TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of Mechanical and Industrial Engineering

STRATEGIC IMPROVEMENT OF BUSINESS PROCESSES FOR ORDER BASED ENGINEERING TEAM IN A GLOBAL TECHNOLOGY COMPANY

TELLIMUSPÕHISEID INSENERLAHENDUSI LOOVA MEESKONNA ÄRIPROTSESSIDE STRATEEGILINE PARENDAMINE GLOBAALSES TEHNOLOOGIAKONTSERNIS

MASTER THESIS

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Tallinn 2021

(*On the reverse side of title page*)

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THESIS TASK

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Study programme, MARM08 Industrial Engineering and Management (code and title)

main speciality:

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Thesis topic:

(in English) *OPTIMISATION OF PROCESSES FOR AN ORDER BASED ENGINEERING DESIGN TEAM*

(in Estonian) TELLIMUSPÕHISEID INSENERLAHENDUSI LOOVA MEESKONNA ÄRIPROTSESSIDE OPTIMEERIMINE

Thesis main objectives:

1. Determine processes of OBE Team
2. Identify current wastes in processes
3. Create proposals for improvement of processes

Thesis tasks and time schedule:

No	Task description	Deadline
1.	Complete Mapping of Processes AS-IS	30.11.2020
2.	Identify Wastes and Generate Proposals	14.12.2020
3.	Generate TO-BE Processes	22.12.2020

Language: English **Deadline for submission of thesis:** 04/01**/**2021 .a

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Preface

This thesis was initiated by Matthew Krisenthal for the conclusion of his studies in the Masters of Industrial Engineering and Management program at TalTech. Matthew is an employee of ABB Group in the Motion Service – Low Voltage AC Drives Retrofit business line which is the primary focus area of this thesis.

The author, having worked in the Order Based Engineering (OBE) team, expressed a keen interest in improving the processes of the team operations and thereby, this thesis was commenced.

The OBE Team Leader, Argo Vooremaa, and the engineers working within the team, provided valuable insight on the existing operations and potential improvements. This thesis would not have been possible without them.

A special thanks to Eduard Ševtšenko, and the rest of the staff at the School of Industrial Engineering and Management at TalTech for the opportunity to develop my skills and career further with an interesting and challenging course.

Keywords: Process optimisation, Engineer-to-order, Master thesis

List of abbreviations and symbols

AC	-	Alternating Current
AR	-	Augmented Reality
BBN	-	Bayesian Belief Network
CAD	-	Computer Aided Design
DC	-	Direct Current
EC	-	Engineering Centre
FPY	-	First Pass Yield
KPI	-	Key Performance Indicator
LV	-	Low Voltage
OBE	-	Order Based Engineering
OTD	-	On-time delivery
VR	-	Virtual Reality

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Introduction

ABB is a leading global technology company with a focus on developing products to increase productivity and sustainability in industry and society. ABB, in one form or another, has been providing technical solutions for more than 130 years and has installed and serviced products all over the world. Some of these aging components and systems are approaching or have exceeded the end of their product lifecycle becoming a "Legacy" product. The legacy products may no longer be supported due to increases in efficiency and safety in the new products or lack of availability of components or materials in the legacy items. In some cases it may not be possible to completely remove and replace the legacy product with the brand new one due to logistical, financial or other reasons. In order to keep the customers equipment and processes running smoothly, ABB offers a service of Extensions, Upgrades and Retrofits for a wide selection from their product portfolio.

Figure 1-1 Current generation ABB ACS880 drives [1]

With such a wide portfolio spanning many decades and applications it can be difficult to cover all the options. Therefore, it is necessary to have teams capable of filling in the gaps in the offerings and directly addressing customer requirements. This team is referred to as the Order based engineering team (OBE).

The thesis will be focused on the Order based engineering team for the Global Low Voltage AC Legacy Drives Retrofit business line. The OBE team expands upon the existing offerings to provide tailored solutions to meet the customers needs. Sometimes this can be as simple as providing circuit diagrams in a customer specific digital format to creating completely brand new designs that require OBE staff to travel to the site and assess and measure the application.

The OBE team for Drives retrofit is located in Jüri, Estonia since 2018. The team communicates with ABB service personnel worldwide to identify and meet the customers order requirements in an accurate and timely fashion. As this is a fairly new business line and there has recently been some changeover in staffing, it was identified that documentation and assessment of the OBE work processes and performance indicators would be valuable at this stage and any potential improvements could be taken into consideration. As the author was a member of the OBE team who is still involved in the drives retrofit business, it was identified they would be the ideal candidate to run the program.

This thesis will open with the provision of the background of ABB and specifically the OBE team for Drives Retrofit and what the desired outcomes of this thesis are.

The current processes and issues will be detailed and discussed with the use of business process modelling methods and learnings based on Lean methodologies for waste elimination. Potential improvements will then be proposed and discussed resulting in the generation of the proposed future business processes and performance indicators being modelled again in ARIS Architect and GenIe.

Recommendations will then be made for the OBE team process improvements as well as a discussion about considerations to be taken into account with the evolving technological and business climate.

1 Background

ABB History and Portfolio

ABB has been active in its current form since 1988 when it merged BBC and ASEA, companies that were both active since the late 19th century. ABB is a global leader in technology with a wide portfolio and over 110,000 employees all over the world. It is a technology leader specialising in developing smart solutions for industry

ABB, at the time of writing, comprised of four distinct business areas which all overlap with the common goal of creating smarter solutions to drive sustainable industry and society.

Electrification

Providing smart and sustainable solutions for the use, management and distribution of electrical power to society and industry. Notable areas include using data driven insights to develop Smart Cities, E-mobility services and Smart power systems for use in Electric vehicle charging networks. ABB is also the main sponsor of the Formula E racing series.

Industrial Automation

Providing integrated solutions to a diverse scope of industries by utilising a wide range of products and services. The key aim of the Industrial automation division is to help industry become more sustainable and profitable.

Robotics and discrete automation

Provides value adding solutions in robotics, machine and factory automation. ABB has it's own range of industrial and collaborative robots and controllers as well as the digital platform RobotStudio which can allow the simulation and programming of ABB robots and machinery.

Motion

ABB Motion is the largest supplier of drives and motors globally [2]. Providing Low and medium voltage motors, generators and drives as well as mechanical power transmission in order to keep industry moving. Motion contains the area that will be the focus of this thesis, Low Voltage AC Drives.

1.1 Low Voltage Drives and Retrofit

Low Voltage AC Drives have been a robust feature of the ABB portfolio since the 1970s when they invented the first high-power AC Drive [1].
Low voltage AC drives or Variable speed drives, allow low voltage motors and devices to be controlled and operated as required and as efficiently as possible by changing the amount of power coming to the device. Without a Drive it is very difficult to alter the speed or power consumption of electrical devices. The install base of ABB drives, as of 2019, saves over 310 million megawatt hours per year. [1]

The retrofit business line was born from the aging install base of ABB LV Cabinet-built Drives and the ever progressing product lifecycle.

Figure 1-1 - Product Life cycle phases for ABB Drives [3]

The Product life cycle status shows the stages at which changes to the manufacturing and support occur. The stages are described in general below.

Active – Product is still in mass manufacturing, replacement parts are still widely available.
Classic – Product is ramping down in manufacturing volumes, spare parts will still be mostly available
Limited – Manufacture of the product has stopped, spare parts will become harder to find and may increase in price due to low volumes.
Obsolete – Product is no longer supported and replacement parts will not be replenished once out of stock.

There may be variations to this general description for different products, especially large items that contain many subcomponents like Multidrive systems.
Some customers tend to start looking at their options as soon as newer products or features are introduced to the market, while some don't enquire until they are not able to buy spare parts anymore and get informed their drive has been in the obsolete phase for many years.
When the customer has identified the need to modernise their drive, ABB has a few options depending on their needs.
As shown in Figure 1-2 there are three options available to customers. The prime option from the ABB side would be Replacement where the complete cabinet drive would be replaced with a new one. This is effective from the ABB side as the manufacturing and product development is geared towards this and the customer would get a brand new, certified product. However, the customer may not be able to perform this replacement for some reason, be it financial, logistical or other practical reasons. In this case Retrofit or Module Upgrade may be viable alternatives.

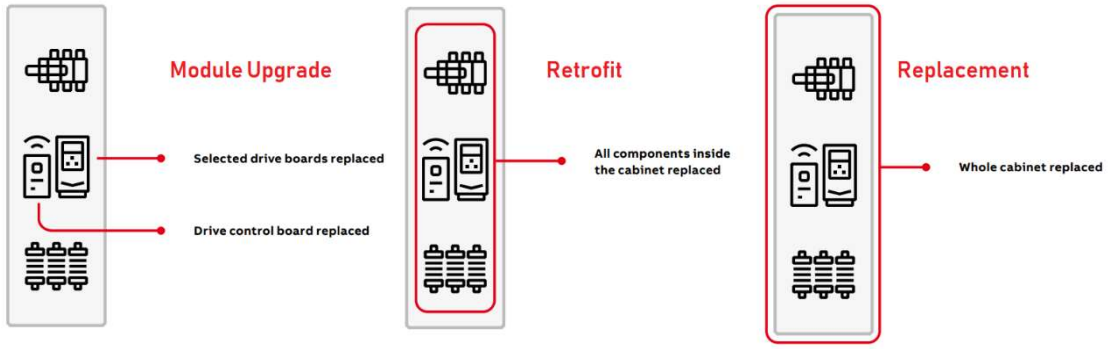

Figure 1-2 - Different forms of modernisation for a cabinet built single drive [4]

Both Module Upgrade and Retrofit are handled by the Retrofit team and can be considered the two limits of the extent of Retrofit. The customer may require a tailored solution, more of a midground, where not all components are replaced but more than just the bare minimum requirements.

Retrofit has a wide library of "off the shelf" standard solutions for most of the common legacy drives that are in limited or obsolete life cycle phases. However, there are some gaps in the offering as there may not have been a compelling business case for creating them. Other cases where there may not be an existing retrofit include, custom designed original equipment, power upgrades and functionality changes. All these cases require custom engineering this is performed in the Retrofit Order based engineering team in Estonia.

