk materials did not correspond accurately enough with construction activities. In addition, construction schedule relied heavily in contractors' planning of their own work, only being reviewed partially by the target organisation´s site supervisors. In turns, the facts during the interviews suggest that it was not clear whose responsibility was to update the materials needs date in the system as the project moved along, and what to base it on. Because of that material coordinators got daily phone calls about materials needs in as soon as possible basis. In short, engineering designs accuracy prior to purchasing decision was not sufficiently discussed and defined. Thus, causing need date forecasting difficulty and errors purchasing required materials.

Next, sharing information was not too successful. In general, all interviewed subjects thought that different parties involved in projects were not always aware of changes made by other. Besides, according to a quality engineer; often, lessons learned from past projects stayed with those directly involved in the projects only. In other words, it looked like communication between project team members was not as fluent and as efficient as hoped. Under these circumstances, it was difficult to know who to share information with and how to make sure that everyone got what they needed. Also, reacting to vital information being missing and raising awareness early enough seemed to be slower and more challenging. Hence, it was not easy to define who should be informed about what and at what stage. Although, it was agreed that sitting different parties together to discuss changes was beneficial, it was challenging to do so efficiently as time was limited. Often, projects could be medium or rather small and many, so the project structure would differ and those with responsibilities would fulfil more than one role. For example, one lead designer would work in different projects simultaneously and one project manager would also be in charge of many different projects. Summarising, relevant information was not shared between project team members as soon as changes or decisions were made which lead to time losses and late actions.

Finally, the target organisation had no previous experience on material management, so adjusting the mind set of those working long time and train new comers could require patience and big investment developing new procedures. The old warehouse way of working had been in force for long time, and it not only involved the target organisation's workers but also contractors. This developing new model had to be designed by

cooperation of all the parties as they all were impacted in different level and degree. In conclusion, individually workers in different projects were doing a big job trying to meet project deadlines and objectives, in reality, projects execution relied heavily on individual experience and methods. This implied that there was a very good capital of people with high skills and sense of work duty. Nonetheless, there was no standardised common way to work and it was up to the project manager and project team to set material management requirements.

In essence, the complexity of projects in the target organisation had changed over the last years but the working ways had not adapted enough to match the evolving times. In other words, prevailing working culture relayed on the familiarity brought by team members working together in multiple projects over the years. The reader can understand this familiarity by picturing an open office with engineers siting together; they have a common understanding and professional trust created over years of similar project work. In this scenario, it was not that important to have that accurate planning in place, nor a very advanced ERP system follow up. This setup allowed natural continuous communication flow. In addition, there was a direct access to the stock buffer level in the old warehouse. Nevertheless, the new setup after the change included more diverse project teams. This diverse project teams were formed by many new hires including those with mother tongue other than Finnish or Swedish, some internationally located and a new materials management process. In short, data sharing flow became more complex, old planning strategies were not sufficient and ERP in place did not support enough new materials needs.

Regarding the linkage between the case company's ERP system and the old warehouse's ERP system, this was direct. In other words, the IT setup at the target organisation was open and gave much freedom to its users. By contrast, IMS unit's ERP system did not have any link to case company's ERP system. In practice, this change according to project management meant that project managers could no longer monitor bulk materials stock, which impacted on their control to handle changes during construction of the project. For this reason, site materials coordinators were granted access to IMS system, because it was otherwise too difficult to manage construction at site without any overview on bulk materials details. However, the access to IMS system was kept limited by the case organisation on purpose. The purpose to keep these two systems from communicating with each other seemed to fall under the case company's strategy. It appears that according to IMS management, the case company wanted to

consider IMS unit as a vendor supplying materials to other clients in the future. In any case, not having communication between ERP systems caused a major impact on processing purchase orders coming from the case company's procurement department. This impact was related to each system having different content for the purchase orders. In other words, the fields in one system did not match those in the other. Moreover, typing details to the purchase orders' fields had to be done very carefully. The reason for this carefulness was that typos or some special character gave errors when exporting or importing then from or to the system. Consequently, purchase orders had to be replicated manually line by line in the system at IMS. Summarising, case company's ERP system not being linked to IMS unit's ERP caused delays on purchase orders prompt handling.

3.4 Summary of current strength and weaknesses

On one hand, the old warehouse was closed shifting the bulk material responsibility to IMS, causing project materials to be handled differently. As a result, confusion period followed where it was not clear what the effects of the change were. Then, existing issues with project bulk materials need date were augmented, it became obvious the importance of creating accurate project schedules. Suddenly, planning required more attention, becoming more evident for the projects to handle their bulk materials needs more carefully. Also, logistics came as a new variable to consider, as materials needed to be delivered and stored somewhere.

In addition, since the IMS worked as a vendor it had also its own ERP system, which was not linked to the target organisation ERP system. Therefore, visibility on the status of the stock was not as available as before so material coordinators became the focal point on enquiries. In addition, the bulk material logic in each side was different, while the target organisation based their bulk material needs on piping isometrics; IMS unit based their bulk material allocation on lot orders. This in turns caused poor traceability of orders status and delivery dates. Furthermore, IMS hired a contractor for the warehouse activities that had no prior experience with the types of materials the target organisation used. Thus, as proper procedure did not exist and old warehouse workers were dismissed, training new warehouse workers proved challenging. This had a big impact in delivering bulk materials to the projects, as they were late and often incorrect.

On the other hand, involving different departments together in different phases of the projects did not always happened; information was not shared to all the project team members that required it. Departments internally had meetings to produce the required deliverables but it did not involve cross disciplinary work. Co-creation of plans regarding materials needs in the project was more ad-hoc than standard practise.

Below, in figure 7, the graphic procedure in bulk materials order/delivery process is described together with a summary of the issues.

1 Schedule of materials

Importance of schedule neglected

2 Design ready

Often not mature design

3 Purchase orders

Need date and delivery address not accurate

4 Purchase orders approved

No stock visibility

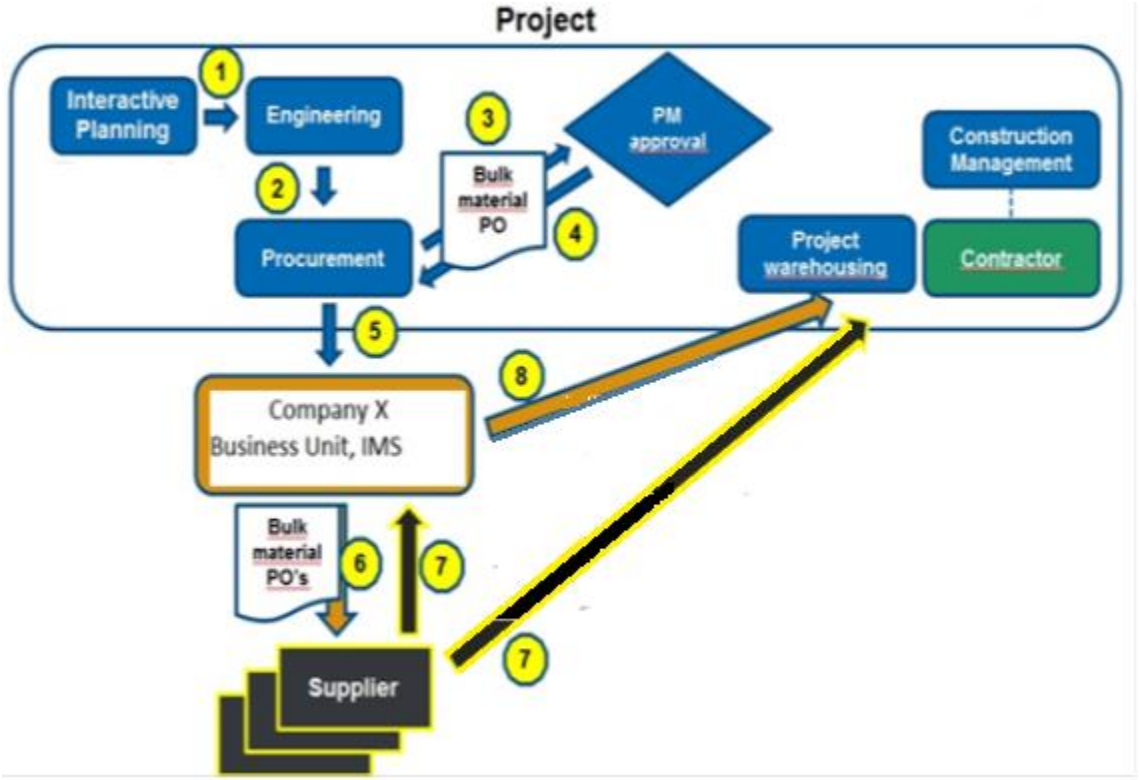

Figure 7: Procedure in bulk materials order/delivery process (modified internal target organization's data).

5 Purchase orders to IMS

Different ERP systems, not linked

6 PO from IMS to supplier

(Outside of scope)

7 Materials delivery from

Receiving inspection and storage to be agreed

8 Materials delivery from IMS

Unscheduled deliveries, delivery authorization process not used

4 Existing knowledge on materials management process

4.1 Materials Management Process Definition

In the book introduction to materials management (Arnold, Chapman and Clive 2012) the following definition can be found; “materials management is a coordination function responsible for planning and controlling materials flow.” Accordingly, its objectives are; to use company’s resources efficiently and to procure according to customers’ needs. Because of this a balance must exist, between the customers’ demands and the target organisation’s cost to provide the service demanded.

The current state analysis of the materials management practices yielded many issues, and eight were specially highlighted in the previous chapter. One of the biggest reasons it could be due to different actors handling project work related to bulk materials in different manners. As a result, the chosen path will be to interpret those issues as symptoms of no unified process. Therefore, the focus of the literature review will be on researching best practices for setting basic process needs to help define common instructions regarding materials management. For finding the most updated relevant literature, only sources from 2006 onwards have been taking into account. Below, in table 2, a graphical summary is presented of an average oil&gas project to give the reader a perspective of the coordination required to handle materials flow.

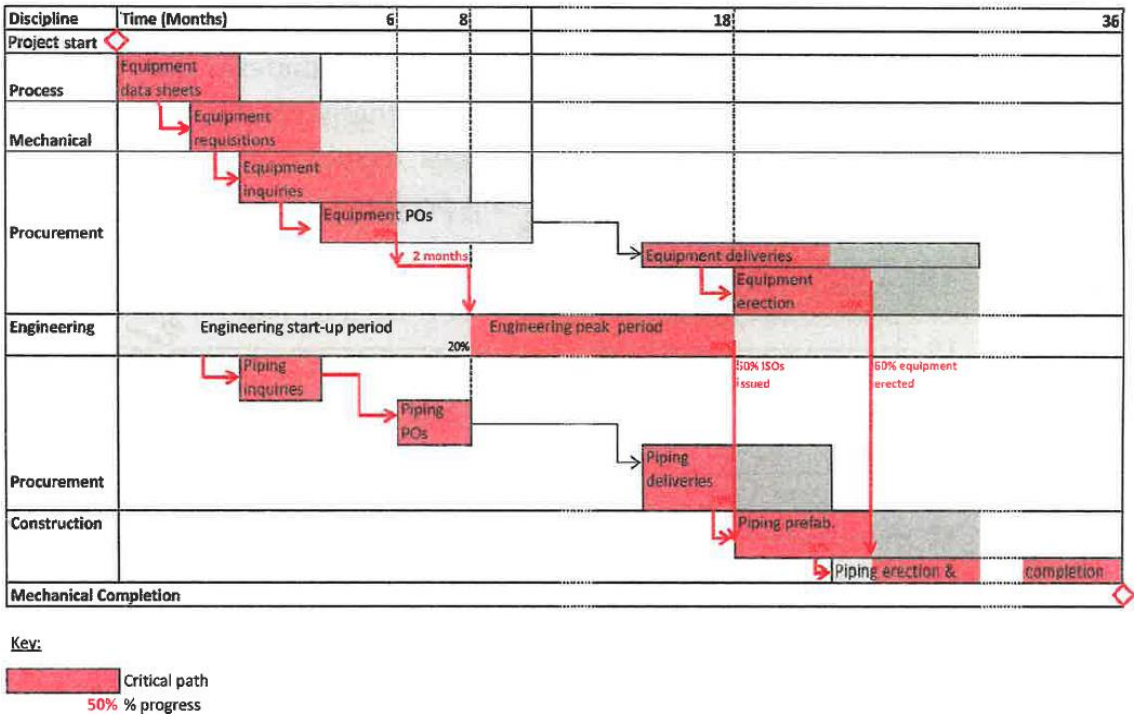

Table 2: Typical project schedule of an oil&gas project (Baron 2015).

4.2 Key Requirements for Materials Management Process

It appears that materials management is a wide concept, accordingly many different steps and terms as used. With the purpose of narrowing down basic requirements, an article in a chemical engineering magazine is taken as a basis (Wyss 2016). In this article, a list of key activities regarding materials management (MM) is proposed, as the basis for creating the needed structure to support an ideal material management process:

- “Materials-related requirements planning
- Project-acquisition strategies
- Purchasing and subcontracting activities
- Expediting activities
- Supplier-quality management
- Transportation and logistics activities
- Site-materials management
- Planning for operations and maintenance turnover”

These points were mainly brought up on the interviews conducted in the target organisation; although there are challenges on their optimal implementation, the need for them starts to be clear.