1.2 Order Based Engineering Team in Estonia

The drives retrofit program was originally based in Helsinki, Finland where the local service teams identified the desire and need to update the existing install base. While the home of the low voltage drives retrofit business line is still in Helsinki where it maintains the "Global Centre of Excellence" for Retrofit, Engineering Center (EC) Finland, as well as the Drives Service Workshop where all retrofits are produced, it has started to expand globally. Some R&D developments are being handled in China whereas Product and Order-Based Engineering take place in Estonia.

The Retrofit OBE team in Estonia was formed in 2018 from the good work and developments occurring in the Jüri campus in other areas of the Drives business unit such as R&D and Reliability. The primary intended role of the OBE team was to provide the short engineering bursts to quickly adapt an existing "off-the-shelf" retrofit kit into one that is tailored to the customer requirements. With the success of the team and the global spread of the interest in retrofits due to the aging install base and knowledge of product lifecycles, the scope has expanded from what was initially considered possible. The OBE team, upon receiving a purchase order, is expected to determine the scope and required works and execute mechanical and electrical design processes in parallel in order to produce manufacturing data and assembly instructions for the retrofit. This can have greatly varying scopes from the modification of some circuit diagrams to adding a brand new cabinet to the end of a multidrive line-up in order to fit all the new components. The OBE team is also required to provide support to sales, manufacturing, and local service units completing the installs. It is a demanding and high paced team that provides many opportunities for development.

Figure 1-3 Drive Retrofit show a SamiStar (L) from 1980's retrofitted to ACS800 (R) [5]

1.3 Issues faced by OBE Team

This thesis was suggested by the Retrofit Team Leader, Argo Vooremaa, as a means of revisiting how the OBE Team proceeds through a project and determining if the KPI's are still relevant and informative. The scope of the OBE projects has expanded considerably since the start of the Estonian OBE team in 2018, from a configure-to-order system to an Engineer-to order, and, as there are only 2 members from 2018 still working within the team, it is important to document that knowledge and experience in strong, detailed processes.

The varied and ever-expanding nature of the OBE works can make it easy for complacency in processes to go unnoticed as the primary goal is to get the job done meeting customer and safety requirements. There have been many attempts to implement new systems and tools for project management in OBE but most have not gathered the traction to be used consistently today.

1.4 Aim of thesis overall

The aim of this thesis is to provide insight to potential changes that could be made in order to improve the retrofit OBE project management processes. The intended goals include,

- Identifying and describing the OBE process AS-IS and discussing the currently utilised performance indicators
- Identifying and discussing the chokepoints and limitations of the processes and performance indicators
- Propose and discuss potential improvements to the processes
- Propose performance indicator selection
- Evaluate findings and make recommendations

2 Methodology and approach

This chapter will introduce some methods and applied theory that will form the basis of this thesis.
As the author has previously performed duties in the OBE team and has very good relations with current and past OBE team members the approach will be more similar to that of a bottom up approach than a top down as typical from a management perspective.

2.1 Business processes

Business processes are a core tool for all businesses, from manufacturing to healthcare and the service industries. "A process is a set of interrelated activities designed to transfer inputs into outputs" [6] this definition can be applied to many business and industry applications. In the hospitality industry, and many others, the ordering of an item can be considered an input which would eventually lead to the output of the desired item. The business process is how the activity of achieving that output occurs. Having a strong understanding of the processes can be critical to the success of the business or service as it can help reduce waste and drive improvement. Documentation of these processes can enhance the aforementioned improvements as well as serving as a knowledge base for new employees and providing compliance for quality management purposes.

2.1.1 Process mapping

Process mapping is the graphical form of process documentation which this thesis will employ. It empowers managers and workers to easily identify what activities are being completed for their workflow. These process maps strongly resemble mind maps which are used for idea generation and brainstorming but have a greater sense of flow to them. They can take many forms but most commonly are a series of shapes with text on them, interconnected with arrows to show directions of work flow. There are various process mapping standards and methodologies that would allow to get highly detailed information and statistical analysis such as IDEF and UML. As this the aim of this thesis is to provide recommendations and drive engagement with the team, the modelling will be loosely based on an Event-driven Process Chain (EPC) so that it is clearly understandable and relatable to the observers.

2.1.2 Mapping tools

There are various tools that can be utilised to generate process maps depending on the level of information you want to include, what the purpose of the map is, skillset available and amount of users expected to be interacting with it. These tools could range from pen and paper, to complex automated workflow software packages. For the purposes of this thesis IOBEYA, an online sticky note board will be used for team collaboration and Aris Architect a business process management tool, will be used to refine the process maps.

2.2 Lean

This thesis will attempt to apply the teachings of lean methodologies to improve the processes of the OBE team. Lean methodology has it's origins in Japan as it was developed in Toyota from the learnings and shortcomings from Henry Fords production lines [7]. The methodologies of lean traditionally were applied in the manufacturing sector but are becoming increasingly used in other applications like in the service and healthcare industries.

The general principles of lean are to

1. Identify the value from the customer
2. Identify the value stream providing that value and reduce waste processes currently necessary to provide it
3. Attempt to create continuous flow through the remaining steps
4. Establish a pull through the processes
5. Manage and continuously aim for further waste reduction

2.2.1 7 + 1 Wastes of Lean

It can be seen that all processes that have waste in their capacity as said in the Toyota Production System "Present capacity = work + waste" [8]. It is important to attempt to minimize this waste to maximise efficiencies and drive profits

The seven (plus one) wastes in office related positions

1. Overproduction – Production of unnecessary work

2. Waiting – Waiting for information, feedback or work

3. Transportation – unnecessary movement and handing off of work which may result in duplication, corruption or defects

4. Over processing – Unnecessary effort put into the completion of the work

5. Inventory – Having too many work items, multi-tasking

6. Motion – searching for information or tools that should be accessible

7. Defects – any work that was not correct with the first pass.

8. Underutilisation – not capitalising on the full potential of the workforce

2.3 Performance indicators

Key Performance Indicators are a vital tool in determining the efficient and effective running of any business. They are a measure of how business processes are running and can indicate, if used effectively, where to focus in order to increase performance and profitability. Effective KPIs should be SMARTER [9] [10]

Specific – Measures process without taking into account other factors

Measurable – The measurements and values are accessible without much effort

Achievable – the target of the KPI should be achievable

Relevant – ensure the KPIs are inline with the desired outcomes of the process

Timely – how frequently the measure may change and affect performance

Explainable – is justifiable to everyone in the company including process operators

Relative – is scalable should the business grow in number

2.4 Engineering design process

Engineering design is a complex process that many have tailored to suit their own style. From the perspective of this thesis which is mainly focused on the business processes, Engineering Design will be considered a "black box" that creates outputs from inputs. This will further highlight the importance of adequate order specification which surveys have found to be a factor in 80% of all time to market delays. [11]

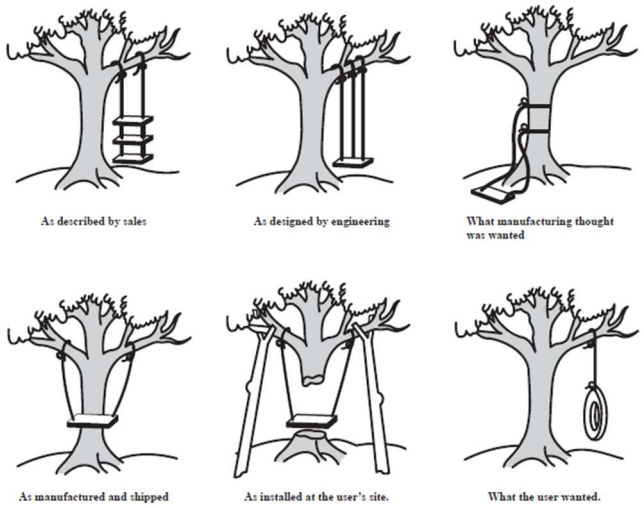

Figure 2-1 Clear order requirements are important [11]

3 Current standing of processes

In order to determine if and where improvements can be made, the current standing of the processes is required to be determined. This can be performed in many ways, as ABB is an ISO certified organisation there is existing documentation that could be utilised or they could be created from information provided by the Team Leader and Process Managers. From the experience of the Author, this information is not always indicative of the real current state of the operations, also, such "Top-down" approaches can suffer in the implementation of any changes as the process owners may feel disconnected from improvement plans. Thereby the decision was made to take a "Bottom-up" approach towards the mapping and improvement processes in order to determine full extent of the current state and, by involving the direct process owners themselves, increasing their engagement and participation in the improvement process.

3.1 Mapping of AS-IS state

The information for mapping the AS-IS process was gathered from multiple sources. A review of the initially available information with regard to the OBE order handling process was conducted by the author. This review, combined with the author's experience of working within the OBE team, drew to attention that there are four distinct phases in the order handling process that the OBE engineers are involved in. These four phases that will form the basis of the mapping process are;

1. Initial Phase, Planning and Disambiguation
2. Design Phase
3. Execution of Requirements
4. Support Phase

3.1.1 Team process mapping

In order to generate the mapped process and engage the process owners, it was necessary to hold a meeting with the involved engineers. As this thesis was created in the times of the 2020 pandemic, in person meetings were very difficult to conduct with a large team there by it was decided to hold the meetings digitally. The online platform IOBEYA was chosen as most of the team had previous experience in using it and there was a capability to hold live interactive meetings in the space. The IOBEYA platform provides a similar experience to a meeting in person where attendees can use sticky

notes, symbols and arrows in order to propose ideas and thoughts in the mapping of processes.

In preparation for the virtual meeting, in order to increase the efficiency and effectiveness of the meeting, the author prefilled some data on to the blank meeting room space. This data included the previously introduced design phases as well as some key processes, people and tools that are fundamental to the process. These were intended as a guide to help the attendees understand what was desired from them but they were made aware that they could be changed if not suitable.

The meeting was chaired by the author by providing ideas of other aspects of the process that were not present and recalling past projects and asking specific questions about works completed. Towards the end of the allotted meeting time the team had to be reminded to keep on the track of how the process is in at the current time as there were more suggestions on how to improve the processes. This is a positive sign as it shows the attendees were getting engaged with the improvement process. The meeting was closed but the IOBEYA page remained open for modification in case something was missed. Figure 3-1 shows the final state of the board.