Moreover, the target organisation faces a puzzling situation when purchasing bulk materials. The dilemma is discussed by Stephen Wyss (2011) in the following manner: how to define the optimal maturity level of designs for the procurement phase to start, while minimising risks of purchasing incorrect material and still supporting the schedule (Wyss 2011). As a clarification for the reader, if a second look is given to table 2, some overlapping of activities can be noticed. In other words, design, supply, fabrication and erection overlap in some stages.

Mainly, once the supply phase is initiated before the design has been adequately confirmed, there is a risk that some of those materials purchases could differ from those required at later stage, resulting in extra costs and delays. However, waiting until the design phase to be final and approved for construction, could take a toll on the schedule resulting in major delays, which usually is not acceptable. As a result, Stephen Wyss (2011, p.47) points out, that the only solution left is to establish a "pre-buy" process, which would try to minimise some of the risks involved, being one requisite, to create a comprehensive materials management plan.

Nevertheless, when there is high bureaucracy involved in purchase procedures these tend to take longer resulting in overestimated inventories in the supply chain. As a consequence, the purchasing process must be as simple as possible allowing lower internal lead time. Moreover, materials productivity could be improved further by the use of technology such as e-procurement and e-tendering processes, as their function is to compress the replenishment lead times greatly. But, that would require further focus and research, as well as the value stream mapping (VSM) technique, which seems to be useful towards exposing those steps in procurement planning that consume too many resources for the little result they produce (Vrat 2014).

Continuing with the requirements of an optimal materials management plan, Stephen Wyss (2011, p.47) suggests that it would ideally use as foundation, a well-coordinated engineering and construction planning where a project is broken down into areas that facilitate both convenient construction and feasible design. Following this principle, seems to be of outmost importance, requiring construction and engineering departments to cooperate to define construction sequences, by area. Obviously, these should match with the engineering departments' capacity to mature the design in a manner backing planned construction sequences. Which bring us to the purpose of those construction sequences, which is no other than to specify need dates on site for all materials according to their respective areas. Naturally, as the design matures, initially planned construction sequences would need to be revisited for viability. Also, most probably as a consequence of the reviews, updates will be required to be made to those need dates and promptly communicated to the relevant parties.

The impact of not having needed materials at site at the time to start the construction, are opportunity costs, which are hidden costs not taken into account in the cost estimate initially approved. However, the result of the shortage of materials can cause downtime or delay on production leading to even losing customers or facing sanctions for deviating from agreed contract (Vrat 2014). Particularly, when engineering changes occur it should be taken into consideration the corresponding impact on the material management planning. There seem to be two types of engineering changes, those that could be carried out at short notice, called reactive, and those that could be planned in advance, called proactive (Wänström and Jonsson 2006). According to Wänström and Jonsson (2006, p.564) in a reactive context, if a delay happens in the information received, purchase orders could be released for items that should have already been phased-out. Moreover, uncertainty in demand has straight influence on fixed cash, out-

dated materials and assets exposure by needing greater buffer of stock available (Wänström and Jonsson 2006).

Previously mentioned article (Wyss 2016) also touches the importance on having a materials management team involved early on the project planning, until all the issues have been addressed and solved. In addition, cross –functional way of working is suggested as opposed to silo way. This is too a recurring problem that is brought up often in the target organisation, the aim is to do more team work between departments as it has been noted that the individual department optimization does not necessarily do good for the project as a whole. However, the target organisation projects focus on customer's refineries related needs, this in turns results in project types varying greatly in size and requirements, thus, needing specific customization. Therefore, as suggested by Stephen Wyss (2016, p.70) it does look like members of the materials management team should have general knowledge of all processes and automation tools but do not required being specialists in any. Especially important is that the material management team should report directly to project management in order to avoid transactional behaviour, which would tend to cause the silo effect. This in practice suggests that material management team would coordinate that each discipline delivers required data for bulk materials continuous follow up.

When it comes to the issues with poor delivery information data, Stephen Wyss (2016, p.73) affirms that materials management team should involve itself early with the expediting effort to facilitate planning of shipments and development of data in the materials-management system. Hence, resulting in scheduling importance awareness and need date of materials at site accuracy. In this context, it appears that vendor-buyer relationship could be important to success in MM, obviously looking to have in place mutual win-win relationship on a sustainable basis. When local vendors with adequate capabilities are chosen then lower inventory lead times can be expected (Vrat 2014).

Another key point is the need for careful logistics and transportation planning. It is no secret that by having an effective materials management, handling and transportation costs will likely go down. According to Prem (2014); "logistics planning, source selection, storage and warehousing choice of transport mode, etc., will have impact on handling costs". Prem Vrat (2014, p. 12) states that often the costs arising from governing

and delivery may be “15–20 % of the costs of the materials” alone and thus turn into a crucial subject for cost reduction.
Also, receiving inspection according to Prem Vat (2014, p. 12) does not create value it actually creates costs; consequently designing an accurate inspection policy is a must. This would ideally include: an accurate design and a “selection of acceptance sampling plan”.

Furthermore, a research by Kärkkäinen M. et al. (2010, pp. 292-306), focusing on inventory transparency, that can be introduced in short-term storage locations, uses shipment tracking systems. According to Kärkkäinen M. et al. (2010, pp. 292-306), the software worked in a way that would “generate the timestamp data on shipments entering and leaving the temporary storage locations of the installation companies”. This could be useful for the site projects warehouses where buffer of materials is required; for instance, in case of installation schedule changes keeping materials for the project more at hand than at the IMS warehouse or even vendor warehouse.

Find below, in figure 8, a graphical summary of the typical project materials purchasing process timeline. This is only to give a general idea to the reader of the phases involved and the time they required.

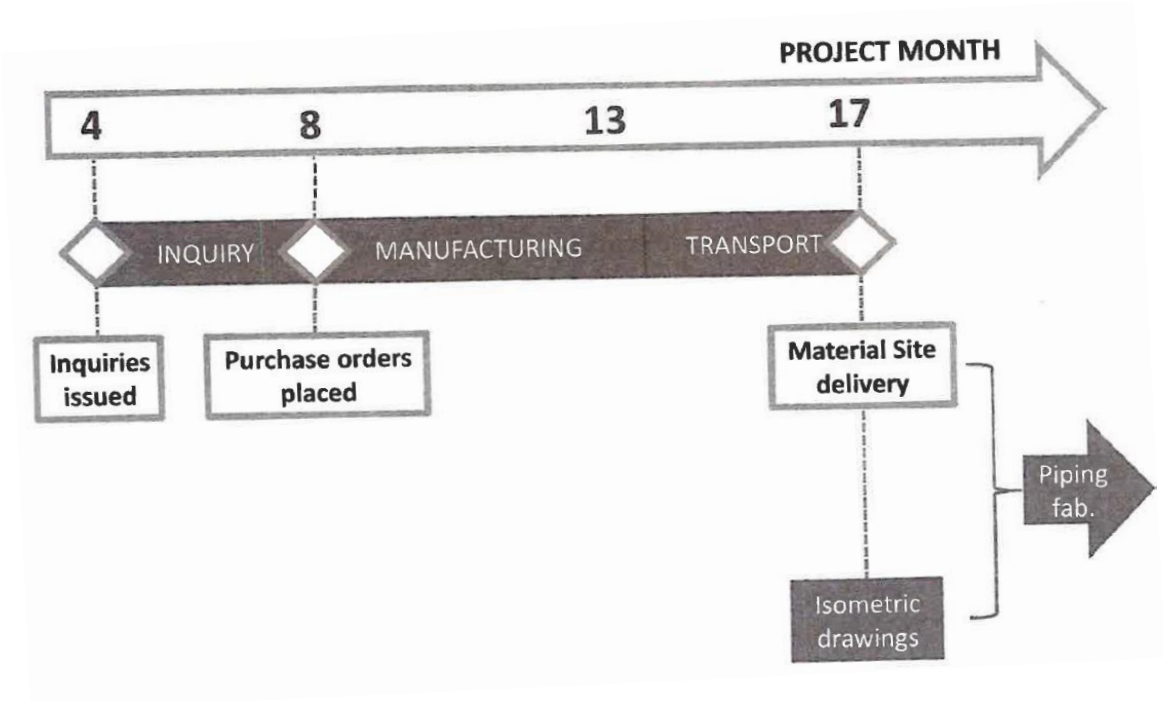

Figure 8: Example of the timeline for procurement of materials (Baron 2015).

4.3 IT Tools for Materials Management Process

The target organisation has an ERP system in use and this has been taken as a base exclusively. Further research would be needed focusing on other MM system possibilities once MM responsibilities have been defined and implemented.

A research conducted by Patrik Jonsson (2008) suggests that the environment which the user is subjected to can impact the planning performance directly as much as indirectly. Furthermore, the affirmation is made based on the difficulty that maintaining planning parameters in the ERP system demands. The requirements on knowledge, responsibility, and available time for those in charge to actively update the ERP system and apply the respective materials planning process as agreed, are often not fully enforced. Moreover, according to Patrik Jonsson (2008) several studies on ERP implementation have concluded that education focused on understanding the planning and control concept that the software system is supposed to support, are more important than the computer/system operations by themselves. This also applies when an ERP system does not back materials' planning. In Patrik Jonsson's mind (2008) there is no doubt that in materials planning environment a software backing is a must. However, he describes several setbacks caused by ERP solutions that are not correctly customised. The causes he cites are "the high complexity of the system, lack of training, and knowledge among managers and personnel, low data accuracy, and lack of support from the software vendor, especially among small firms" (Jonsson 2008).

Actually, Stephen Wyss (2009) goes further as to say that " Any good MM system will possess an allocation system, and generally, the finer the level of priority granularity, the better the system is able to allocate materials to support desired fabrication and erection sequencing." In addition, he argues that it would be beneficial for a company like the case company to have the same overview on materials status as the fabricator or in this case IMS, such as on-hand materials, issued materials, wastage, and constructability. By linking materials management systems, both EPC and fabricator, could see what the other sees, communication would be more open, and where either one wants information from the other, that information could be available one click away, instead of asking for it and waiting for a response.

The main needs that materials-management software should support for an ideal integrated approach would be (Wyss 2011):

- “integrated design (for instance, 3D models) with requirements
- component attributes
- requisitions
- need dates
- purchases
- material statuses”

The software, according to Stephen Wyss (2011, p.47), should in a timely manner be able to forward design changes to lower modules, to add up requirements and produce requisitions. Also, it seems it would need to handle and keep lead time data. This data could be as an example purchasing time, fabrication and individual component delivery to different destinations. In addition, the software would have to transform required on site dates of all component into latest materials requisition dates. It should be suited to assign risk characteristics to all components. Above information gives the project management team solid data to aid evaluate risks when conducting previously mentioned pre buys of bulk materials in uncertain design maturity situations.

Below, there is a summary of a theoretical integration of materials management systems at enterprise level, including all the functions.

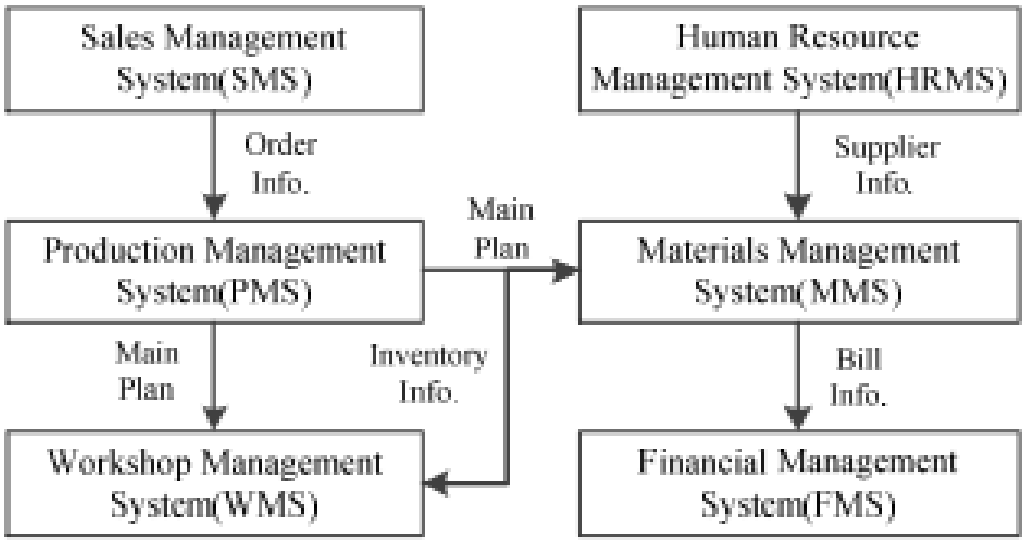

Figure 9: Relationship of systems (Wang et al. 2013).

One example of materials management software, would be Integraph Corporation‘s SmartPlant® Materials solution. This solution seems to promise to address issues regarding procurement efficiency, projects costs and risk management by managing reference data at one place, introducing engineering and procurement integration and enabling better supply chain management and site management. This module for materials management is part of a wider portfolio of products, from which the target company has few in use for engineering design (Integraph 2012).
Another example of such software is Aveva offering. This solution appears to promise similar benefits as Integraph and also one of its modules is in use at the target organisation for plant design (AVEVA Group plc n.d.).

Therefore, it would be a matter of deciding on the long term investment and customisation of some parameters to fit the target organisation’s needs. Moreover, these solutions tend to have a high maintenance cost and certain lifecycle of updates. Finally, integration to existing ERP system at the target company should be taken into account.

4.4 Strategy and Leadership for Material Management Process

A good starting point for managing the materials management team is to take Stephen Wyss's (2016, p.70) advice on describing the ideal set of skills required. In his view, materials manager should possess a wide knowledge and expertise on designing, construction and supplier processes. Prem Vat (2014, pp. 7,8) goes further and proclaims that "there is no way one can practice a systems approach in managing materials if the materials management function is not given adequate empowerment in the overall organization structure of the firm or the corporate entity." He argues that to have the overall view and control of the materials management function fully integrated with all departments, the function should be elevated to the board level of the company. Because otherwise, the strategy falls under the department which is put under, an each department has certain KPI to fulfil.

For example, if engineering or construction departments are in charge of MM function, they will want to make sure there will not be a shortage of materials even if it causes oversupply. Likewise, in the case where procurement department is in charge, it seems some risk could exist of wanting to reduce inventories leading to situation where needed materials are not found in stock and lead times are long. Or even situation when materials thought to be of similar characteristics are bought because of difference on price or discount offered. In short, the risk of buying things that may not be needed is high. Therefore, it seems that adequate empowerment is the key to look at materials management as a whole as opposed to departments narrow subsystem objectives.

Since, materials management was a new function, it could best to avoid communication relied solely upon charts, graphs and process flows, as it appears that it does not always produce intended results. This is because charts, graphs and process flows do not directly address the people side of improvement, the source of all the symptoms noted earlier, as Kay Server pointed out (2007). Under these circumstances, the tools proposed by Kay Server (2007) for breaking down silos and getting commitment for change with process orientation include:

- "A joint meeting between all process suppliers and the process owner or customer.
- An agenda that creates a shared need for cooperation and change.

- A visual of the entire process, showing the activities that occur and all the stakeholders involved in the execution of the work processes, communication and approvals.
- A clear description of the process steps involving the process suppliers.
- A list of the specific tools or tasks that will be different for each supplier to the process. This will help each supplier understand what will be different for him or her without having to understand the details for other suppliers.
- An estimate of the value being lost due to the current state.
- What will be gained if everyone does his or her part to adopt the new procedures and tools.
- What will be lost (financial and otherwise) if a supplier to the process drops the ball."

In addition, it would be required from the leader to create a sense of urgency on materials management responsibility change (Kotter 2013). This urgency has to be the driver to act on pushing departments to adjust to the new process. In addition, leading change is needed when it comes to the target company culture. This culture is defined by the customisation of projects performed for the co-owner of the case company. But, as markets change the case company would benefit from a culture of determined leaders to proactively seek improvement and cooperation in materials management.
In line with determination, courage is also a basic ingredient for a good management. Kathleen K. Reardon (2007) argues that business courage is skill gained by continuous decision making practice. Nonetheless, risk undertaking requires training and rigorous pondering for success. She defines several steps for calculating courage: "setting primary and secondary goals; determining the importance of achieving them; tipping the power balance in your favor; weighing risks against benefits; selecting the proper time for action; and developing contingency plans." (Reardon K. (2007).

In short, the leader of materials management function in the target organisation has to be able to deliver the strategy to be followed by materials management project team members. These need to understand upstream and downstream requirements regarding material management, in order for them to commit to cultural change and include them as part of their daily routines. For that reason, those detailed explanations should be carried out via face to face workshops and/or meetings. Consequently, making sure everyone is on board and understands what the aim is. And lastly, a true sense of urgency has to be transmitted. Because, managing materials management costs have a

direct impact on projects. And finally, have the courage to take decisions for improving materials management processes by setting and achieving relevant quality goals from the beginning.

4.5 Performance Indicators for Material Management process

At the time of the study, no key performance indicator (KPI) measurements existed for materials management. However, as this new function is implemented it will be critical to set some parameters to follow its performance. The reason behind needing performance measuring is the optimal use of resources and bringing attention to cost drainers. In other words, it has to be known what the weak points of materials management flow are and what needs to be improved. After all, when something is measured and understood it is easier to develop it further.

Sjøbakk et al. (2015) describe in great detail in their case study the benefits of introducing a performance measurement system to systematically monitor how well materials management is carried out. Besides, according to the article, it seems that designing such a system amounts to setting relevant performance indicators and systematically measure the results on a given timeline. After, results given by the indicators should be processed with certain goal in mind. Generally, the goal would be to reduce waste and extra costs for the target company and help constructability at site.
Below table includes performance indicators for materials management that Sjøbakk et al. (2015) propose:

Indicator	Explanation
Warehouse inventory accuracy	Comparison of the data in materials database with physical inventory
Accuracy of forecasting	Comparison of real and forecasted material demand
Material receipt problems	Percentage of material deliveries with information discrepancies that if not detected and corrected would cause inaccuracies in the project
Jobsite rejection of tagged equipment	Percentage of rejections of tagged equipment
Incoming delivery quality	Percentage or number of incoming deliveries containing defective materials
Procurement lead time	Ratio of average to planned procurement lead time, or average material procurement lead time to total order fulfilment lead time
Bid/evaluate/commit (BEC) lead time	Average duration of BEC relative to planned duration
Purchase order to material receipt duration	Ratio of average to planned duration from the issuance of a purchase order to the receipt date of the materials

Commodity vendor timeliness	Percentage of vendor deliveries on time
Construction time lost	Percentage of construction time lost due to materials
Total surplus	Percentage value of unused materials to total purchase cost of materials
Inventory carrying cost	Total of storing any raw materials, WIP and finished products
Cost of material obsolescence	Cost associated with obsolete inventory incl. spoilage
Cost of stockouts	Cost of lost orders due to stockouts, or # of req. items out of stock
Inventory turnover	Ratio of a firm's cost of goods sold to its average inventory level
Cost of reworking inventory to meet engineering changes	Cost associated with reordering of material due to engineering changes
Materials availability	Ratio of total number of material line items issued to the total number of material line items requested

Table 3: Performance indicators for materials management (Sjøbakk et al. 2015).

Despite all of them giving valuable information in practice they may require a number of resources that could be too great in short term perspective, in addition, some of them may not be relevant for the target organisation. Thus, most critical ones could be chosen as to have a better follow up of the overall situation. Sjøbakk et al.(2015) do a further division as to choose those that were most relevant for their case study, in the case of the target organisation those same five indicators could be defined as starting point; material receipt problems indicator, incoming delivery quality indicator, procurement lead time indicator, purchase order to material receipt duration indicator and production time lost indicator. In any case, the indicators chosen have to be of value for the continuous improvement, and advantage of projects in term of cost savings and efficiency.

The target organisation could start evaluating those by linking them to the business processes, consequently discussing it with relevant responsible persons. After, the team would need to map the performance goals for the different indicators. Moreover, during the discussion some tuning could be required to truly adapt those indicators to the real situation of the target organisation and maybe even discard some if they prove not to be relevant. As a result, raising awareness upon this measurement system could aid benchmarking and further developing process of material management flow.

4.6 Summary of Basic Best Practices for Material Management

In order to meet evolving market conditions for optimal materials management, Stephen Wyss proposes a number of objectives (2016, p.74):

- “Maintain cradle-to-grave oversight throughout project duration
- Develop skillsets that are knowledgeable in all enterprise and supplier materials-related work processes
- Address all materials-related work processes cross-functionally
- Remain knowledgeable in enterprise, partner and supplier automation tools
- Be assertively proactive and no transactional in execution
- Maintain close alliance with, and support by, project management”

Generally, many people are involved in project work; one discipline creates a set of deliverables that passes to the next disciple and the flow goes on. When changes happen especially in urgent situations, the chain of communication and officially recording the deviation can be delayed and difficult recognising the consequences early on. For that purpose is that supervising the material flow process could benefit from having a dedicated team synchronised with all the disciplines involved in the project at all times.

Undoubtedly, the size and value of the project defines the resourcing but material management function, based on literature and interviews carried out in the target organisation, should not be completely replaced by distributing the responsibilities within disciplines.

Regarding the impact of engineering changes in the materials planning; when items are interchangeable is not that big as long as the engineering change does not affect other items around it. Since the thesis focuses on bulk materials, special materials fall out of the scope. Nevertheless, those especial materials would have a bigger impact on planning as the probability to be reused elsewhere often is rather low, and the cost of that significantly high.

In addition, having a material management function supporting software would enhance the communication between the different departments, as the same information would be ideally available to all in real time.

Summarising, based on literature mentioned, it seems to be beneficial to have a materials management team; to supervise the execution of all material related processes, so deviations are spotted early enough to avoid delays in construction and economic losses, working together with an ERP system supporting that process. This in turns, would generate reliable data in real time that could be used for updating the schedule accurately, thus, placing purchase orders at the right time and bulk materials being delivered at the right time and in the right place.

Figure 10 captures the conceptual framework of the materials management process based on the literature researched.

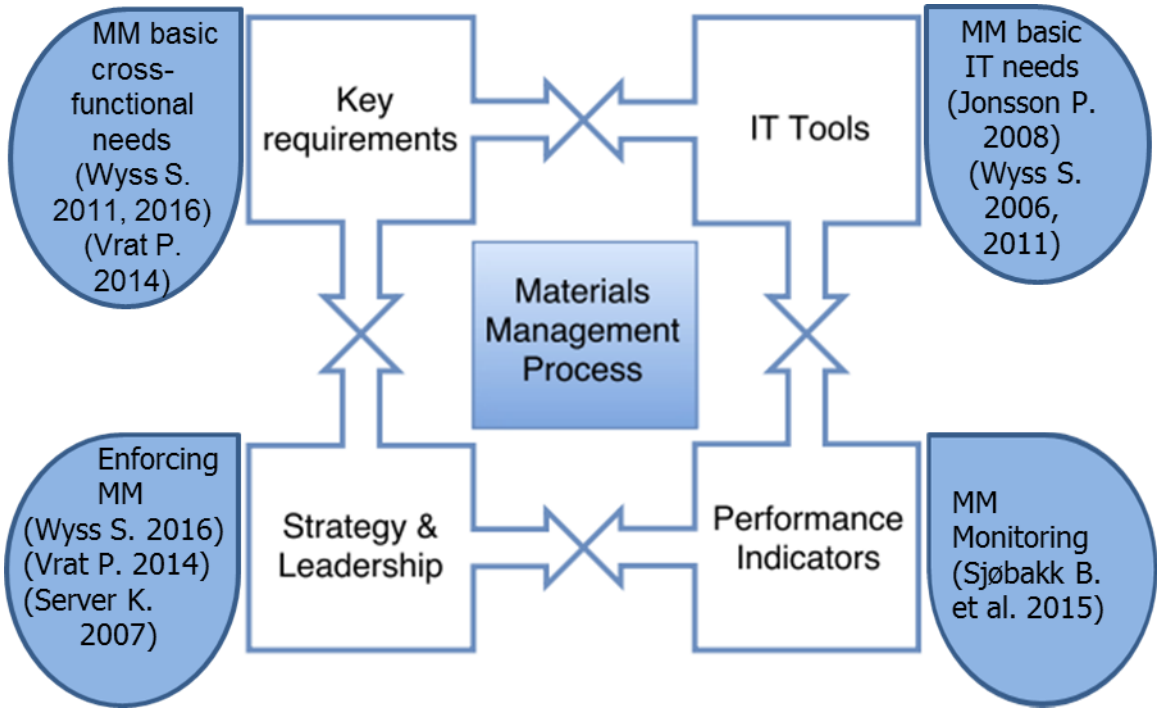

Figure 10: Conceptual Framework of materials management process

5 Co-creating a project bulk materials management guide for the case company's co-owner in Finland.

5.1 Overview of proposal building

The material management guide resulting from the collaborative process with the target organisation is expected to address and improve some of the weaknesses found during current state analysis process, by using cited literature review as a foundation. These issues to be improved are related to:

- Maturity of design
- Importance of schedule
- ERP integration
- Need date details
- Stock visibility
- Receiving inspection and storage details
- Delivery details

The proposal for project bulk materials management guide for the case company's co-owner in Finland begins with a process chart showing graphically the materials management function in relation to process data maturity level communication flow with other existing functions. In addition the process chart proposes a new responsibility sequence. Then, the guide follows with a matrix chart summarising critical requirements and it ends with a list of concrete actions checklist. These different items included in the proposal originated from a meeting with both site materials coordinators, previously interviewed for the current state analysis. Hence, in that meeting current state analysis findings, together with literature best practices and proposed process chart for defining process data maturity communication and proposed responsibility sequence were discussed. As a consequence, a matrix chart was produced covering the main needs management of bulk materials required. This matrix is especially useful to understand the link between different departments; engineering disciplines, materials management, procurement and construction management. In addition, it summarises specific and critical actions to be implemented for a smooth materials management process.

Next, the process chart and the matrix chart were presented to a project manager, previously interviewed for the current state analysis, together with current state analysis results and literature review findings. In this presentation, the project manager suggested to modify the process chart by changing the condition wording. In particular, he recommended using the words process data maturity instead of P&ID design maturity.
In the first one, specifications are also included while in the later one only drawings are, accordingly the modification was implemented. Also, he questioned the placement of materials management function before procurement. However, after grounding the decision on the need to coordinate materials management needs from the start until the end for accurate planning purpose and focal point communication reasons; in essence, using materials management team as a general coordinator of materials, he agreed that it made sense.

After this, previously interviewed, project procurement manager and technical services purchasing manager were next to assess the content of the proposal based on current state analysis and literature review. Overall, they directed several positive comments at the outcome and brought few different points to be added. What is more, these points were directed to adding a checklist of critical actions to be defined as a complement to the process chart and the matrix chart. Consequently, this proposed actions checklist was added as a summary of the initial plan.