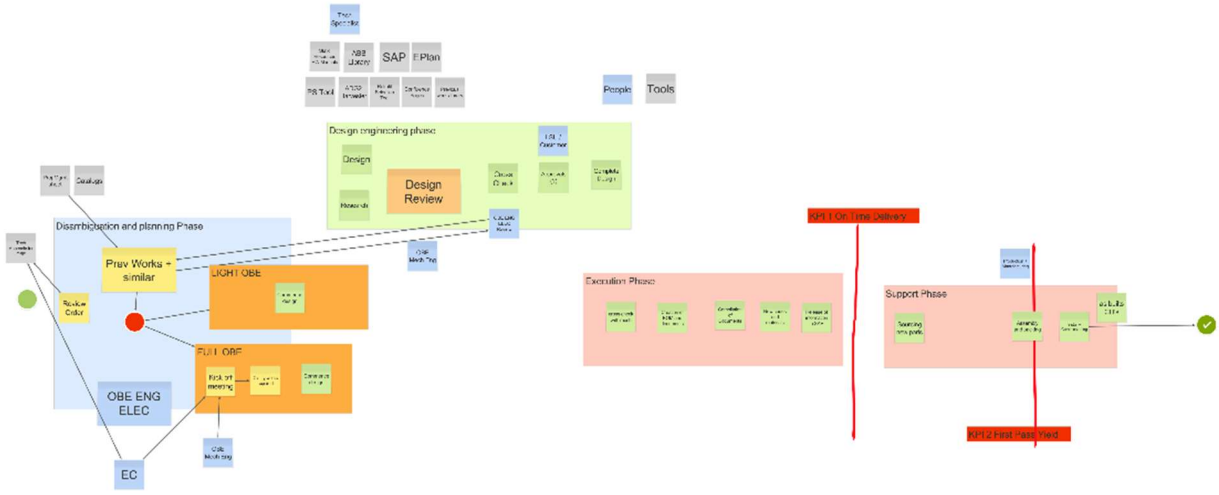

Figure 3-1 Iobeya team process mapping [12]

3.1.2 Remodelling of processes in ARIS

The information from the team meeting was then transferred into ARIS where it was restructured to show the processes in a clear fashion.

3.1.2.1 Overall Retrofit Process

The figure below shows the Retrofit order process and where the KPI measurements are taken. In the case the order does not require the input of the OBE team, the OBE step is skipped and goes straight to the production phase. This would be classified as a standard retrofit.

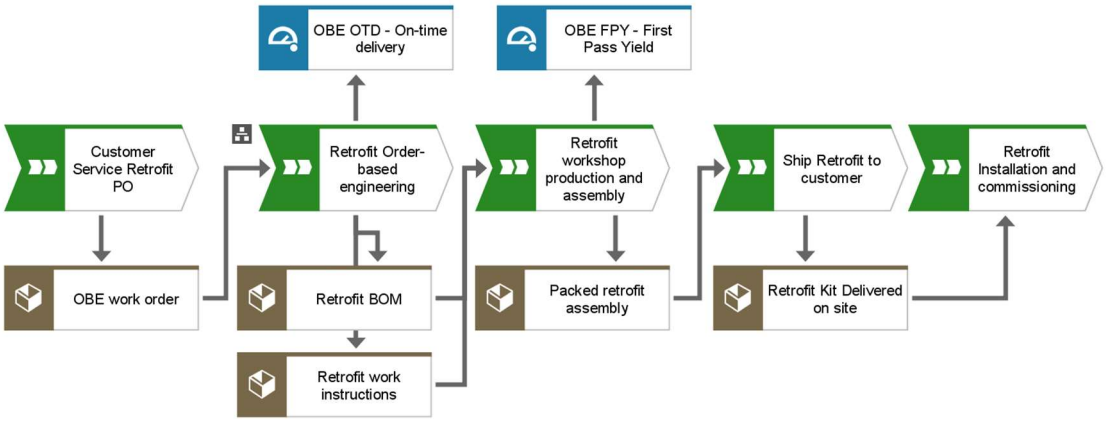

Figure 3-2 - Overall Retrofit Process [12]

3.1.2.2 OBE Process Overall

The figure below shows the expanded form of the Retrofit Order-based engineering process from the previous level. This shows the 4 phases of the OBE process that were previously discussed with the relevant parties that are involved in each phase. One notable feature of the figure is the feedback loop from the support phase. If an issue is determined in the support phase. This can have varying levels of severity. It could be as simple as an additional, unused item being returned to stock by production and removed from the BOM by OBE. Or, it could be from the installation team during installation where some custom item or functions are missing and would require the entire OBE process again to complete.

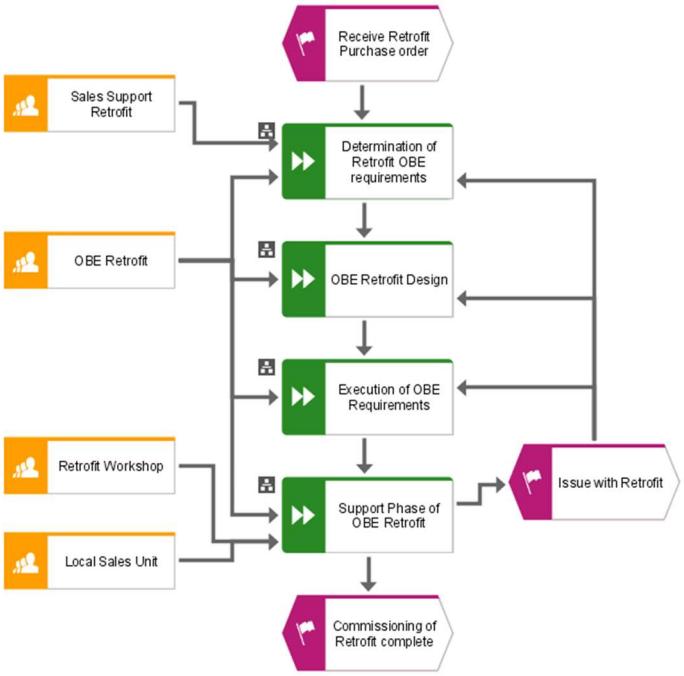

Figure 3-3 - Overall OBE Process diagram [12]

3.1.2.3 Determination of Retrofit OBE Requirements

The Determination phase of the OBE process is shown in the figure below. A notable feature of this process map is the parties involved, both Mechanical and Electrical design engineers are involved and reviewing requirements of the order which is a varied processes for the difficulty of the work and the experience and knowledge of the design engineers. This review requires assessing the Technical Specification file from the sales support team (if it exists) as well as other documentation such as photos from site, circuit diagrams and old hardware manuals and project data.

The map showcases two streams, one for Full OBE and the other for Light OBE. It can commonly occur that a job will be mistakenly created as Light OBE and then upon review, it is determined that it should have been Full OBE for the quantity or complexity of works required.

There is also no formal generation of documentation at this stage, maybe some modification to the Technical Specification file.

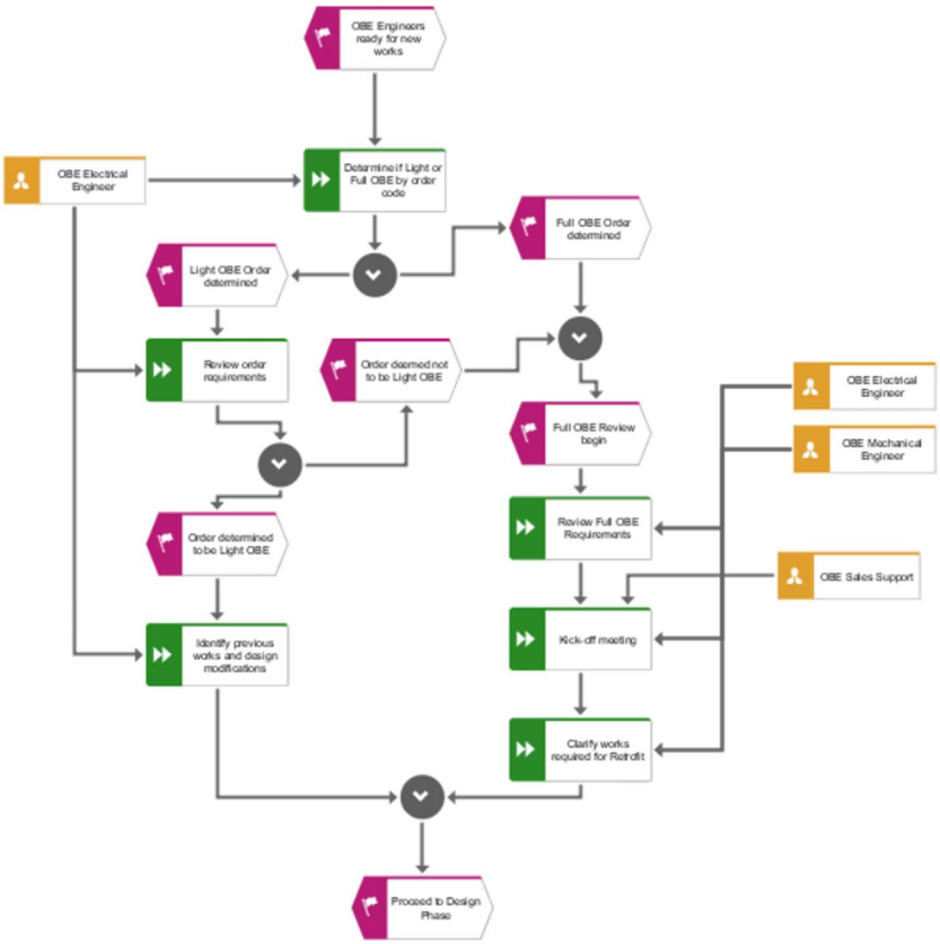

Figure 3-4 - Determination of Order Requirements diagram [12]

3.1.2.4 OBE Retrofit Design Phase

The figure below shows the design phase of the OBE process. This is the phase where the design work is mostly completed in CAD. There can be clarification of requirements as the engineers work through the design phase and this can change a lot depending on what is discovered in the research and design processes. A notable feature here is the cyclical nature of the design process where the both sides, Mechanical and Electrical, move from research to design to review and back. This can occur multiple times or just once. The cross check typically consists of the Electrical engineer checking that the mechanical engineer is taking into consideration all the components and elements required to make the unit functional. The electrical design is also cross-checked by another electrical engineer in this step. Sending the required design documents (circuit diagrams/layouts) for approval can take multiple weeks to receive a response, not accounting for any changes requested. One week is typically scheduled in for approval requests. The only process documentation created in this stage is the receipt of approval for the design.