Finally, proposed bulk materials management plan checklist for the case company's co-owner's projects in Finland was discussed with the project manager and the technical services purchasing manager. From this workshop few wording changes were introduced for the shake of clarity, for example, instead of packing list in the last proposed action, shipping authorisation was used. Fortunately, overall attitude towards proposed charts and checklist was enthusiastic. The thesis was considered a valuable guide for future materials management function implementation.
Regarding IT solutions for materials management, examples given in literature were discussed briefly, and it was mentioned that quotations from mentioned suppliers will be requested.

5.2 Proposed materials management function process chart

Based on current state analysis findings together with the literature review, the conclusion pointed at the determination of maturity of the process data being the critical point. For that reason, the flowchart below would be the base for the bulk materials management process in case company's co-owner's projects in Finland. In addition, when the design is not mature enough but the decision is taken to go forward, the team would be aware of the details and possible risks to take into consideration. In other words, below chart would define the risk factor of the transition from basic engineering phase to execution engineering phase of the project.

In the figure below, blue squares represent: engineering department, materials management department, procurement department and construction management department. In this regard, materials management team would take over materials related responsibility once engineering team is developing basic engineering design. As a result, the materials management plan would be the output, used by procurement and construction management to produce their plan specifying their roles and responsibilities. Similarly, the materials management plan would outline the strategy to follow, by defining roles and responsibilities of materials management team in relation to bulk materials needs in the project at hand. Specially, important will be the materials management team coordination role, as it is proposed to be the focal point to give answer to all details regarding bulk materials. In other words, they would be the link between engineering, procurement and construction, watching over the overall bulk materials flow.

The reason to have materials management function right from the basic designing stage is that materials management specialists can assist on technical vendor evaluation to aid cost estimation and scheduling. In this way, they can collect all or most of the required information before forwarding details to purchasing. The materials management plan will contain required details concerning the project bulk materials. Moreover, if enquiries have to be made the assigned materials specialist will be the contact person to solve possible issues. In the same manner, he/she will be the responsible one to request information from engineering for example. In this approach risks can be seen at early stage and contained. Furthermore, when awarding contracts to contractors for execution phase they can assist procurement.

In Figure 11, materials management function is shown graphically together with other existing functions to define the communication flow process in relation to process data maturity level and proposed responsibilities sequence.

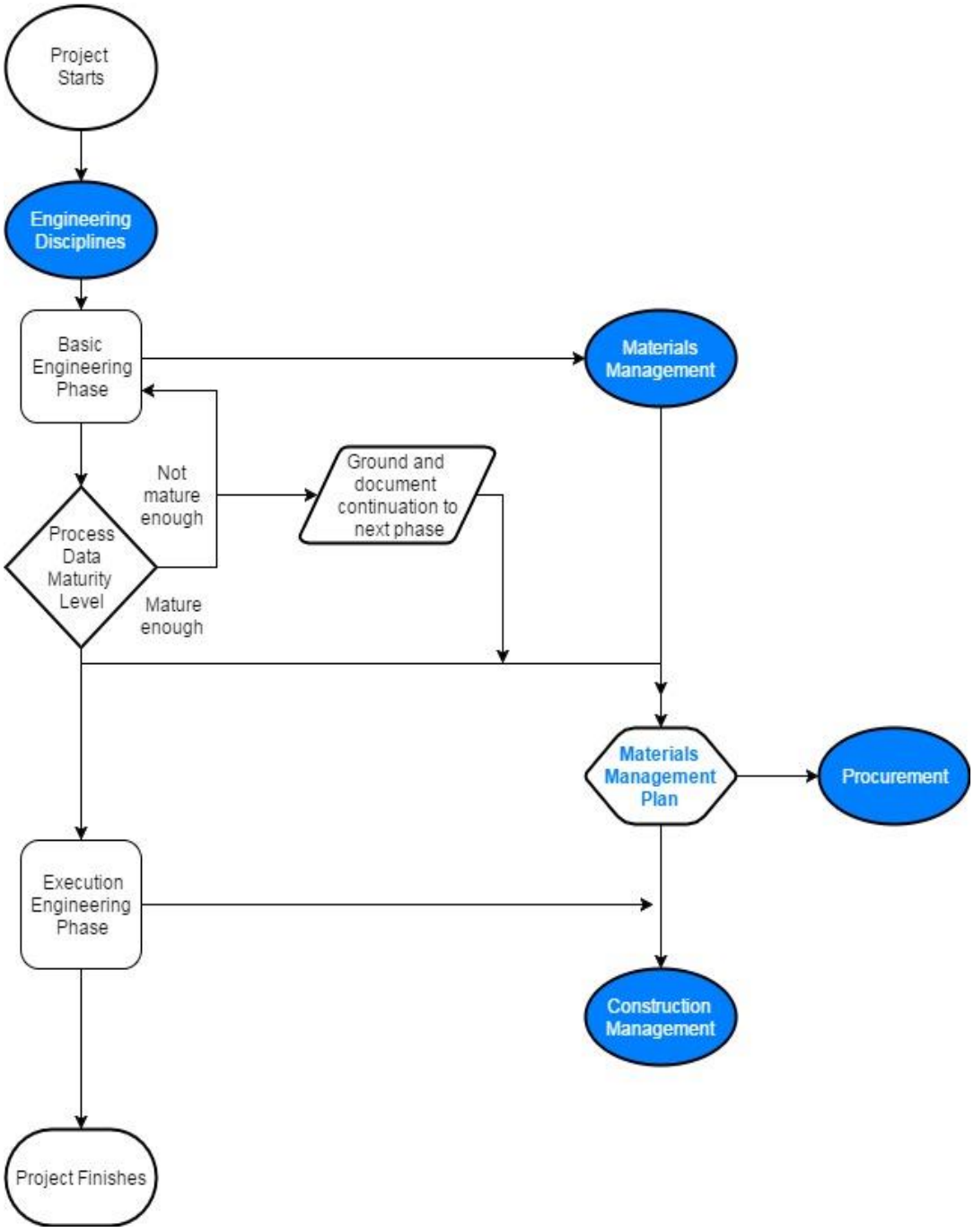

Figure 11: Flowchart for management function representation and design maturity level determination

5.3 Proposed project bulk materials management guide for the case company's co-owner in Finland

Project bulk materials management guide for the case company's co-owner in Finland could be used as a base to build on more detailed procedures. Hence, to give a general solution to the main issues, it seemed that creating a guide to aid bulk materials management flow from start of the project to construction could be the best idea. Furthermore, this guide was to produce recommendations on what needed to be agreed and discussed beforehand regarding project bulk material management in early stage of a case company's co-owner's project in Finland. Nevertheless, there was no information available on a possible implementation plan resulting from this report in the target organisation.

The steps that the materials management process should cover are explained next. First, materials management responsibilities would need to be outlined based on key requirements found in literature. Let me bring these back to the reader:

- "Materials-related requirements planning
- Project-acquisition strategies
- Purchasing and subcontracting activities
- Expediting activities
- Supplier-quality management
- Transportation and logistics activities
- Site-materials management
- Planning for operations and maintenance turnover" (Wyss 2016).

Incidentally, engineering, procurement and construction management representatives would be required to collaborate to define those. Then, in parallel, the selection of adequate software integrating materials management process would need to take place, as proposed by Stephen Wyss (2011). The reason it is suggested to happen in parallel, is that the software also dictates the working procedure, because of the opportunities and limitations it would offer. After, once materials management requirements and matching software are found and implemented, a materials management team can be created. Moreover, training and cross department communication could be enhanced following previously mentioned, process orientation steps by Kay Server (2007). Finally, a measurement system would need to be implemented to follow bulk materials

management efficiency, as a mean to identify possible bottleneck or constrain areas but also to avoid economic losses (Sjøbakk et al. 2015).

Next, in table 4, a matrix chart is used to explain graphically the main content of the proposed materials management process guide.

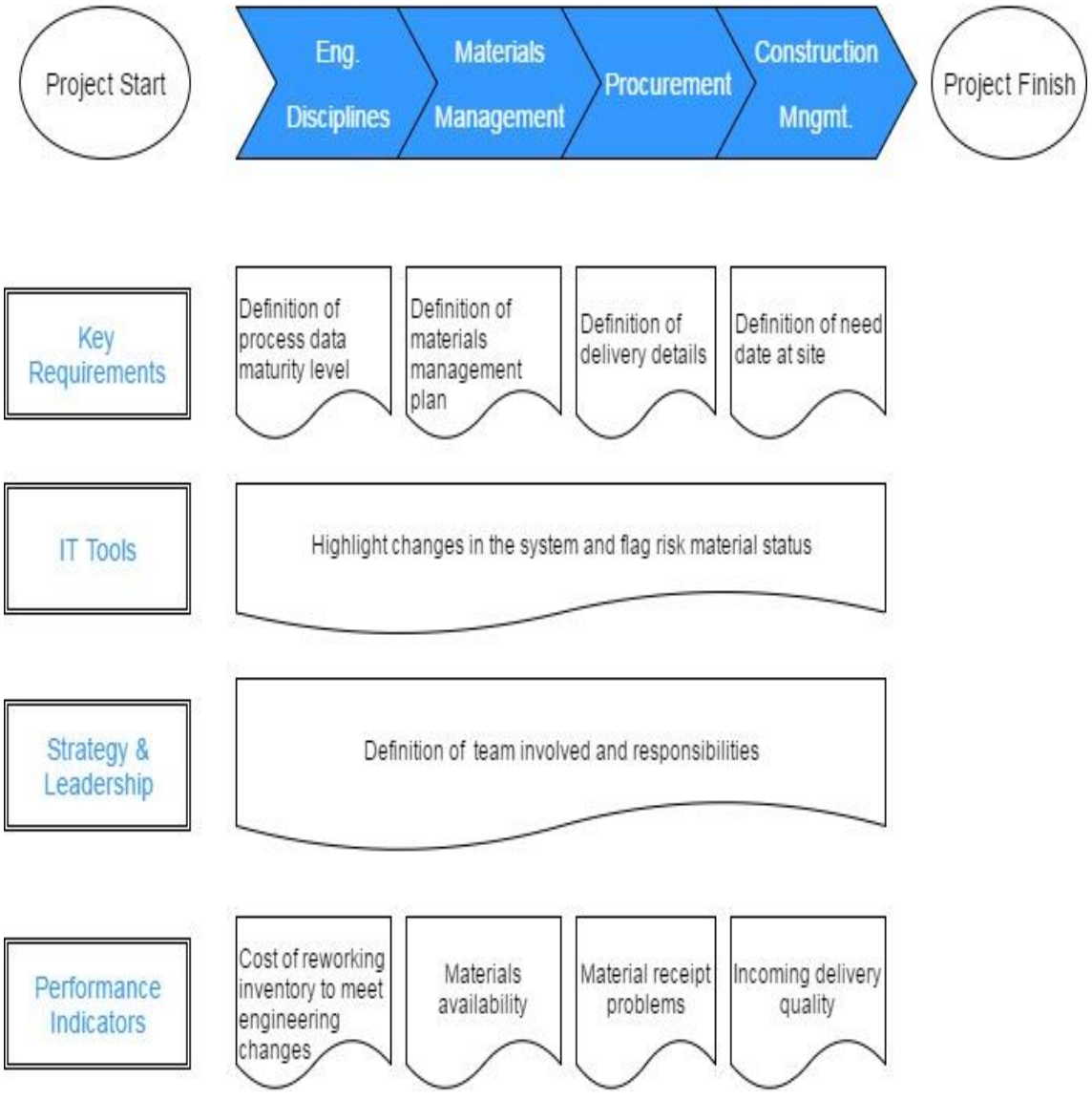

Table 4: Matrix chart for bulk materials management process guide for the case company's co-owner's projects in Finland

In above matrix chart, key requirements by department are outlined, which does not imply that these are the deliverables each department creates independently. On the contrary, materials management team would take responsibility to oversee the inputs and work together to fill as needed the materials management plan. In conclusion, materials management does not end at the point where procurement starts, but it coordinates what comes from engineering together with what comes from procurement and construction management regarding bulk materials for smooth flow of material management.

In the literature review a bit different selection of performance indicators were proposed compared to the ones in the matrix. However, for the shake of setting one indicator per discipline during the discussion with both material coordinators the ones in the matrix were decided as a base. Above all, these indicators would need to be reviewed further and probably more included once the materials management process is implemented. Therefore, the discrepancy is not to be taken too seriously.

In particular, regarding IT tools the biggest need is to have further customization of the ERP in use at the target organization. It was noted, especially by materials coordinators that changes in the system were not emphasized. For instance, when a need date was changed this was not displayed differently to draw attention. Consequently, it was left to materials coordinators to remember details of many projects running simultaneously or to manually record them. Even more challenging situations arose with materials status; this refers to additional orders due to design change for example. When a design change occurred project managers were sent an email by engineering regarding additional materials. In turns the project manager had to accept the suggestion for additional materials in order for these to be bought. Nevertheless, if the project manager did not notice this email materials would be left unbought. Obviously, the impact to the project execution could be major. Therefore, color code for need date changes would greatly help follow deliveries and notifications for additional materials would avoid delays on purchasing additional materials.

5.4 Summary on initial plan

Previously presented process and matrix charts give a general top layer solution to bulk materials management. Nevertheless, in the view of the project procurement manager and technical services purchasing manager involved with materials management development, there is still room for a lower level concrete action plan.
This action plan contains few steps for the materials management plan, which will in turns aid the materials management team and ultimately the project manager follow up the materials and consequently, the project. Thus, following steps are critical for each project to have as bulk materials management plan checklist for the case company's co-owner's projects in Finland:

- Asses process data maturity level.
- Assign materials management lead/coordinator.
- Define the system to be used to track purchase orders and update need date.
- Define change management strategy.
- Define construction sequences by area; also include them in the schedule.
- Include materials management responsible in contractor negotiations too.
- Have a planning session with contractor, client and project organisation
- Define storing, receiving and inspection responsibility and details.
- Co-create construction schedule together with contractors.
- Make the schedule available to materials management team.
- Define the policy on materials left-over.
- Get order confirmations from suppliers on bulk materials delivery date.
- Require shipping authorisation for all bulk material deliveries before delivery and made available to materials management responsible.

Because of the nature of the projects, it was not that easy to benchmark projects and create one size fits all solutions. Consequently, it is essential to have a team that has the skills to adapt. Especially important though is to document diligently all the decisions taken. Documenting decisions is rather important to understand the grounds and the risk. Above all, when time goes by and there is some error or change required this will prove valuable. Also, following a standard procedure in each project grants the opportunity to avoid forgetting a valuable step. Shortcuts and deviations should be avoided, and only used when proper grounding and documentation is in place. In short, strong management will be needed to enforce standardisation of processes to ensure quality of work according to site and project regulations.

6 Discussion and conclusions

6.1 Summary of Whole Project

This research was conducted in the target organisation to unveil the biggest issues regarding materials flow in projects arising from the closure of the site warehouse and the creation of IMS unit. Once biggest issues were analysed it was concluded that a new function and processes were needed. Therefore, a materials management guide for bulk materials was proposed.

Materials management responsibility was a new service for the target organisation and processes were under development. Moreover, it was not defined as an own function, parts were included in different disciplines. Those disciplines involved were engineering, procurement and construction. As a result, boundaries and responsibilities were not easy to define and follow up. In any case, even the parts included in different disciplines regarding materials management had to be modified. The inclusion of materials management responsibility in the target organisation it was more than just a switch from existing model to a similar one. The new model had a different concept and employed many new people. Above all, the new model impacted all disciplines at some level. This impact was related to having designed projects in certain way for many years to fit the materials flow in place. And suddenly, a new materials management function is placed and there is no assessment of the impact shared neither with project managers nor with the rest of the parties affected. In addition, certain level of frustration was described by interviewed personnel but also a remarkable willingness to achieve project goals despite of the troubles presented by the materials.

In the same way, materials management responsibilities differ from industry to industry and even from company to company. For that reason, it was challenging to find relevant literature on similar cases written in the last 10 years. The market integrating different software solutions has changed materials management requirements in the last years. Often, the software implemented defines the process and working procedures. Therefore, it is difficult to forecast the outcome of the proposed steps once they are implemented.

6.2 Practical Next Steps

The evidence in literature suggests that, creating a function for Materials Management would be the first step to gaining overall control and follow up of the materials flow (Vrat 2014). This would translate on creating a team of experts, involved in early stages of projects that would report to the project manager, but also to the Head of materials management.

It is apparent that those team members would need a wide knowledge of all processes and automation tools but without requiring specific specialisation in any (Wyss 2016). Moreover, their responsibility would fall into coordinating that each discipline delivers required data for bulk materials continuous follow up. Besides, materials management team would also facilitate planning of shipments and development of data in the materials-management system. Next, the purchasing process must be as simple as possible allowing lower internal lead time (Vrat 2014). In essence, a materials management plan would need to be defined at the beginning of the project, to address "pre-buy" needs, for minimising some of the risks involved when designs are not mature enough but bulk materials need to be ordered (Wyss 2011). The strategy basis of making those decisions would need to be explained in the plan by the project manager.

In addition, it would be beneficial for the project scheduler to organise together with construction lead and engineering lead a meeting early enough to define construction sequences, by area, that match with the engineering departments' skills to mature the design in a manner supporting planned construction sequence (Wyss 2011). As a result, allowing better process for specifying need dates of materials on site according to their specific scope.

While talking about the materials management system, it may be required a deeper training on ERP usage to those that actively would be in charge of updating the materials management system to enforce a unique standardised materials planning process ensuring the correctness of data (Jonsson 2008). The literature on material management systems indicate that, having the target organisation's materials management system linked to IMS materials management system would be beneficial to have more open and accurate communication in real time (Wyss 2009). The data that should be available in the ERP for project materials management team should include: integrated "design with requirements, component attributes, requisitions, need dates, purchases

and material statuses” (Wyss 2011). Accordingly, helping project managers building the strategy with “pre buys” previously mentioned. In theory enterprise level integration of systems modules is possible, therefore developing ERP for materials management purpose module should be possible (Wang et al. 2013). Likewise, building a link to IMS ERP module would be easy, which in turns would aid in stock visibility of bulk materials. However, it is possible to work around not having stock visibility by requiring vendors, and in particular IMS, to send confirmations of bulk materials deliveries. In this way, need date of these materials could be kept accurately updated in the system. Moreover, the system should include some colour attribute to highlight critical dates for constructability. Similarly, additional bulk materials orders, usually related to design changes, should be recognisable by some notification.

Generally, “logistics planning, source selection, storage and warehousing choice of transport mode, etc., will have impact on handling costs" (Vrat 2014). Therefore, these have to be defined on the materials management plan also. Likewise, even if receiving inspection does not create value it creates costs, consequently designing an accurate inspection policy is a must. This would ideally include: an accurate design and a “selection of acceptance sampling plan” (Vrat 2014). From the interviews, it is apparent that the procedure for receiving and storage can be negotiated with the contractors. Thus, the terms of that negotiation have to be stated on the materials management plan. The roles and responsibilities have to be clearly defined from the start when the contracts are awarded, and it seems of advantage to have the materials management team involved in those. Also, despite deliveries from IMS happening sometimes randomly, shipping authorisations have to be sent in advance. There are procedures that other vendors have to follow. However, it appears that those are not followed by IMS systematically. Consequently, it would help materials management team if delivery procedures would also apply to IMS.

The evidence in literature suggests that, when introducing a new working way, which may also alter existing working culture, face to face workshops together with flowcharts approach may best suited to convey the intended message across (Server 2007). After all, the goal is to create a materials management team that works synchronized and following unique standardised procedures. Furthermore, deviations have to be recorded and strongly grounded as localised exceptions, and available to consult when in doubt.

In addition, it would seem that it would be beneficial to set up a performance measurement system to systematically monitor how well materials management is carried out. The target organisation could start evaluating those by linking them to the business processes, consequently discussing it with relevant responsible persons (Sjøbakk et al. 2015). In turns, it would feed valuable information to materials management team to be aware of the possible bottlenecks and areas of improvement. Finally, a very important aspect to bear in mind is that for any process to succeed strong top management support and budget limiting is needed (Vrat 2014).

After the warehouse closure and new unit creation, materials management development was launched via internal developments projects. These projects were aimed at defining the flow of materials, roles and responsibilities and the best IT solutions to support the functions. However, the progress appeared to go rather slow leading to frustration among some of the most affected parties. On one hand, designated people were overloaded with manual tasks trying to deal with ongoing projects and not prioritizing materials management requirements. On the other hand, strong leadership may have not being in place. It seemed that there was no real consequence for missing deadlines. It looked like objectives were simply postponed to a later date.

In summary, based on observation and interviews, it is apparent that clear direction was not set. Moreover, there seem to be a delay on specifying objectives and having a team committed to producing results within a deadline. It might be that the target organisation has skipped few important steps on change management; by going from one way of working to another one too quickly without in depth analysis of the implications or the risks to relevant stakeholders. Fortunately, after the workshops kept for co-creating proposed guide a sense of urgency and wish for implementing the content was raised. With that in mind, the thesis owner hopes that proposed steps will be added to the decisions for the future project materials management responsibilities adopted by the target organisation.

6.3 Thesis evaluation

6.3.1 Trustworthiness of the study

The four criteria on trustworthiness of qualitative research according to Shenton (2004) are applied here:

Credibility, transferability, dependability and confirmability.

Credibility

Credibility refers to the degree to which the findings of the qualitative research bring significance.

Measures of credibility	**Applicability in this research**
Adoption of appropriate, well recognised re-search methods	Qualitative research method applied in the form of informal interviews.
Development of early familiarity with culture of participating organizations	The researcher and the interviewees were all employed by the case organization. Based on this, all the stakeholders within this study are familiar with the organisational culture of case organization.
Random sampling of individuals serving as in-formants	Not applied. In contrary, targeted interviews conducted to ensure that the interviewees have the best possible knowledge in the field.
Triangulation via use of different methods, differ-ent types of informants and different sites	Interview data used. Informants only from a sin-gle site on the case organization representing relatively homogeneous group.
Tactics to help ensure honesty in in-formants	During open interviews questions reformulated and asked again if any doubt of untruthfulness was suspected.
Iterative questioning in data collection dialogues	The flexible nature of open interview was utilized in an iterative manner depending on the eager-ness of the interviewee to respond to questions arising from the interview.
Negative case analysis	Not applied.
Debriefing sessions between re-searcher and superiors	Face-to-face sessions attended with the thesis supervisor.
Peer scrutiny of project	The thesis reviewed by the company representa-tive before the final release. No comments were received
Use of “reflective commentary”	Not applied.
Description of background, qualifications and experience of the researcher	Not applied.
Member checks of data collected and interpreta-tions/theories formed	The results and the synthesis of the current state analysis were provided to all key informants before the proposal building phase.

Thick description[3] of phenomenon under scrutiny	Provided in the sections 1.2, 1.3 and in the literature review chapter of this thesis.
Examination of previous research to frame findings	A review of existing models conducted and documented in the literature review chapter of this thesis.

Transferability

Transferability it is assured by describing thoroughly how the data collection has taken place.

Measures of transferability	Applicability in this research
The number of organizations taking part in the study and where they are based	Single organization participating in to the study. Organization located in Finland.
Any restrictions in the type of people who contributed data	The data was collected solely from the persons working in the case organization.
The number of participants involved in the fieldwork	10 interviewees in the theme interviews 4 interviewees in the process model proposal review sessions
The data collection methods that were employed	Informal interviews, workshop discussions and written feedback requests.
The number and length of the data collection sessions	10 interviews, about 30-60s minute each. 4 proposal creation interviews, about 30-60 minutes each
The time period over which the data was collected	January-March 2017 (theme interviews) April–May 2017 (feedback interviews)

Dependability

Dependability in the qualitative study entails the reliability, consistency and accurateness of the study.

Measures of dependability	Applicability in this research
The research design and its implementation, describing what was planned and executed on a strategic level	Description can be found in the section 2.1 Research design.
The operational detail of data gathering, addressing the minutiae of what was done in the field	The data gathering practices are described in the section 2.2 Data collection plan and those practices were followed in practice.

Confirmability

Confirmability in the qualitative research refers to the objectivity of the researcher and assurance that the findings originate from the informants only.

Measure of confirmability	Applicability in this research
Triangulation to reduce the effect of investigator bias	Interviews and feedback session were used as a method to confirm the perceptions receive from different data sources.
Admission of researcher's beliefs and assumptions	Discussed in the section 6.3.2. Reflection and Afterword
Recognition of shortcomings in study's methods and their potential effects In-depth methodological description to allow integrity of research results to be scrutinized	Discussed in the section 6.3.2. Reflection and Afterword. Description of research method, conceptual model and data analysis method described in the section 2.1 Research design.

Based on the assessment performed for the trustworthiness of this study, the conclusion is that majority of the items outlined by Shenton (2004) are realised on adequate level in this study. Thus, it can be concluded that the study has reached a satisfactory level of trustworthiness.

6.3.2 Reflection & Afterword

The study owner started the thesis looking forwards to being part of a development project team for materials management. It was a topic given by the target organisation that the thesis owner had no prior knowledge about. However it sounded interesting and seemed as an opportunity to help the target organisation with a new business and add competences on the way.

However, language barriers seem to be an issue for personal participation on project meetings or activities related to materials management development, near native Finnish seemed to be the only one accepted. In addition, some opposition to materials management function could be perceived, in other words, not everyone working in projects was informed about the future impact and the present impact was not too positive for all. Besides, a well-defined strategy for the study was not set from the beginning; it was left to the thesis owner to come up with the frame and scope. For that reason, she took the approach of starting interviewing relevant personnel in order to define the scope.
Hence, a lot of time went into academic reading to try to tackle the issues identified over the interviews on the target organisation personnel. As a result, the conclusion came to be that it was too difficult to provide proposals with solutions to each issue. Because, each issue could be a hole research on itself. Thus, the focus was adjusted to look for an overall solution as a mean to tackle these. Hence, setting the scope took a bit longer than expected. Otherwise, it was a good opportunity to get familiar with different topics related to materials management. Based on the literature, it could be determined that the target organisation's bulk materials management needs differed from commonly studied manufacturing and warehousing services or other similar contractors.

It would have helped to have a clearly defined materials management process running and seek to improve certain area or application. In the current situation, it was rather challenging to provide a guide, as it was quite abstract the concept for an outsider. Also, proposed best practices would require further follow up and even adjustments in the future once were put into practice. Unfortunately, there was no room for personal participation on the implementation and it was not known the implementation date. Naturally, at the start of this study it was not known to the thesis owner the status of materials management in the target organisation and the limitations ahead.

Summarising, proposed guide is a good base for materials management process mapping and team creation. The fact that the thesis owner worked in parallel to similar targets' company development team had also brought new ideas. Personally, she got to familiarise with different concepts from change management, to process creation, and lean theories for avoiding waste in processes. Also, different materials management software solutions were studied. If those were not included in this research was because they went into a different scope. In particular, the aim was to highlight the basic needs, and get to implement them before going into details. Often, when too many details and options are on offer decisions to choose the required ones are delayed.