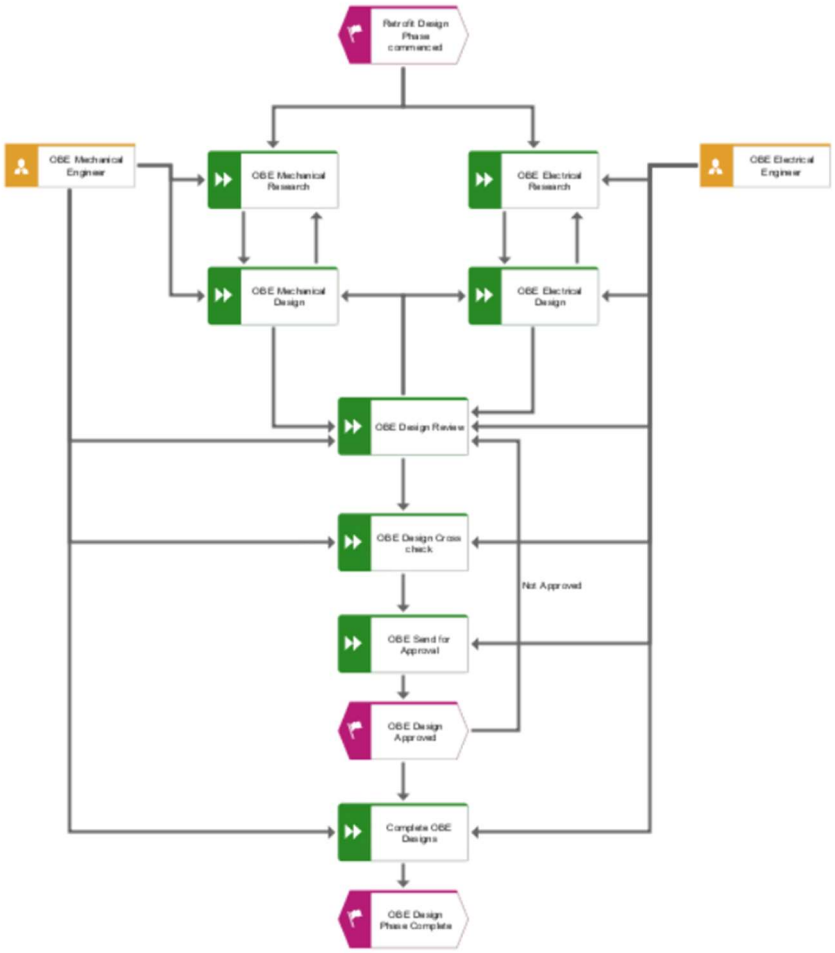

Figure 3-5 - OBE Design Phase diagram [12]

3.1.2.5 Execution of requirements Phase

This phase is where the bulk of the documentation required is created. Part drawings and circuit diagrams are finalised and the information is created within the ERP system SAP. There is a check here to ensure nothing has been missed from the design process. Work instructions and assembly instructions are place in the project production folder and BOM's are created in excel then compiled by the electrical engineer then entered to SAP. The job is released to production via email notification.

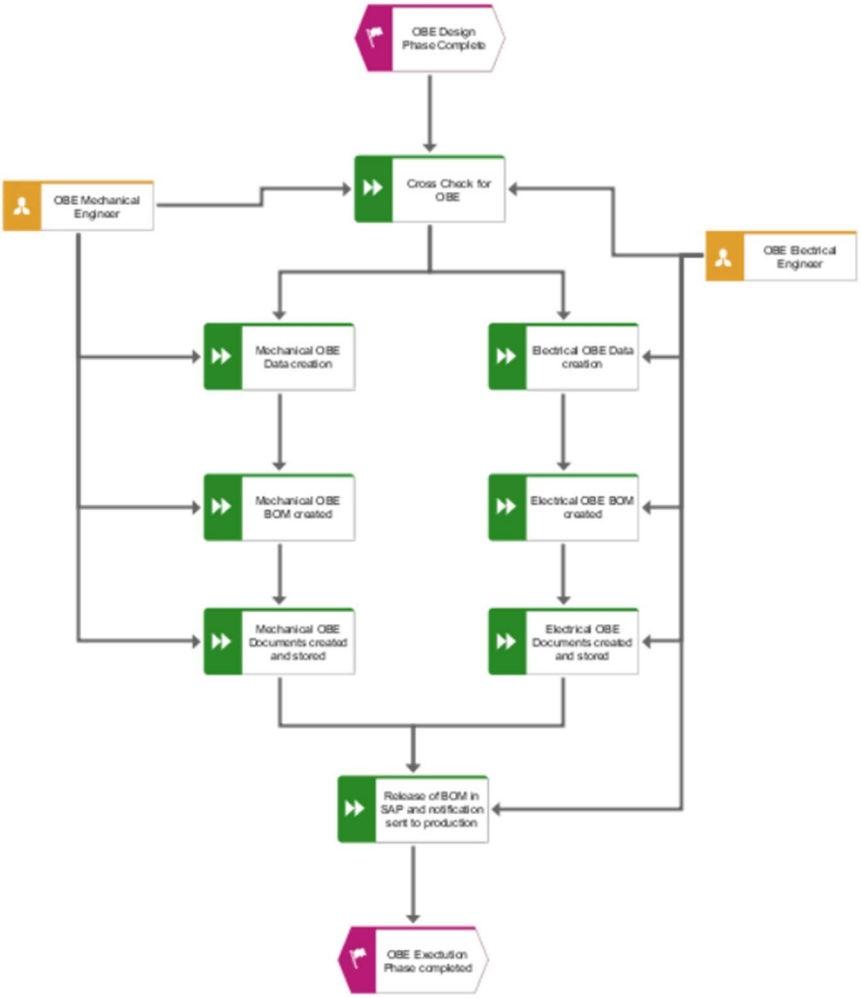

Figure 3-6 – OBE Execution of Requirements phase diagram [12]

3.1.2.6 OBE Support Phase

Once the documentation is released to production at the completion of the previous phase, the support phase commences. The OBE engineers provide support to the subsequent phases of the order handling process shown in the Overall Retrofit Process (3.1.2.1). If everything from the previous phase is completed correctly there typically would not be a large amount of support required. As the sourcing and manufacturing

phase can take up to 6 weeks, the OBE engineers have likely moved on to other works by the time it comes to the assembly phase. The installation phase can occur anytime from 1 day after dispatch from the workshop to over a year. The primary objective of this phase is to determine quickly what the issue is and take actions to resolve it.

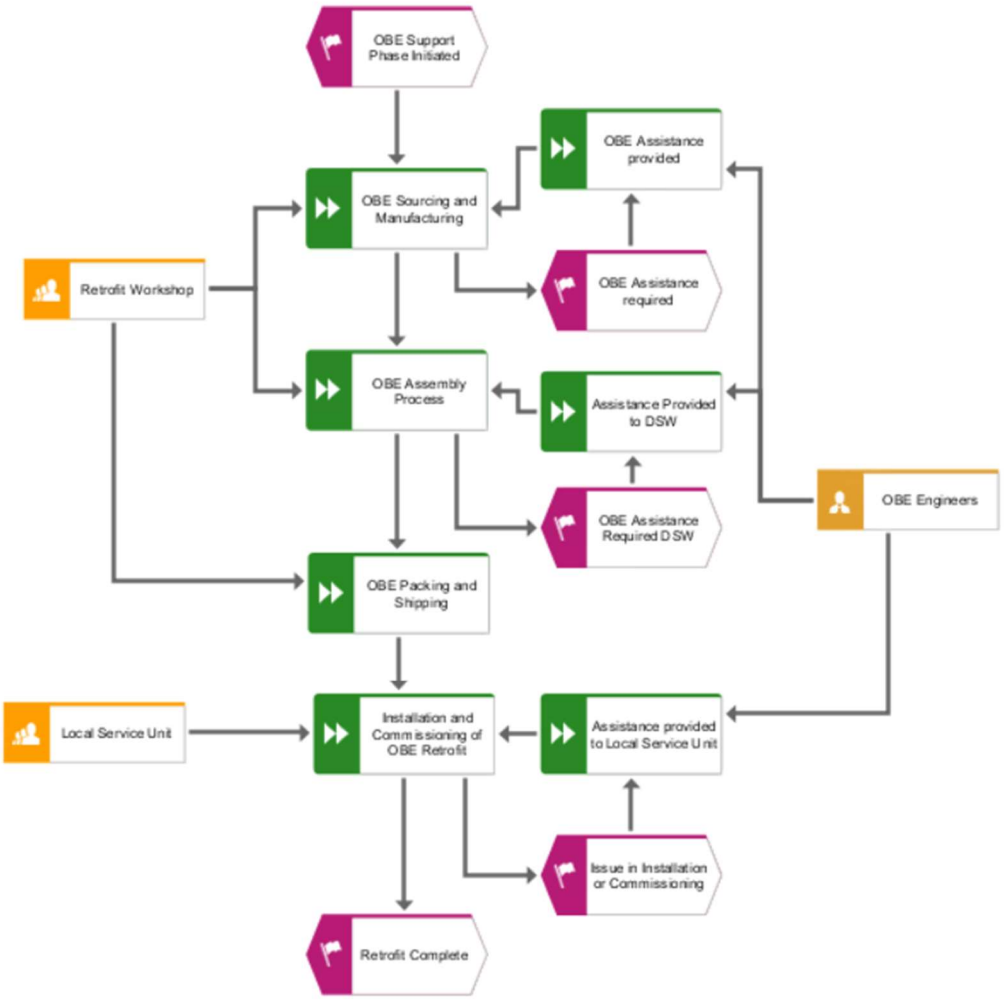

Figure 3-7 - OBE Support Phase diagram [12]

3.2 Current Key Performance Indicators

There are two performance indicators by which the OBE order handling process is measured. These are "On-time delivery" and "First-pass yield". The figure 3-8 shows the relative positions of their measurement in the order handling process.