As a result of the current state analysis, many hidden issues are described. These issues are significant for the target organisation because they provide an insight from different angles on the issues that other disciplines perceive. What is more is not often that a document contains different views summarised together. There is limited time for discussing developing ideas on project materials management so it is more natural to keep those between peers. Overall, proposed guide highlights important points to work on and solutions to aid better follow up of costs in target organisation's co-owner's projects.

For further research are left possible issues arising from implementing proposed solutions. Although, it would be interesting to follow the process of creating a new function and seeing to a new team developing improved materials management flow. Equally interesting would be to see if a new IT solution for materials management can support target company's projects in a more suitable manner and what complications and further possibilities could bring.

References

- The Construction Industry Institute (1998). *Project Materials Management Primer* [Online]. Available from: http://www.ce.berkeley.edu/~tommelein/CE267FS05/MMPrimer.pdf [Accessed 21 April 2017].

- Arnold T., Chapman S. and Clive L. (2012). *Introduction to Materials Management*. 7th Edn. Upper Saddle River: Pearson Prentice Hall, pp 1-14.

- Baron H. (2015). *The Oil & Gas Engineering Guide*. 2nd Edn. Editions Technip, pp 205-245.

- Wyss S. (2016). Materials Management - Evolving the Process for an Evolving Marketplace. *Chemical Engineering* [Online], March, pp 68-74. Available from: http://www.chemengonline.com/materials-management-evolving-process-evolving-marketplace/ [Accessed 18 March 2017].

- Wyss S. (2011). Piping: Minimizing the Risk of 'Pre-buys'. *Chemical Engineering* [Online], November, pp 46-49. Available from: http://www.chemengonline.com/piping-minimizing-the-risk-of-pre-buys/ [Accessed 21 March 2017].

- Vrat P. (2014). *Materials Management An Integrated Systems Approach.* Springer: Springer India, pp 1-18.

- Wänström C. and Jonsson P. (2006). The impact of engineering changes on materials planning. *Journal of Manufacturing Technology Management,* 17(5), pp 561-584.

- Kärkäinen M., Ala-Risku T., Främling K., Collin J. and Holmström J. (2010). Implementing inventory transparency to temporary storage locations A solution design experiment in project business. *International Journal of Managing Projects in Business,* 3 (2), pp. 292-306.

- Jonsson P. (2008). Exploring problems related to the materials planning user environment. *International Journal of Production Economics*, May, 113 (1), pp 383-400.

- Wyss S. (2009). Active Management of Pipespool Fabricators. Chemical Engineering [Online], January, pp 40-45.
  Available from: http://www.chemengonline.com/active-management-of-pipespool-fabricators/
  [Accessed 23 March 2017].

- Hong W., Zhou J., Ji X. and Tang H. (2013). Research and Development on Materials Management System of Foundry ERP. *Applied Mechanics and Materials,* August, 364, pp. 859-863.

- Integraph Corporation (2012). Effective Materials Management.
  https://www.intergraph.com/assets/global/documents/SPMAT_EffectiveMaterialsManagement_WhitePaper.pdf
  [Accessed 23 March 2017].

- AVEVA Group plc. AVEVA MATERIAL™
  http://www.aveva.com/en/Solutions/Product_Finder/AVEVA_Material/
  [Accessed 23 March 2017].

- Server K. (2007). The Power of Process Orientation.
  Quality Progress, 40 (1), pp. 46-52.

- Kotter J.(2013). Leading Change.
  Leadership Excellence Essentials, Feb, 30(2), 6.

- Reardon K.(2007). Courage as a skill.
  Harvard Business Review, January, 85 (1), pp.58-64.

- Sjøbakk B., Bakås O., Bondarenko O. and Kamran T. (2015). Designing a performance measurement system to support materials management in engineer-to-order: a case study. *Adv. Manuf.*, 3, pp. 111-122.

- Shenton, A. K., 2004: Strategies for ensuring trustworthiness in qualitative research projects. Education for Information, 22, pp. 63-75.

Research Interviews for current state analysis

Interview 1: Site material coordinator, 26.01.17, 1h.

Working with various Finland related projects as a material coordinator taking care of the contractor interaction. At the beginning of the materials handling change, this function was under procurement department but later it was added to construction management department. The purpose was to make it a link between the site and procurement. Which in practice meant, assure communication flow between, contractors, site supervisors and procurement, especially due to the change on material handling practices. The material handling change was communicated within procurement but not enough to project managers and neither to contractors. Cooperation with contractors and projects was not good enough; negotiations did not happened in planning phase of a project.

As a material coordinator, she also supported IMS department, communicating the contractors when the materials were arriving. She worked on the project material need. Otherwise, generally resembling what expediters do but for bulk materials. Generally, lead engineers created purchase requisitions, then, procurement created and expedited the orders, and IMS unit delivered ordered bulk materials. However, communication and follow up was not dynamic. For instance, when needed material was not in the field; the process of looking into who had not done his/her part started until the issue was fixed. These items that were purchased by the customer were then expedited by the target organisation's procurement and material coordinators had to make sure about the receiving process at the site. Besides, suppliers were responsible for delivering the materials, but material coordinators had to make sure those were according to the needs requested. Moreover, deliveries were late in many cases due to lack of communication and instructions were not up to date, on how the material process should happen.

Incidentally, internal development project was launched for creating instructions and updating existing ones. In contrast, procurement process was well defined but what happened before and after lacked enough planning.

Overall, the biggest part of her day went into problem solving, starting with informing the warehouse what to deliver and where to deliver it. After, following up on bulk material status, there were no reporting systems in place so, it was performed manually. Furthermore, orders were not always linked to specific project, so it was not that easy to track whether they were arriving by the need date or they were late. In addition, if project's need date was urgent even if it was not part of the initial order; it could take the materials reserved for another project.

Next, approving orders and doing the receiving inspection was also part of her duties, so when orders went straight to contractors, contractors had to inform her about the received goods, consequently, she could go or send someone to perform the receiving inspection. However, this was not so straight forward. When the goods were shipped to the warehouse in Kotka, everything was handled locally by the outsourced logistic team. By contrast, inspections carried out at subcontractor's premises did not have a standard procedure; in essence, it depended on the material coordinator's skills and knowledge. There were quite outdated and vague procedures on how bulk material was handled and inserted in the system before the change happened. In other words, people working in the old warehouse knew their duties and shared knowledge among their team members, but they all left when the new system was implemented.

On one hand, material needs came automatically from engineering to the system, but on the other hand registration of receiving and handover were done manually. There were two systems in use, one for company level and another one for IMS unit, but they did not communicate; accordingly, information had to be typed in twice, based on excel sheets. Unfortunately, those two systems did not have same fields; import/export functions could not be used. As a result, the systems did not print out report straight, those reports had to be created in excels with macros. Generally, daily meetings were scheduled with the warehouse in Kotka to make sure that confirmed orders were being delivered. The reason was that there seemed to be difficulties to deliver what it was confirmed too. Specifically, the system at IMS unit did not support multiple picking lists at once, as they had to make sure about the balance status of the material.

In addition, quality requirement was another aspect that made the process difficult; the trust level on materials delivered matching requirements was sometimes questioned. In other words, until what extent could be trusted that the materials delivered were correct

based on accompanying material certificates. In any case, those doubts applied only to those materials being shipped from the warehouse in Kotka to the site. Particularly, in relation to the H number in the bulk materials, this was a mandatory identification number. Also contractors had to mark were they had use it, as it gave important information on the type of pipe and location for safety reasons.

Unfortunately, training plans did not exist in the near future, leading to occasional mistakes happening in different places of the process. All those working did not necessarily know their duties fully. Because many people worked in projects it was not always clear who the site manager was to be able to do early planning for the materials. Furthermore, there were no requirements to whether a material coordinator was needed on projects.

In short, decisions in developing and clearing out roles were progressing too slowly.
As a result, Project Managers did not have overall overview, because they did not have access to both systems. Therefore, material coordinators were providing most of the information on demand basis.

Interview 2: Project Procurement Manager, 26.1.17, 1h.

First, internal development project was lunched to define the overall materials management function at the target organisation. The template for materials management plan was hoped to be more detailed. Accordingly, process diagrams to map the intended processes were to be created and based on those the template details could be defined. The project material management plan was hoped to include those tasks that had to be thought and planned for the materials required in the project to arrive correctly. In short, a checklist detailing the different steps materials required following the materials management process.

Material management process had to be described on the template by assigning tasks. For example, when the first revision of P&ID was done how materials needs appeared for instruments and equipment, so the scope was managed correctly from the beginning.

The material management plan was thought to start when engineering defined their needs as material take overs (MTOs) or material lists, continuing with whether they were installed at the site or handovered to the contractor, obviously taking into account which materials were included in the contracts. These MTOs had to be translated into a system where procurement could purchase those items included. In other words, engineering specified needs suiting their designs, after, those lists were adapted for procurement, in order to be used in a form for purchasing. However, the process to define the materials flow was still in planning phase. In this point, parts related to material management in a project were described vaguely in the in engineering plan, in the procurement plan and in the construction plan. Therefore, the intention was to remove it from those different plans and have it all exclusively in the project material management plan with greater detail.

In addition, some of the procedures and work instructions available regarding procurement of materials were in the process to be removed or updated.
Existing process diagrams were being replaced by a new tool called QPR, where new processes were going to be described and old ones updated.
Warehouse service had changed; therefore, those procedures related to the new service were underdevelopment. In essence, material flow happened in the following way; material need came from engineering design, procurement did the supplying based on the need and construction performed installations from those materials. Subsequently, material management was wished to be the process linking these three.
On one hand, in the need side there was engineering plan to issue material requisitions, MTOs...etc.; next, the procurement plan defined what to do with the input from engineering, such us, send quotes, purchase and delivery coordination; and on the other hand, the construction plan managed the installations of those materials coming from procurement. But there were no links defined between those plans, each one took care of the specifications included in own plan. Meaning, each department fulfilled the set of requirements, but there was no overall view of the process as a whole.

For example, how materials were handed over to constructions, after delivery was not specified anywhere. In particular, scaling the process outside of Finland proved problematic. The reason behind it was that the old site warehouse was used as a focal point for all local projects and workers running it and contractors working with it were very familiar with the work principle and materials, this combination made the material man-

agement manageable in Finland. In addition, materials were handled by engineering disciplines, never by projects. However, this in practice meant that the project overview of the materials did not exist.

According to the interviewee, EPCM contractors only manage tasks at engineering, procurement and construction level, they do not engage in ”real work” regarding materials. It seems that, usually warehouse service is subcontracted or hired by the client. Based on the previous, the EPCM contractor’s role is to supervise that the hired subcontractor is managing the materials flow correctly. Although, this EPCM way seemed to be the regular way in the interviewees’ words, by contrast, the target organisation included warehouse responsibility in projects carried out in Finland. As a result, problems aroused for not having a process defining this different way of working. Moreover, with the new way, the mechanical contractor at site would the one managing the materials, with temporary warehouse and temporary workers. In the old way, there was a permanent warehouse with permanent workers supplying all the needs. For instance, the interviewee mentioned that the subcontractor handling the IMS warehouse does not seemed to be a project management specialist. Furthermore, they appeared to do operative logistics work, consequently, management would ideally come from the company. However, facts seemed to point to the target organisation outsourcing both management and hands on job to the subcontractor in IMS warehouse, which was starting to become a problem for both parties. One lacked the training and the other one was not getting the results it is aimed at.

The interviewee believed that the subcontractor had logistic operators trained to manage materials at the warehouse, but the information had to be either sent in a way they could process it or they had to be trained more to understand and handle the technical sheets the company sent. Furthermore, the processes were still highly manual in every step of the way. In principle, other materials than bulk were supposed to go to the site too, where the project happened or at subcontractor’s in charge of the installation premises, but this was a grey area at that time, as there were no standard procedures. In any case, no matter who the party receiving the materials was, the target organisation had the responsibility for the receiving and inspection of materials. The interviewee indicated that a better process would have to be developed in the future. As, the existing one did not work well enough always.

In essence, the material management function was hoped to take full responsibility of materials after receiving the order confirmation from the vendor. First, expediting together with vendor document control carried out the delivery control process. After, when the delivery was ready the vendor asked shipping permit, expediter agreed about it with the site material coordinator and handed over the order to the site material coordinator. Finally, the site material coordination gave the shipping authorization for the materials. Following with the site material control seeing that the materials were delivered to the construction or prefabrication site. However, it was not yet decided whether material management function was required or was it enough with defining a process with different functions supporting it.

Interview 3: Supply Chain Manager, IMS Unit, 30.01.17, 50 min.

According to supply chain manager these are the elements needed in bulk material management process: firstly, clearly defined materials, secondly a warehouse (stock) and thirdly stock location. Those should be parameters in a system. Data is feed to an ERP system and the need comes as an impulse. The impulse must lead to a purchase order. When that is translated into a delivery then receiving appears. Which leads to the material received being a balance, in stock, in stock location, in other words, a well-defined material representing numbers and value. In IMS unit some of the above described process did exist, but in the target organisation was mostly missing. Which was under development by an internal project.

Inside warehouse management there were few functions about material needs, resulting in picking and delivery. Delivery could happen in different ways, such as; a sales order, hand over authorization or a work take. The hand over authorization was a kind of work take without the work take information.
When material was delivered the balance should show the decrease of the amount delivered. The interviewee defined and sketched the material management as a pool of water, where you had a reservoir, which had a water level, where water came in by a pipe and went out by another pipe. Having measurements and valves to control the balance. Being the need the feedback. That is, the incoming material by purchase order, it can be induced by stock level, once buffer levels are defined, therefore, when those decrease, automatically an impulse is sent to procurement department for an

order to be placed. On the other hand, outgoing materials cannot be influenced; projects, clients, etc. take out what they need, otherwise it would become a bottle neck. So, incoming materials and buffer levels in stock are the only tasks that can be controlled. Picking and delivery can be foreseen in short time, meaning under a week, but for longer time is a mystery what will go out. The reasons behind being so difficult to know about materials, is that projects can be delayed, they can be speeded up, projects can be cancelled, scope of the project can change, etc. The only way to handle the mystery is with the buffer level in stock. For incoming purchase orders, one indicator is the buffer level and another one is the need.

Even if the material needs were coming from different projects, IMS unit was a cross dealer, their organisation did not work in project way. Thus, there were no material reservations for a certain project. Shorting out the materials happened via sales orders. This was highly discussed as projects were promised own warehouse but the system in place at IMS did not support it. It seemed that IMS unit and the projects at the target organisation had different ways of working. In the first vendor like mind set was in place and in the second materials reserved on project basis was in place. At the start, the main concern was the receiving of material. The reason for this was that for four months materials had been arriving at IMS warehouse and were kept lying on the floor. There was no one responsible to do anything with them. Shorting this out was the first priority of the interviewee. Next, it was to look at the materials arriving whether they were all that were ordered. In short, check that all the items existed in the ERP system and no forgotten orders were left behind. This rechecking was due to suspicion on data correctness in the ERP system. In the end, a new inventory was made and corrected the ERP system accordingly.

After, purchasing process was analysed. The aim was to have purchase proposals handled, if not daily several times a week, to make sure everything needed was purchased, there were cases where materials were forgotten to be purchased. Then, material delivery process had to be developed, so that materials were delivered at the right time, in right quantity and to the correct place. This still is struggle, the process has improved but still more needs to be done. After that, buffer level and feedback had to be defined. Stock of different materials were created, buffer levels defined and feedback added to give impulse if the levels were going down. And finally, a new inventory was created, all materials in stock had to be counted and inputted in the system.

At the time of this interview, the problem was the outgoing of materials; those materials delivered were late and some errors occurred. But continuous development was made to improve the level. The reason for the challenging start of the IMS unit was the existing different ERP systems that did not communicate. All the work to bypass that was manual; also the content of those systems was not identical. This created the basis for many errors to occur in the process. If the typing and details were not carefully checked bugs would corrupt the data when copying it from one system to another.
So, since the import export excel option could not be trusted, it was done manually and errors did happen. People were hired for this purpose only.

It is not known why a link did not exist between different ERP systems used in the the target organisation. But maybe it followed the principle of considering a regular vendor.
At that moment, the alternatives pointed at; either building a link between ERP systems, continuing with the manual way of working or removing one of the ERP systems. The items in the databases of both ERP systems were not always identical; therefore, problems could arise with the purchasing process. Manual check had to be carried out to spot those discrepancies. Besides, all the receiving and updating of the delivery dates were not accurately inputted to the ERP, but still, it did not seem a big concern from IMS unit perspective as it happened similarly elsewhere, this was not specific target organisation problem.

In receiving, the process was complicated and time consuming due to the fact that each components handled had to be hand marked with a permanent marker. The reason for this, was that there were welded to an oil pipe and each component welded to an oil pipe had to have a complete tracing. However, it was on discussion phase to have industrial markers; the identification of the materials had to be so strict that automatization was not that easy. In addition, valves were also time consuming part, when these arrived in the warehouse in Kotka, they had to be sent to be checked in the valve workshop in Kilpilahti before being dispatched back to the warehouse in Kotka. But, this function of valve checking was on short term plan to be implemented in Kotka.

When design changes occurred and materials needs had to be changed, the buffer was there to replace the materials. However, when the needed material was not common, like big diameter valve, then it became a problem. Lastly, materials return policy

was rather undefined. This meant that purchased but not used materials were project expenses. These materials could be grouped in those that were of common use and those that were rather specific. Moreover, the distinction is made because common used materials would be bought back by IMS, as addition to their buffer stock level. By contrast, specific materials could be of no interest to IMS because of the difficulty to reuse them in future projects. As example, in a big project recently made in Porvoo all materials were returned. But this was more like an exception. Small bulk material was taken back, because it was easy to sell it back.

Summarising, delivery of materials was the biggest issue, together with the need date coming quite late. A forecast of those needs could improve the planning. The IMS concept could be copied anywhere; it was scalable if the ERP system could be more open.

Interview 4: PM&PC of a big project in Porvoo, 6.2.17, 1h.

At the end of basic engineering each engineering discipline created their material needs as materials take offs (MTOs) and those were used for cost estimation and budgeting. In addition, purchase requisitions were inputted in the ERP system. These were lists of equipment that had long lead time and had to be inquired in advance to avoid threats in execution phase.
Preliminary reservations were made in ERP of the bulk materials, as to have ready starting material for construction in execution phase. Initially before having the drawings approved for construction (AFC), some bulk material was already ordered based on previous revision (AFD), it was not possible to wait until the last revision was made to order all the materials, as it would have caused a big schedule impact. So, when the last modification to the order was made, the system was balancing these materials already ordered from those to order. However, this balancing of materials stopped working when the new system started to be implemented.

The change in material handling happened in the middle of the process of procurement of bulk materials in the project, consequently creating problems. First, there was no information on the impact of the change in the project, there was no knowledge distributed about what functions will be changed and how. Furthermore, it was communicated that only the price of the materials were changing. Second, the structure to support the

new system, the investment material system (IMS), was set up, but not taking into account the process from the project side. In effect, it was a new unit operating its own interests. Thus, engineering disciplines did not have anything communicated to them about how their way of working had to adjust. Third, the warehouse process and location change slowed down the orders handling process, as also, new people were hired to the new location. These newly hired were not familiar with the procedures and materials handled, and trainings were not sufficiently arranged. Under these circumstances, some orders were not delivered, others were not created and others were created multiple times. As a result of that, even though initially it was planned to have one material coordinator assigned to the project, another one was hired, to cope with the additional hassle. Moreover, both materials coordinators worked fulltime and even extra to keep track of the materials and make sure everything was ordered and delivered accordingly. At the time of the interview, the costs of the materials of the project were to be clarified, it seemed that the different ERP systems used for the material handling, were giving different costs. Hence, it was not clear which were committed costs and which were actual costs. Obviously, impacting the forecasting of the project greatly.

Another key point was that costs of the contractors were also impacted. Materials delays and/or mistakes created higher downtown time than anticipated; nevertheless the schedule had to be kept. As a result, extra work had to be performed in overtime manner. The project team did not have neither visibility nor enough information to see when materials would be delivered, which materials and what the capacity of the materials in the warehouse was. Earlier system allowed them to see the balance of materials and pick them or order them accordingly. There were cases, when materials were promised certain delivery time, but even when these were not fulfilled, explanations did not come. Project team had to inquire about when they could expect their delivery. There were some examples were upon asking it was found out that the trucks with these materials were sent to another site, or contractors' warehouse or just wrong address.
Although, the project did not have own warehouse at site, it was left to the project the responsibility of receiving and storing the materials at site. Finally, left over materials had to be handled upon completion of the project.

Interview 5: Technical Services Purchasing Manager, 15.02.2017, 40min.

The spotlight was on lack of understanding on information sharing between the departments. There was not an existing tool/system shared that integrated all departments. Discussions on material handling were carried out, nevertheless, decisions were delayed. Resources were scarce, therefore, some planning was required in order to have the best for the job available or have time to train someone for the project at hand. For instance, a piping lead engineer could have raised the alarm on not having certain specification for a certain design system. Then, that was created and piping design started, however, when it came to buying some material related to the design, the information of the specification was not shared with procurement.

Inserting details of new specifications in the ERP system required time and skills, consequently when this was not part of the plan, it was not either taken into account on the schedule, so there were grounds for a potential delay. Therefore, before purchasing they had to already be in the system. The materials from 3D modelling design, meaning piping material, came straight to the ERP system as a list of materials to be purchased; other disciplines logged their needs filling a form in the system.
In procurement the prices and lead times of the bulk materials commonly used in Finland existed in the system, based on frame agreements mostly. It seemed that in procurement the biggest challenge was to have the correct need date in the system. Which it was required for purchasing the materials at the right time to avoid downtime or logistic problems. Often, the bulk material buyers did not have the schedule; it was not shared with them. They did not know when the materials needed would be at site.

Interview 6: Quality Engineer; Lessons learned, 15.02.2017, 1h.

The customer requirements in Singapore, Rotterdam and Finland projects were different, therefore, they used also different software tools. There was a lessons learned procedure of things that went wrong in Rotterdam projects, and some of these had been implemented in Singapore as best practices. However, in Singapore projects, it was decided that the customer would handle most of the material needs by themselves, so not all the corrective actions would be needed in the near future. For in-

stance, it was seeing that piping components should not be purchased by material requisitions, but with ERP system by applying frame agreements.

In piping engineering, there were many errors in tag codes of piping components due to non-automatic transfer of MTOs from the designing tool (PDS) to the ERP system. Manual work had potential for human errors, especially with long lists of items. Also, there were some errors in the PDS database itself, causing piping specification update errors. PDS is an engineering design application, used especially for piping design. When changes happened in the piping design not everything was updated in the piping and instrumentations diagrams (P&IDs) automatically. It was not always known the mismatches, specially which one was the right version. Bulk way of ordering piping material was preferred over ordering them via MR (material requisition). This way was based on frame agreements, the needs were logged in, which contained some margin. The piping material that was not used or needed could be returned anyway.

When talking about the warehouse and material management in Rotterdam projects, this was almost none existent. Main lessons learned where; the need of enough warehouse personnel. Paying special attention to material receptions and resourcing at contractors' premises. Also, an inventory system should have been kept with at least certain codes, such us; product locating, status, owner, delivery addresses and dates…etc. As a consequence, it was seen as a must to create a material management plan in advance for handling site warehouses in the future.

About the schedule of materials, having these materials at the right time in the right place was of outmost importance. In many cases the customer did not deliver too accurate schedules, consequently projects had difficulties providing exact dates of arrival of material, dates kept changing, so it was difficult to define accurate dates. Good data in advance was required to have better planning in place. However, when there were turn-arounds involved, projects needs changed; some projects were done pre turn-around, some within and some postponed for later. In addition, defining which items could be kept in a warehouse and which delivered to the site could have been done before the materials arrived.

Too often, customer would not give enough data early enough, hence, decisions were postponed and defining need date of materials delayed. Thus, assumptions and

guesses were done and revised with the client as the projects progressed. This resulted in changes and continuous updates. Also, making procedural changes on the middle of ongoing projects did not yield the best results. Therefore, it was agreed for Singapore that those instructions existing at the beginning of the project and used at the kick off meeting, would not be revised unless there was a major change needed and top management together with customer agreed and approved it.

Lessons learned of known issues could be taken into account for future projects as a pre step when projects started. So the Project Manager could have an overview of existing issues, and shared it among the project team. By keeping an open communication loop issues could be spotted early enough and make updates and plans easier.

Interview 7: Project Control Group Manager 15.02.2017, 30min.

Material reservation template in ERP was used by each engineering discipline, to define bulk materials and contractors needed. And when were these needed.
Specifying this need date was difficult especially at the beginning of the project as the schedule was still not known. Other dates in the template were calculated automatically; based on the time that procurement needed to do negotiations, send bids out, biding time, etc. This template could be available for the planner, who used it to create the project schedule and compared the dates in the template with those in the schedule. Usually the need dates in the schedule did not match the template dates. The reason behind it was that the planners used the material need date with the earliest possible logic and the template showed the latest possible logic.

Engineers had an idea of when the construction would be done. Thus, they defined materials needs in the template by the latest in the field logic. Planners checked when the material could come earliest and defined it in the schedule accordingly. The reason behind it was that if the project was delayed, there was still some float. Quite often projects were late; therefore, the schedule could be considered the pushing tool. In addition, the pre-defined procurement time in the template, at times could be too long and other times too short. There were some general calculations behind these automatic dates, which were mean values. This created some discrepancies when materials needed shipping from overseas or just a truck from around the corner. Most of the time,

materials arrived in between these two logics, not as early as possible but not as late as possible either.

Older ways of working were based on projects being finished whenever they were finished. There was no real schedule to follow. As a consequence of the old ways, the function of the schedule was not widely understood or its usefulness as a project management tool too clearly seen. Often, some project managers did shortcuts in building the schedule, as to create something that passed the requirements to go forward to the next project phase. Unfortunately, it was not widely understood that the schedule was a tool to drive the project. This tool, could allow project managers to take ownership of the schedule and plan it together with the team. Then, material needs would be more highlighted and the project team more aware of the strategy to follow.