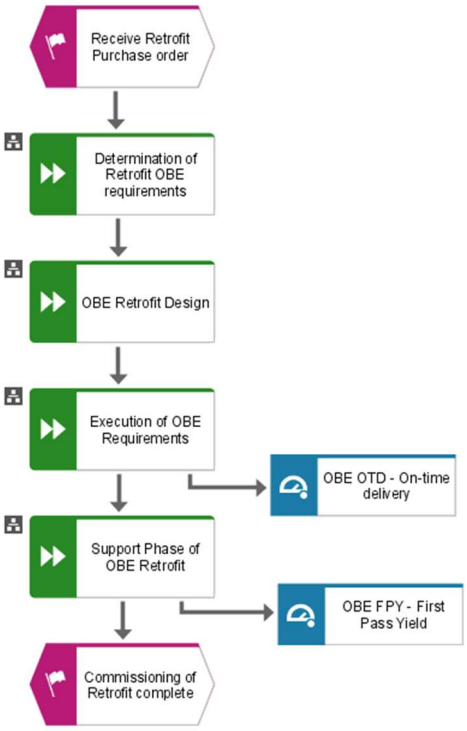

Figure 3-8 - Current KPI Measurement location [12]

3.2.1 On-time delivery (OTD)

In the case of the OBE team, OTD refers to the completion and release of the documentation required for the commencement of the Sourcing and Production processes at the date listed. This date is listed as "Operation End" in the OBE Work queue from the ERP system SAP. The expected outcome at this "Operation End" state of the project is that everything is completed and a new project can be taken by both engineers but this is often not the case.

3.2.2 First-pass yield (FPY)

The FPY for the OBE team is a measure of how often the project passes through sourcing and production first time with no notable errors due to the documentation and information provided by the OBE team. This is a manually recorded KPI decided upon the completion of the project based on information and feedback provided to the OBE Team Leader.

3.2.3 Suitability of the KPI

The two KPIs mentioned here have been in use since the beginning of the OBE team being based in Estonia. The author was surprised by conducting this enquiry to discover the manual and subjective nature of the KPI reporting processes. In the case of the OTD, the Operation end date in the work queue, as well as the other dates, can be incorrect to the actual order requirements. Therefore, relying on the Team Leader to accurately convey and adhere to the required dates which can lead to confusion as the OBE engineers can see these incorrect dates in the system as well. Upon agreement with production and/or the end customer, the Operation end date can also be moved if unforeseen issues or an increase in urgency arises. This makes judging the achievement of this target very confusing and potentially erroneous.

FPY is an idealistic statistic to strive for but can also be limiting to flexibility in the OBE environment especially with short, urgent projects that may require multiple releases of documentation in order to balance long lead time items or evolving customer requirements. The success of this metric depends entirely on the diligence of the workers performing the subsequent processes as an error could pass through the workshop unnoticed and get to the site installation where the technicians fix the problem and do not report it.

As this is also manually recorded based on second or third hand information there can be subjectivity and errors included in the calculation.

As both the OTD and FPY KPIs are measured after the completion of the project, there is very limited real time measures in place to be able to proactively address issues before they cause a problem.

From this evaluation it has been determined that while the KPI's themselves are what should be strived for, perfect delivery of information on time first time, there requires more detail and structure to create truly useful and indicative performance measures.

3.2.4 Current Performance levels

The figure below shows the indicative performance of the OBE team in regards to the two KPI's discussed above. The statistics show a fairly poor rate of first pass yield while the on time delivery stays relatively high, although not as high as would be desired. When asked about the rates and what caused the variations in the scores, there was no clear answer as these measures happen at the end of the OBE process with no other measures earlier in the process.

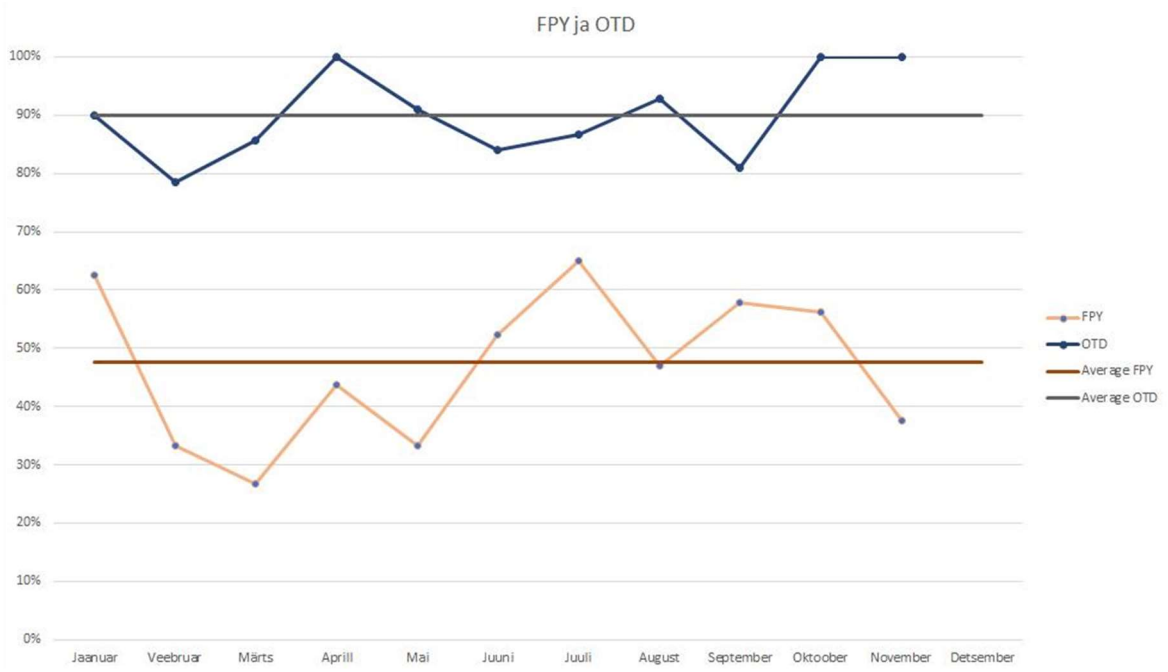

Figure 3-9 - FPY and OTD KPI results [12]

4 Evaluation of AS-IS processes

After the initial mapping of the process is complete an evaluation of them is performed to identify where the process can be improved.

4.1 Identification of Value

The value of any process is often determined by who the specific customer is in relation to the process. The OBE team has multiple customers, one of which is the end customer that see's value in a functional retrofit installed on time. For the local unit to provide this they need correct instructions and items delivered when promised. The Retrofit workshop determines the valuable output from the OBE team to be the correct bill of materials and work instructions. For the purpose of this paper, the primary customer of the OBE team is taken as the Retrofit Workshop as it is the next step in the process and the immediate beneficiary of any operational improvements in the OBE process.

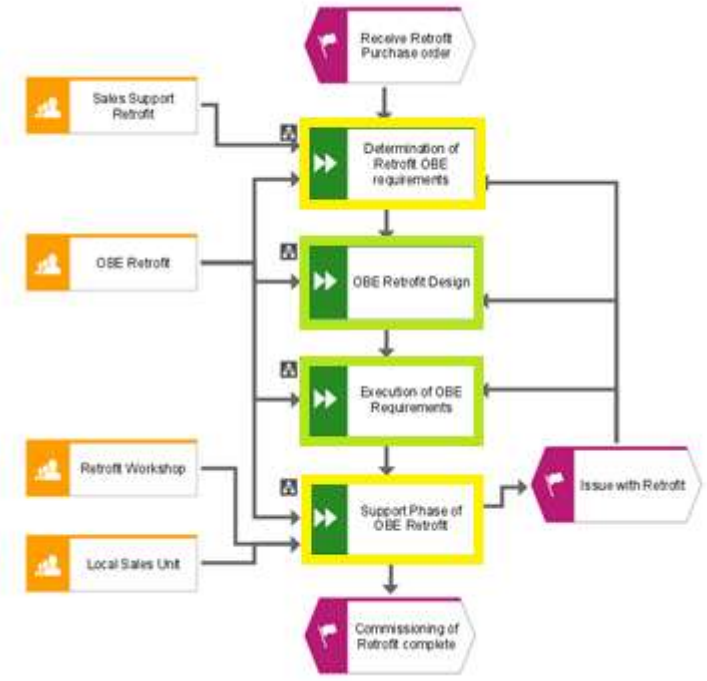

Figure 4-1 - Value adding processes overall [12]

As shown in figure 4-1 above, the Design Phase and the Execution Phase are deemed as value adding (green) from the perspective of the customers as this is where the content they require is created. The other two phases are perceived as required (yellow) but not directly adding value to the customer. The support phase is determined as required but not value adding as the support is only required if something is incorrect

or unclear. The Determination of requirements phase is determined as required but not value adding from the customer perspective as the specification should already be finalised and clear as a purchase order has already been issued for an agreed price and specification. This is not considered waste however, as product must be correct as per the actual end customer requirements otherwise the entire order will be deemed waste.

4.2 Identification of Waste

As mentioned earlier waste can come in many forms and it is important to minimise it to have lean, reliable processes. OBE projects can be difficult to identify the wastes as each project has different requirements and is handled by different engineers. The wastes discussed below are a result of reviewing the processes created as well as taking into account previous projects and the experience from working in the team.

Over production

There is overproduction in the OBE process from creating and maintaining so many different streams of information. For example documentation to go to production is put in a local fileserver while the BOM is uploaded to SAP and the customer receives individual emails with documentation. This could also be said that some of the documentation created for the production and installation by the OBE team is wasteful as it is not utilised by all.

Waiting

This is one of the key wastes present in the OBE process. If there is an issue with the order requirements, the OBE team will contact the Sales responsible or the local team for clarification. From the point of identifying the issue, the OBE engineer and the project itself are in a waiting state until the information is provided. Getting an answer to continue can sometimes take over a week. Often communication can go back and forth in email over a long time period with confusion of requirements potentially lost in translation and lack of clear communication.

Transportation

Transportation wastes can occur if multiple people are working on a project at once which is not typical of an OBE job but it can happen. Tools such as the roduct data management tool Windchill for 3D CAD and cloud services such as office365 make collaboration reasonably simple.

Over processing

This is waste that can come from doing more work than is required from not understanding the order and task requirements entirely. This can occur if the OBE engineer is not aware of existing designs that may meet most of the requirements of the work they need to do.

Inventory

In the OBE engineer sense, this could mean having multiple jobs in progress at the same time which is quite often the case for the Electrical engineers as their work time can be much shorter than the mechanical side. This can generate problems due to multitasking and can lead to confusion and defects. The support phase of the OBE process typically happens much after the operation end of the OBE engineer and while other projects are in progress. This can bring in more waste to this completed project that will flow on and affect other subsequent projects with waste.