When it came to equipment and instruments, data was needed from other engineering disciplines, hence these materials had to be bought to finalise the designs. If the need date in the template was used, it could be too late for the design to be finalised. The template did not allow for this situation to be recorded. Which meant that the need date specified on the template correspondent exclusively to the date when materials were needed for the construction. Because of the limitations of the need date in the template, planners often only used the data regarding the materials but did not pay much attention to the need date the engineers have inputted. Obviously, it was good to compare the need dates so as to prevent errors, and have grounds for mismatches. Generally, schedules were updated for big projects on monthly bases, changes regarding materials, due to design for instance, were often translated into delays. Procurement time then would be updated accordingly. Updates to the schedule meant, the forecast of those activities happening would be changing as the project progressed. Nevertheless, the baseline agreed at the beginning of the project was always kept, unless client demanded a change. By contrast, the template in the ERP system, did not allow that many changes. The initial dates were planned dates kept through the project, regardless of the changes; the forecast column did not exist. Also, the template was more detailed in terms of materials than the schedule. Mostly big items, long lead items or those needed for design were defined. Unfortunately, remaining bulk materials did not appear detailed in the schedule; correspondingly, need dates were the best guess of the engineers.

In conclusion, having the schedule automatically linked to the ERP would be the best. Then, data could be extracted from the schedule about dates when things happen and imported to the ERP. By contrast, engineers could concentrate exclusively on making lists of materials and subcontractors without caring for need dates. Then, these would be handed over to project control to create the schedule, and after, discuss with the engineers the need dates.

Alternatively, bulk materials were handled a bit differently; usually, they were created via MTOs, and after the engineers would feed them to the ERP. In other words, purchasing happened via ERP system. Therefore, the need date defined the date when materials would be needed at site. This need date was difficult to schedule as IMS came into the equation; thus, the schedule was logged based on feeling of the project. In any case, there was always a review of the schedule with the project team, with all; procurement, construction and engineering disciplines. The schedule worked as an integrator of all the disciplines. The planner was supposed to talk with all the departments to create the schedule.

In the same way, storage of materials was an issue. As previously explained, the schedule could only define the earliest possible date when materials could be delivered if engineering activities followed as planned. But, it did not define when were needed at site nor when would be delivered. In theory, the project schedule could be used as a basis for planning materials schedule. Often, the schedule had an activity for warehouse; which was the timeline when materials could arrive, from the earliest to the last delivery. However, the planner could not know which materials needed indoor storage, which outdoor and which could be kept at the factory of the vendor. This information would come when the vendor contracts were negotiated by procurement together with construction.

In any case, bulk materials were not that easy to track. Basically, the difficulty lied on defining accurate enough need date. In most cases, bulk material was represented by one lot in the schedule. In practice this meant, a timeline starting with the first possible delivery until the last possible one, almost at the end of the project. Hence, many deliveries would come within that timeline, stretching over a long period of project life and also coming from different vendors. When projects progressed and depending on the size of them, more detail was added to the schedule. Maybe more reviews could be

done for having even more details but a schedule also had some limitations on relevant data that could contain.

Summarising, the process before the purchase orders were placed was quite defined and easy to schedule, the issue came after these were placed, when and where did materials get delivered. In the material reservation template, there were mostly days defining the material procurement, meaning what happened before the purchase orders were made, but then only purchase confirmation and needed date were defined for the process after.

Interview 8: Project Procurement Manager; 2.3.17, 45min.

In projects carried out outside of Finland, bulk materials followed the same principle as materials bought by purchase requisition. This was due to not having the integration between designing systems and ERP system used by the target organisation.
Therefore, in projects outside Finland, bulk materials were handled in excels, there were not inputted in any ERP system. The excel containing the piping bulk materials was sent to the vendor for quotations on those materials, then the vendor answered with offers, next it came the technical evaluation, and when all the requirements were met, the purchase order was submitted. As a next step, the excel containing those piping bulk materials was inputted to the ERP system in use at the target organisation. Once the items were inputted to the ERP system, and the purchase order sent, expediting started for the project materials, following with delivery and receiving. In expediting, the follow up of the delivery schedule of the materials was done, meaning checking the planned delivery dates against the estimated delivery schedule. Thus, if a mismatch happened between these dates, the expediter would update the ERP with the forecasted date and flag it to the project procurement manager, the project manager and the construction manager. Although, the planned delivery date was the date agreed on the purchase order, sometimes due to project needs, the forecasted delivery date could differ.
By contrast, in bulk materials expediting was not seen as necessary. Instead, the follow up would be handled between material coordinators and IMS. In addition, a shadow order was created, meaning a copy of the original order from customer ERP; this copy was created to be able to expedite the project materials. In other words, the customer

issued the purchase order but the target organisation had to create a copy of it in its own system to monitor that the schedule of delivery was followed. The ultimate responsible on approving the need date of materials was the project manager.

Generally, the overall process leading to a purchase order happened as follow. First, engineering disciplines issued a purchase request to the project manager; next, the project manager reviewed it and approved it and handed it over to the project purchaser. This purchase request had a budget and schedule linked to it as per the project plan. Therefore, the purchaser had to take into account those in order to send the enquiries to the vendors. Once the information from the vendor was clear, the purchaser completed the purchase request form and sent it back to the project manager. Correspondingly the project manager after evaluating the options provided would decide to go ahead or re-evaluate. In some cases neither budget nor schedule was that easy to meet so further planning could be required. In any case, the need date was not absolute as this came at the end of basic engineering when the information about construction details were still to be defined. In other words, it was based on the best forecast of when construction activities would take place. However, together with the project scheduler it was included in the schedule as a baseline. Frequently, the need date did not have participation of the project scheduler though; the engineering disciplines or the project manager communicated the needs straight to procurement. Consequently, it posed some challenges when the project schedule was not detailed enough or not updated. It was heavily relied on subcontractors and construction manager to organise the details happening in execution.

To put it in another way, there could be a line in the schedule for bulk materials; in contrast the project had different site areas were different deliveries needed to be carried out, depending on the work at hand. For this reason it was confusing at times to follow up and forecast the correct delivery date as the project progressed. There were cases however, where the construction schedule was updated regularly but changes were not communicated to procurement. Additionally, it seemed that often when projects were in a hurry, project meetings were kept separately by departments, consequently limiting the share of information between departments. It was not common practice to involve different disciplines together. As a result, the project schedule was revised several times during execution phase and yet, by the time it was clear enough, some of the materials would be late. This schedule accuracy would improve when the project pro-

curement manager would sit together with the scheduler, the disciplined leads and the construction manager to define the schedule for the materials. It required somewhat cooperation in the beginning but then it could give a reliable picture of the materials need date. Furthermore, when purchase orders regarding bulk materials for IMS were created, there was neither information available about the estimated delivery time, nor the status of the order.

Interview 9: Head of Construction Manager, 06.03.17, 1h.

The project schedule was very often squeezed so that during basic engineering phase some purchase orders were created, mostly for long lead materials. Nevertheless, at that point it was not known much about the construction phase. Therefore, assumptions were made as the contractor was not yet known. As a result, in the project schedule a timeline was given for the contractor to perform the installations, obviously, many materials were needed beforehand at site. And that is how the planned need date was defined. Later, when the contractor was known, more information was available and within the timeline given he was in charge of creating the schedule for his own works. This meant that, the contractor created a plan for the prefabrication and for site installations. Before those plans and schedule were defined it was not possible to know the exact day for the delivery of materials.

It appeared that when the contractor schedule was clarified and finalised it was not always shared with procurement. This sharing task seemed to be project manager dependant. Project manager and construction manager were the ones receiving the information coming from the contractor. In fact, material coordinators would be the ones in charge of controlling the material flow, so bulk material would be in the right place at the right time. Previously, in the old site warehouse, materials could be delivered anytime and in varying quantities. Hence, the contractor could go and pick up whatever he needed to carry out his installation works. In other words, there was no need for coordination. The site warehouse handled the coordination, in such a way that provided storage and materials for contractors, on demand basis. Accordingly, the contractor did not need to provide a detailed schedule to the project organisation at the target organisation.

Also, there was no link between the purchase orders and the isometrics regarding piping materials. This link was missing from the ERP system. Thus, when the contractor defined the material needs according to the dates he needed them; it was difficult to pass the information to IMS unit and to follow which materials from the purchase order where reserved for that project and had to be delivered where. In essence, excel sheets travelled back and forth and phone calls had to be made to correct the delivery dates in the purchase orders multiple times in each project. For the most part, the biggest challenge seemed to be the lack of reliable information flow from IMS to the project and the contractor. On one hand, delivery status was not communicated in advance and on the other hand confirmed deliveries did not arrive at promised date. Moreover, when a delivery was sent, it was not necessarily informed that it was on the way to the project site.
The role of the material coordinators was also to collect the mistakes in deliveries and inform IMS of those, to try to get the correct materials as soon as possible. On the positive side, at delivery the materials were recorded in the ERP system keeping a reliable inventory at site. As a result, the project manager could see the status of the received materials versus the purchased ones, and follow up the project schedule based on it.

Regular project related challenges in construction would be related to a tight schedule and design changes. Regarding design changes, they could come at any phase of the project and the way to handle them was the key to success. Change management could at times prove challenging. For example, design mistakes may arise only at installation time. In this case the change would delay the construction as the design had to be reviewed again. Thus, there was a possibility that new materials would need to be ordered. This in turns would end up impacting overall project schedule, most likely causing a general delay. Finally, selecting contractors early enough was also at times challenging. This relied heavily on having mature enough design from engineering disciplines. Particularly, piping isometrics need to be nearly finalised.

At the time of the interview, there was internal development ongoing to create procedures that support the new working way. However, this is proving to be challenging as many factors have changed at once. Consequently, workers are learning and fixing issues as they arise.

Interview 10: Site Material coordinator, 7.3.17, 1h.

Her responsibility on the target organisation was to follow deliveries to the contractors, the project warehouse and to the project site, related to bulk materials. When a project had a need for bulk material, she passed the information to IMS and the purchaser. For instance, site supervisors would be typically contacting materials coordinators for project needs. Furthermore, materials coordinators handling customer projects in Finland had access to the stock in IMS. This access was a rare privilege, but vital to check the status of materials requested from the site. Based on that, they could pressure the warehouse workers at IMS to speed up the delivery. Moreover, most of materials deliveries happened more on direct requests basis. By contrast, significantly lower amount of material deliveries were based on available ERP system information. As previously mentioned, projects could not reserve materials regardless of the purchase orders need dates. Hence, materials were handed over on first come, first served basis.

IMS unit had purchasers to do expediting too, but this was not always done. Therefore, materials coordinators helped in that task. The reason is that, project needs could not be seen in advance in IMS side as clearly as materials coordinators could see it.
On one hand, the need date defined in the purchase order of different items could be the same, as it refers to the planned need date when construction schedule was not clear enough, but in practice items are needed at different times.
On the other hand, the delivery address could be blank in the purchase order and the information arrived to the material coordinators later in the project. Ideally, purchase orders with delivery address information and need date correctly displayed, could be handled by IMS without any extra help. Similarly, delivery could be done based on the information retrieved from ERP system. However, the level of trust on the information coming from the ERP system was not too high, so it was not happening automatically. Hence, everyday supervision of deliveries was needed to make sure materials where going to the correct location and with correct content. As a rule, each project had to deliver information regarding delivery address and real need date of the bulk material to the material coordinators. Nonetheless, these often came in short notice and caused materials to be delivered late at site. Project manager, site supervisor or construction manager were the ones passing forwards previously mentioned information.
On one hand, project schedules were not always available to material coordinators. On the other hand, the big amount of projects each coordinator had limited proper follow

up and advance planning actions. Usually, they would know about the project schedule once materials were needed in short notice. However, at this point it was not relevant anymore. They were immersed at full speed on the construction already. For the most part, it would be beneficial for materials coordinators to have the contractors schedule as soon as it is created. Then, they could have an overview and time to foresee needed materials timeline.

Another key point was the lack of standardised unified procedure at project level regarding roles and responsibilities of project managers, site supervisors or construction managers. In practise, each one had his/her own method to handle materials needs. Under these circumstances material coordinators had different tasks depending on the project. In other words, they had to get confirmations from different sources and do somewhat detective work to find out details about the materials. Nevertheless, projects differed greatly in size and complexity. Therefore, also control and planning structures required, would need to be flexible.

At the time of the interview, IMS was still facing challenges to deliver the right materials at site. It appears that materials used in the target organisations projects are quite unique and specific. Thus, a good training and experience of the warehouse personnel is quite critical. Moreover, a system that supports more automatic and reliable working way could reduce the mistakes rate. In particular, the difficulty on delivery for IMS lied on the fact that one purchase order could contain different isometrics. Consequently, in the target organisation's ERP system a line would be created for each. In comparison, in IMS ERP system there was only one line created for the same. So, when need dates of these different isometrics was different, they could not track it easily in IMS. What is more, it was impossible to remember every order by heart. Therefore, a problem was born. This mismatch caused some orders to be forgotten to be delivered. To put it simply, when partial delivery was made from an order, there was no alarm stating that there were some left to be delivered. Particularly affected by this where the cases when there was not enough stock to supply all ordered quantity, and when the stock was available still the order would not be flagged.

Quality inspection of bulk materials was done in IMS warehouse for those gods delivered in Finland. Next, when materials were delivered at site contractors had to make sure they got what they were supposed to and in good condition, this could be seeing

from the packing list. The packing list is the document containing the information regarding the materials delivered. However, often the packing list arrived when the delivery was already on the way, so material coordinators had to send the information fast to the contractor without much time for planning.

Ultimately, the target organisation was responsible for making sure that materials installed at site fulfilled the requirements and were correctly marked according to the standards. As a rule, a welding log is kept to trace materials in pipelines. In addition, the target organisation's quality inspectors inspect contractors' warehouses prior to delivery of materials. This inspection is to ensure materials safety. In the cases whe contractors did not have required storage for specific materials; it had to be agreed how that would be handled. As soon as the construction schedule was clear, material coordinators stablished a dialogue with the contractors to discuss the details of the deliveries.