Motion

This is another of the key wastes generated in the OBE process, typically in the early and latter stages of the process. Searching for information, drawings, parts and manuals be a huge factor in the length of a project and it's completion on time.

Defects

In the OBE process, defects is the creation of non-usable information, designs or parts. This has created a lot of problems in the past, especially when the defect is on the information that forms the technical specification of the works to be completed. A defect at the start of the project can jeopardise everything that comes after if it is not identified quickly.

Under utilisation

This has been an issue in the past with some engineers being having skillsets beyond their tasks and duties as well as having engineers that have not gained the advanced knowledge and skillset others have to make their jobs easier.

4.3 Historical performance

In addition to the process evaluation performed for this thesis, there was a study performed of all the feedback and questions posed to the OBE engineers from production. It was identified from this study that there were quite often many small issues that would require additional information or input from the engineers in order for the production to continue. This communication was quite often through email which can lead to miscommunication and misunderstanding.

Some of the more notable and dramatic jobs that have occurred in the tenure of the author in the OBE team have been issues due to the lack of understanding of the requirements of the works.

An informal measure has also been commissioned by the OBE Team Leader to determine how often the information of the order requirements is available in the project folders upon commencement of works.

5 Potential improvements and To-Be Processes

From reviewing the information presented in the processes and the evaluations, the author has created a list of recommendations for actions to be taken to improve the overall performance of the OBE team. These recommendations were created with knowledge of what has been trialled before and instances of ingenuity from the OBE team to meet the customers requirements.

5.1 Improvement of information input - Pre-Engineering

A key factor in the success of any process is the quality of the input. As shown in the evaluation, a considerable amount of the order handling process can be attributed to determining what the order requirements are and what work is required by the engineer in order to achieve the needs. With the results of the evaluation combined with the experience of the author, a restructuring of the initial phase of the order handling process is proposed. This improvement is intended to reduce the Lean wastes of motion, waiting and underutilised skills and hopefully, in time, defects.

5.1.1 Aims and goals

This improvement is to minimise the amount of time being spent by the engineers searching or waiting for correct information. With the limited time span given and the importance of design engineering to the success of the project, it is vital that it is made the primary focus of the design engineer.

Key aims of the new process are,

- Ensure a complete Technical Specification is in the project folder.
- Assess if the requested design is possible with the information provided
- Request further information and clarification if needed
- Identify early any jobs that are of a difficult, complex or not possible nature.
- Gather all additional documentation or information as required into project folder or links to information if not possible to move.
- Confirm all dates that are agreed upon into Project management document.

The overall goal is to make sure all information required for the works is in the correct location or noted where it is prior to the Design Engineer commencing works.

5.1.2 Implementation

This improvement is already underway with two of the more experienced members, one from mechanical and one electrical, being chosen to build the phase with the team leader. Both of these team members no longer work directly in the OBE Design team but have skillsets that make them valuable in the early stages of this new process. As ABB is a large organisation, it is likely that most information about historical and new products and projects exist in some form it can just be a matter of knowing where to find it.

A further proposal for this Pre-Engineering phase for OBE is to create a checklist to ensure the accuracy and quality of the work being performed by the Pre-Engineering team which will also act as the time stamp for works completed.

5.2 Digitalisation of processes and documentation

Effective and clear communication is key to being able to reduce waste and provide effective solutions. In order to increase the quality and speed of the communication the author will suggests some digitalisation of the process using digital tools.

5.2.1 XMReality Remote Guidance

XMReality is an Augmented Reality program which allows technical specialists to provide assistance in real-time from the other side of the world. The program, operated from the recipient's mobile phone or augmented reality headset, allows the technical specialist to see as if they were on site and guide the user by interacting with the environment on the screen.

Figure 5-1 - XMReality is use showing hands overlay [13]

This is advantageous for clear conversations and understanding as the visual elements can reduce miscommunication due to translation or regional differences. As the conversations occur in realtime as opposed to email there is also a much reduced waiting time for trying different things and getting more information.

XMReality has been used by the author to great effect in providing assistance and receiving information during the travel restrictions due to the global pandemic of 2020. Calls have been made to multiple countries for Pre and Post sales assistance as well as being used in house to trouble shoot production issues in the workshop in Helsinki.

Implementing this tool as the primary method of providing assistance may have dramatic effect on the amount of time and disruptions created for the OBE engineers during the support phase. This would reduce the occurrence of multitasking due to the support issues being resolved quicker allowing the engineers to focus on their current jobs.

5.2.2 EPlan for all circuit diagrams

EPlan is a design software platform that is used for generating circuit diagrams and layouts. The primary tool, historically for generation of electrical diagrams and layouts has been AutoCAD which is a robust tool. In recent times, the author, who is mechanically trained, began looking at the circuit diagrams to determine specifications and provide technical assistance. It was noticed that the newer versions of diagrams were far easier to navigate and had smart features within the files and in general they were more presentable. I was informed that this was because the new "standard" documents were created with EPLAN while the old ones were in AutoCAD. There is a little more work to do if the existing diagrams to integrate to are DWG format but as customers are beginning to request EPlan files there is a clear benefit to move across. The clearer and easier to read format of the EPlan drawing make it easier to identify Defects and prevent reworks from misunderstood diagrams.

Figure 5-2 EPlan for Electrical Design [14]

5.2.3 CreoView and assembly animations

Creoview is the free viewer software from PTC who also makes Creo, the 3D CAD program that the OBE teams uses. It allows users to manipulate 3D models on simplified versions of the Creo files. This can be very useful as a supplement to traditional 2D drawings and DWG files typically provided for non designers as the cabinet assembly can be difficult to convey and unnatural to understand on a flat page. There is also the possibility to create animations of the retrofit assembly instructions but these are more timely to create and non-interactive.

The use of this tool could reduce the instance of enquiries for production and installation issues as the users may be able to identify the issue or their misstep prior to contacting the OBE team. If they still need to contact for assistance they will be able to with a clearer idea of what the problem is and reduce the overall support time.

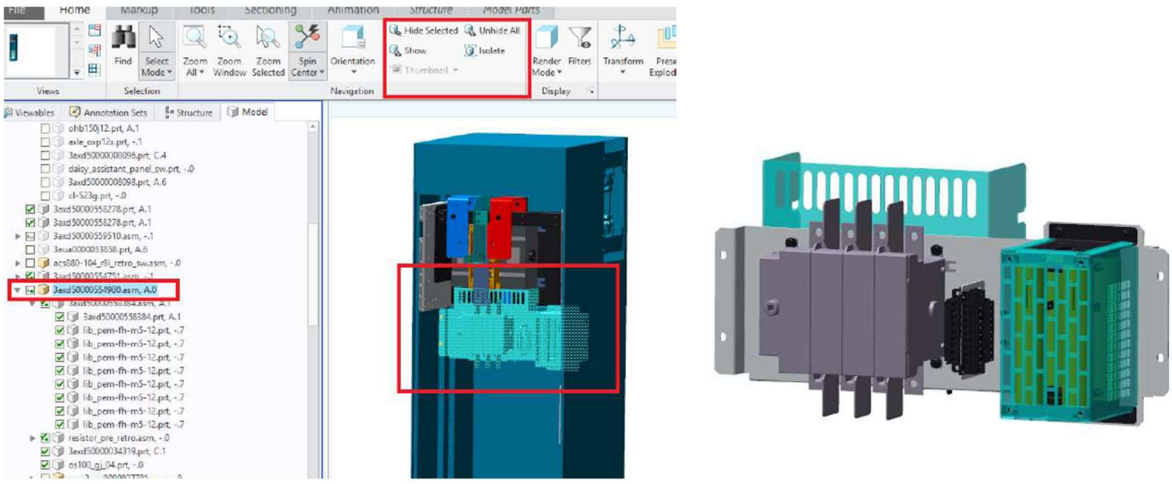

Figure 5-3 Excerpt from a CreoView manual showing the isolation of subassembly [15]

The author has created a guide and provided training and guidance to the workshop and OBE electrical engineers which has empowered them to make some decisions and foresee issues such as cable routing prior to it being a problem.

It is a recommendation due to the potential benefits and the small amount of extra effort required to generate the models that the availability of this service is more widely announced and it is at least offered for all Full OBE projects.

5.2.4 Vuforia

Vuforia is a PTC Enterprise contains a range of Augmented or mixed reality offerings. These offerings range from remote guidance similar to XMReality to collaborative design review platforms and digitised mixed reality service and assembly instructions.

Figure 5-4 - Vuforia offerings in Augmented and Mixed Realities. [16]

Use of the Vuforia offerings could be highly beneficial as it should integrate seamlessly with the existing tools used in the engineering process also produced by PTC. Benefits to the OBE process would be clearer communication and transfer of information there by reducing the time spent providing support. However, as the retrofit team has had limited exposure to the Vuforia platform the additional works required to utilise the platform remain unknown.

5.3 Standardisation of processes

There have been many attempts to introduce tools and structure to the way that the OBE team, time recording apps such as Toggl, in house developed tools and process checklists. Many of these have failed due to lack of use as the engineers deemed them not necessary and inconvenient to use. This may have been due to the heavy load that was placed on the engineers in combination with the mentality that the tools served no purpose. With the creation of the Pre-Engineering process and the use of digital systems to reduce the load on the OBE Design Engineer there should be more available time to perform tasks to a standardised format. In this proposed new format of the OBE Processes, the design engineers are also now aware of the importance of the KPIs and how it can help them complete work in a less stressful manner. Also, as there is a relatively new team of design engineers performing the works it will be seen as a valuable tool in their learning and ensuring the quality of the work. There will be 3 key items that will be proposed for consideration these are, Project Management Tool, Standardised documents and Teams based activity board.

5.3.1 Project Management Tool

The project management tool was developed in house by the OBE team in 2019 to be a tool used to simplify and automate some of the simpler and repetitive tasks of the Electrical design engineer such as generating work instructions and documents as well as being a reference library of previous works completed by the retrofit OBE team. This tool was disregarded for a while as there were some issues with unique cases that didn't fit the framework of the tool and it seemed easier to bypass the tool. With the changeover of staff and new team members coming in, the tool has begun to be used again but will likely need some modification to be truly optimal.

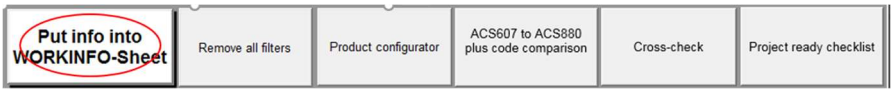

Figure 5-5 Project management tool [12]

It is proposed that the project management tool be updated and expanded in scope to cover the full range of OBE works and including the mechanical engineer. The project management tool, if used effectively and consistently could provide the entire environment required to complete and record the project management and reporting side of the retrofit.

5.3.2 Standardised documents

With the processes as it currently stands, there are some requirements on the documentation, Work instructions, Technical Specification files, circuit diagrams and part drawings. Everything else is open for the Design engineer to create as they desire. This can lead to communication issues, missed information and further defects. As a part of the process improvements and the revitalisation of the project management tool it is proposed that the scope of standardised documents be increased and utilised. Additional documents that would be advisable in standardised format include

- Checklists for each phase of the OBE processes
- Request for clarification of requirements
- Requests for approval
- Bill of materials and data management sheets.

5.3.3 Teams based activity board

There have been many iterations at attempting to implement a team progress board so that issues can be identified quickly and dealt with. However, these have stopped with the movement to home office during the pandemic of 2020 and movement of staff to other positions. This made the management of design engineers a very manual task for the OBE Team leader which relied on the design engineer to raise questions with the team lead. As the OBE team is also distributed over a large area with differing responsibilities, both work and home, home office hours can vary considerably. Also, as mentioned in the previous sections, dates in the ERP system are often inaccurate and require the team leader to keep track of. A centralised system which the whole team has access to, that can show real time project statuses, link to required folders and provide a record of completion of tasks and milestones would greatly benefit the team process and improve clarity of information.

Microsoft Teams has a function called Tasks / Planner which allows the visualistation of this information and assigning of tasks and information on cards that can be moved between buckets in similar fashion to a Kanban board. These cards can have template files, checklists and project specific information on them as shown in the figure below.

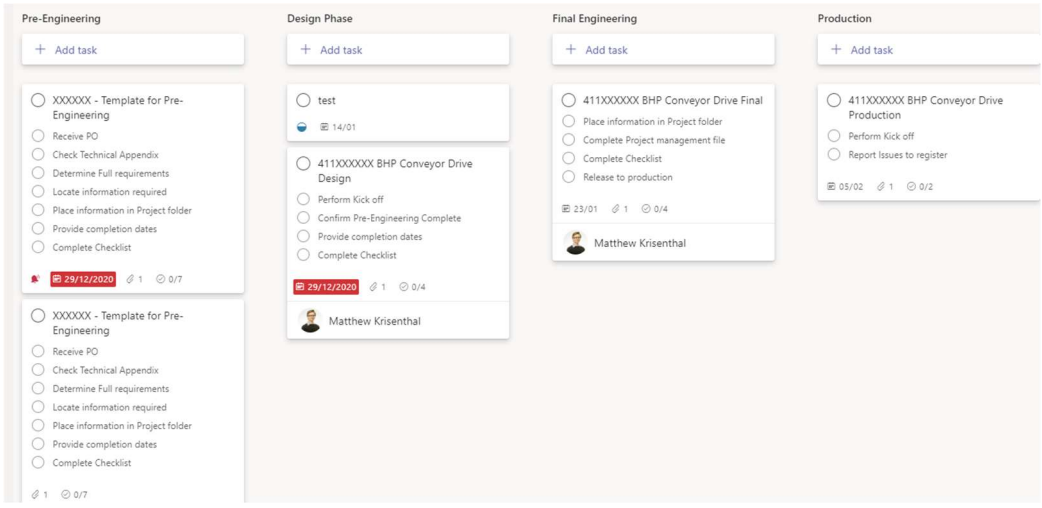

Figure 5-6 Board view of Teams Planner system [12]

From a performance management point of view, it is possible to have a real-time view of the works that are in progress in different states. MS Teams has an integrated board that can visually show this data whilst keeping record of the completed tasks.

Figure 5-7 MS Teams Planner statistics view [12]

This would provide useful data to keep on-top of project statuses and information for the entire team. It is the recommendation that these cards be created in the Pre-Engineering phase and be situated on the checklist for Pre-Engineering.

5.4 Update of KPI

After the evaluation of the current KPIs it was determined that a new approach should be taken in order select suitable new KPIs. That is not to say the previous KPIs were attempting to drive the wrong results but the methodology of getting there was loose and arduous.

As Customer satisfaction is the strategical goal for the OBE Retrofit team, a suitable level one KPI was selected as Perfect Order Fulfillment (RL.1.1) from the SCOR11 reference manual [17]. From there, suitable sub level KPIs were determined based upon the requirements to satisfy the customer (delivery of correct information on time). Each of these metrics are measured as a percentage of the instances that they are achieved.

- **Perfect Order Fulfillment (RL.1.1)** is the percentage of cases that the requirements are delivered without fault and on time
- **Documentation Accuracy (RL.2.3)** is the percentage of cases that the requirements are delivered without defect in documentation
- **Commit-to date (RL.2.2)** is the percentage of cases that the receiving of the requirements is completed as expected

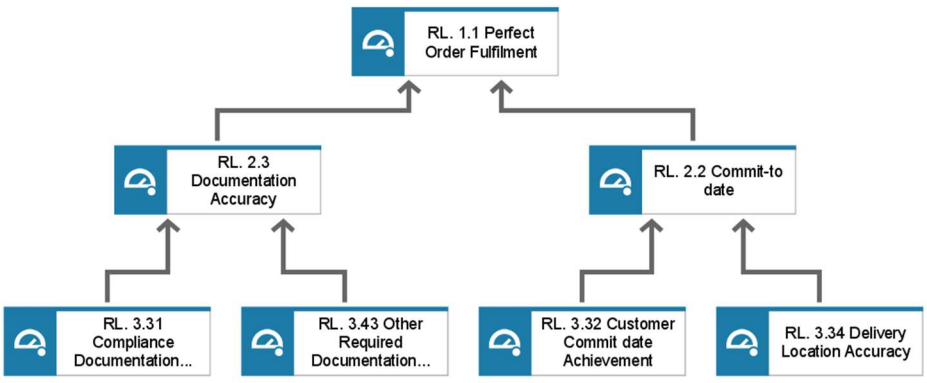

Figure 5-8 Proposed KPI allocation diagram [12]

The KPIs were then placed into the To-Be processes where appropriate processes and milestones could be linked to them which will later be simulated using a Bayesian belief network. Full details of the selected metrics from SCOR11 will also be added to the Appendix.

5.5 To-Be Processes

5.5.1 OBE Process overall To-Be

The primary changes from the original to the To-Be in the overall process is the removal of the determining requirements phase and replaced it with a Pre-Engineering phase. The new KPI's are also added to the diagram.

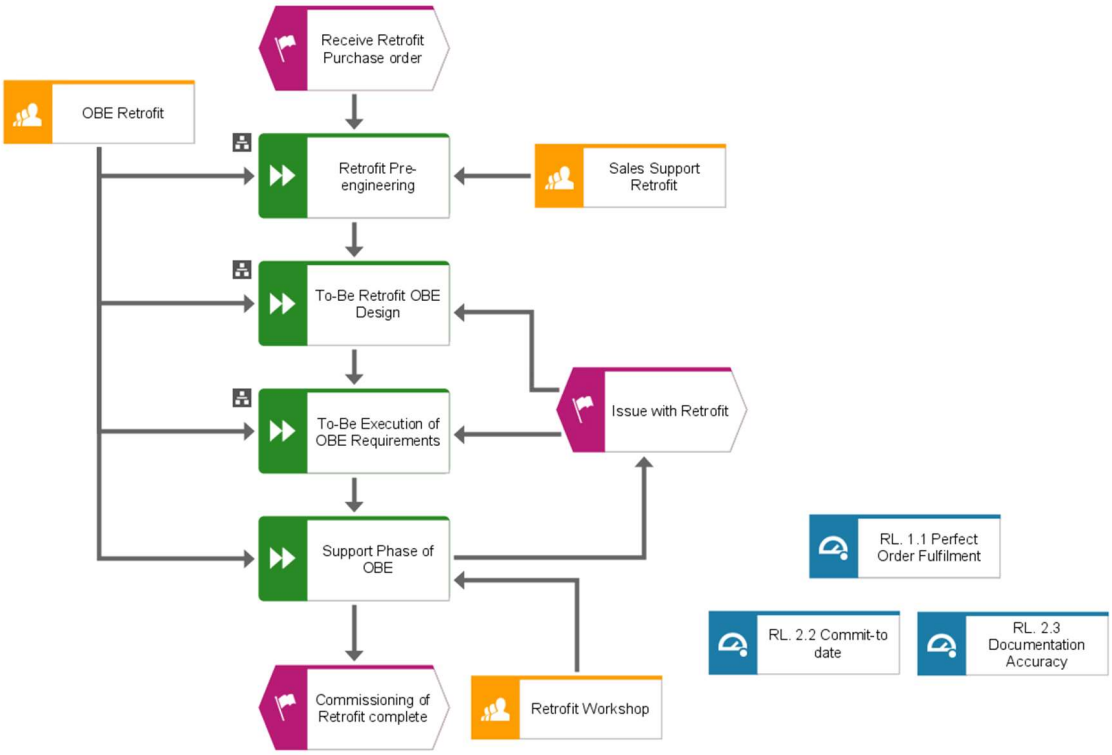

Figure 5-9 TO-BE Overall process [12]

5.5.2 Retrofit Pre-Engineering Phase To-Be

The new Pre-Engineering differs from the original Determination phase as it is now mainly conducted by experienced personnel in the OBE planning team that are skilled in determining order requirements and obtaining accurate information in order to proceed. There is also a Checklist added to this stage which will list all the requirements and considerations to be completed in the phase. The completion of this checklist and the time stamp will directly affect the KPI's.

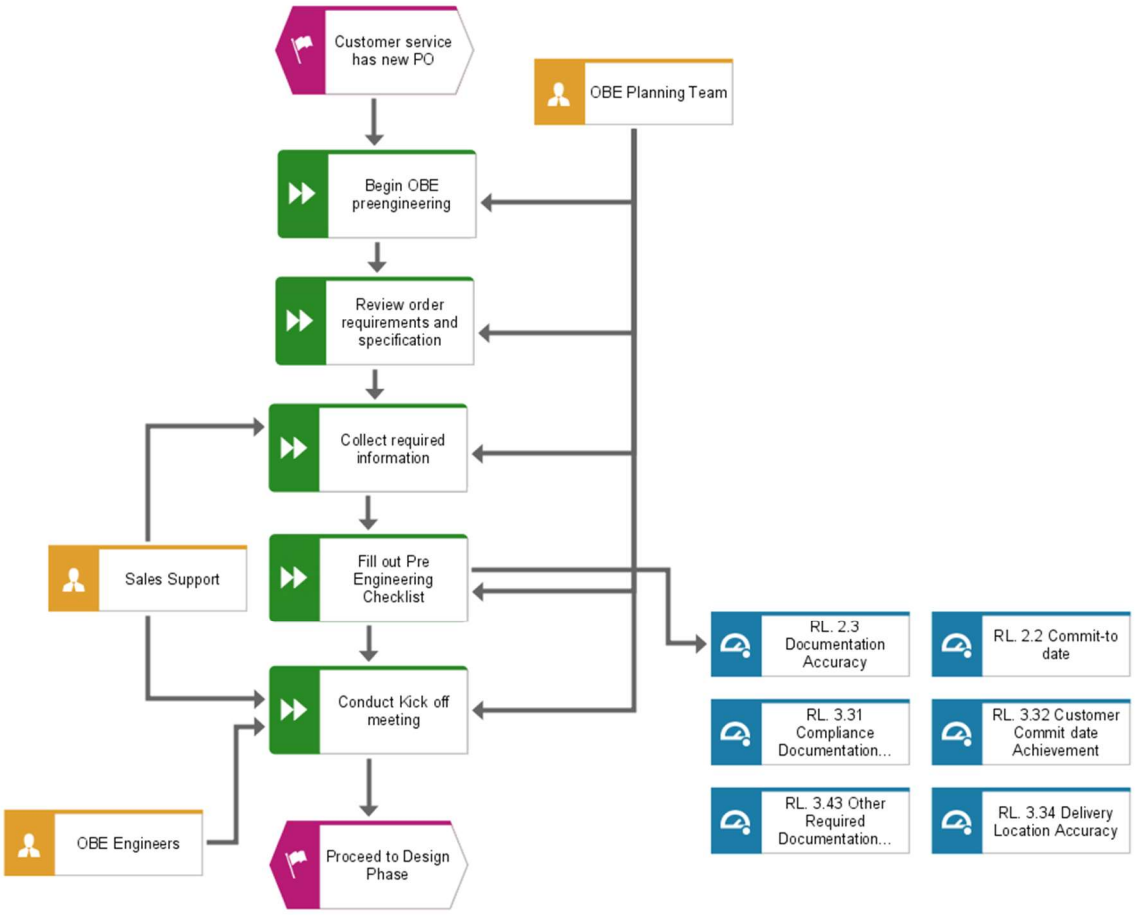

Figure 5-10 Pre-Engineering To-Be [12]

5.5.3 OBE Retrofit Design Phase To-Be

The Design phase remains mostly the same on the top surface except the possibility of passing through the design phase quicker has been made possible by the increase in the quality of the order requirements generated in the pre-engineering phase. This should reduce the Research, design, review feedback loop. Also, the improvements made through digitalisation and standardisation of documents and processes should make sending for approval a more efficient process. The Design checklist is a good indicator for the completeness of the phase. KPI's will be linked to the approval and Checklist completion date.

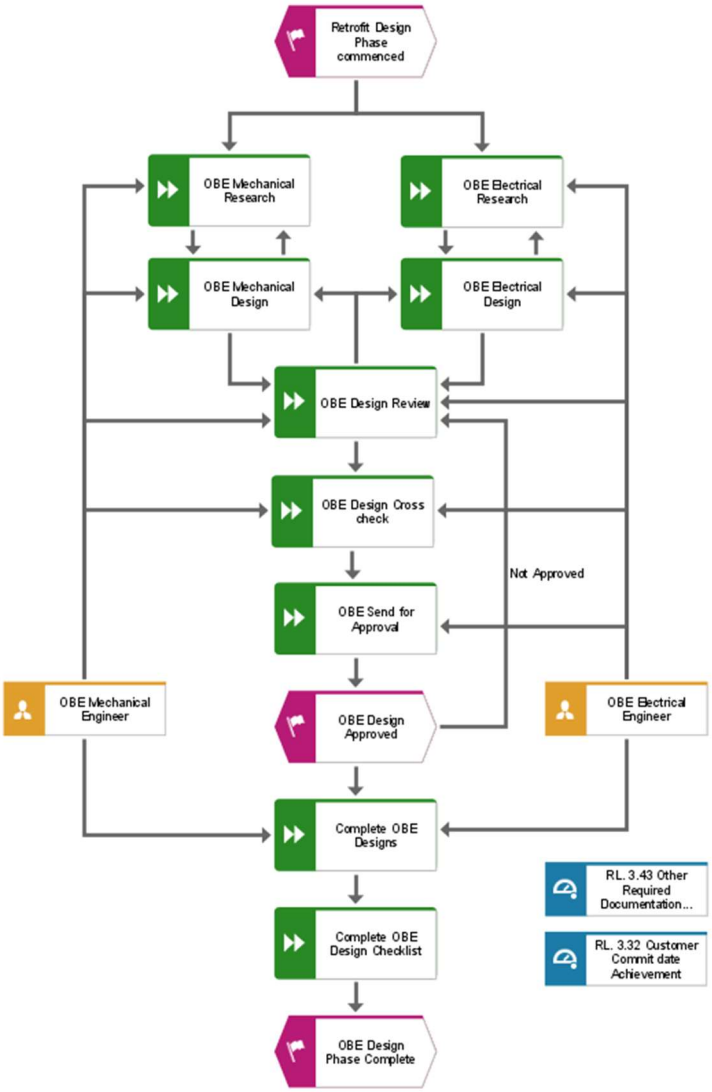

Figure 5-11 OBE design phase To-Be [12]

5.5.4 Execution of requirements phase To-Be

This process was not impacted much in the improvement process as it is the primary value creating phase for OBE in terms of the order requirements. The only modifications are from the standardisation of documents improvement where the BOMs and instructions must meet the standard specified and the inclusion of the project management checklist which, in conjunction with the Release to SAP will be the points of measure for the KPIs

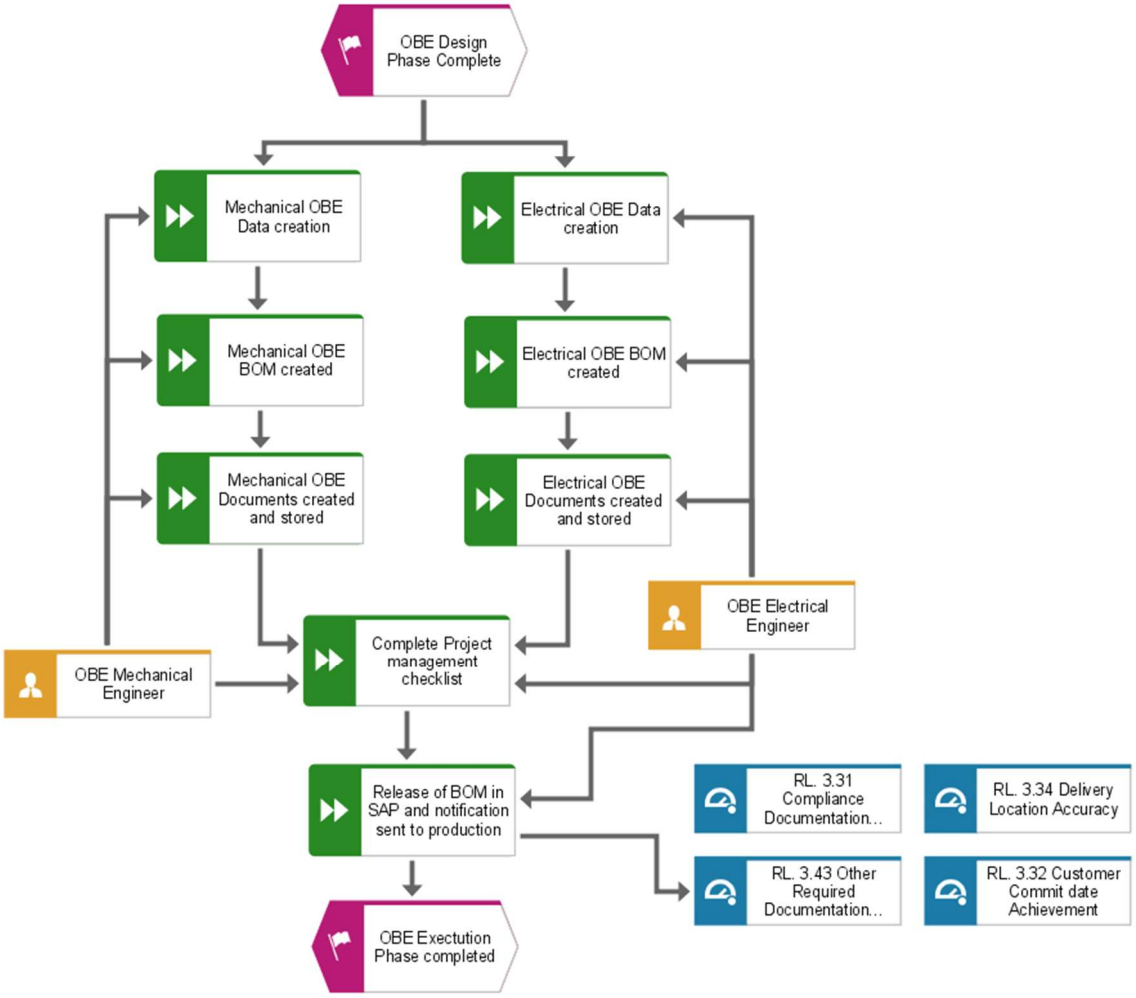

Figure 5-12 Execution of requirements To-Be [12]

5.5.5 OBE Support Phase To-Be

The support phase of the OBE process on the surface is identical to the initial mapping as the requirement to have OBE assistance has not been changed. However, due to the improvements suggested, there should be a great decrease in the frequency of assistance being required and an increase in the speed and efficiency of resolving the incidence.

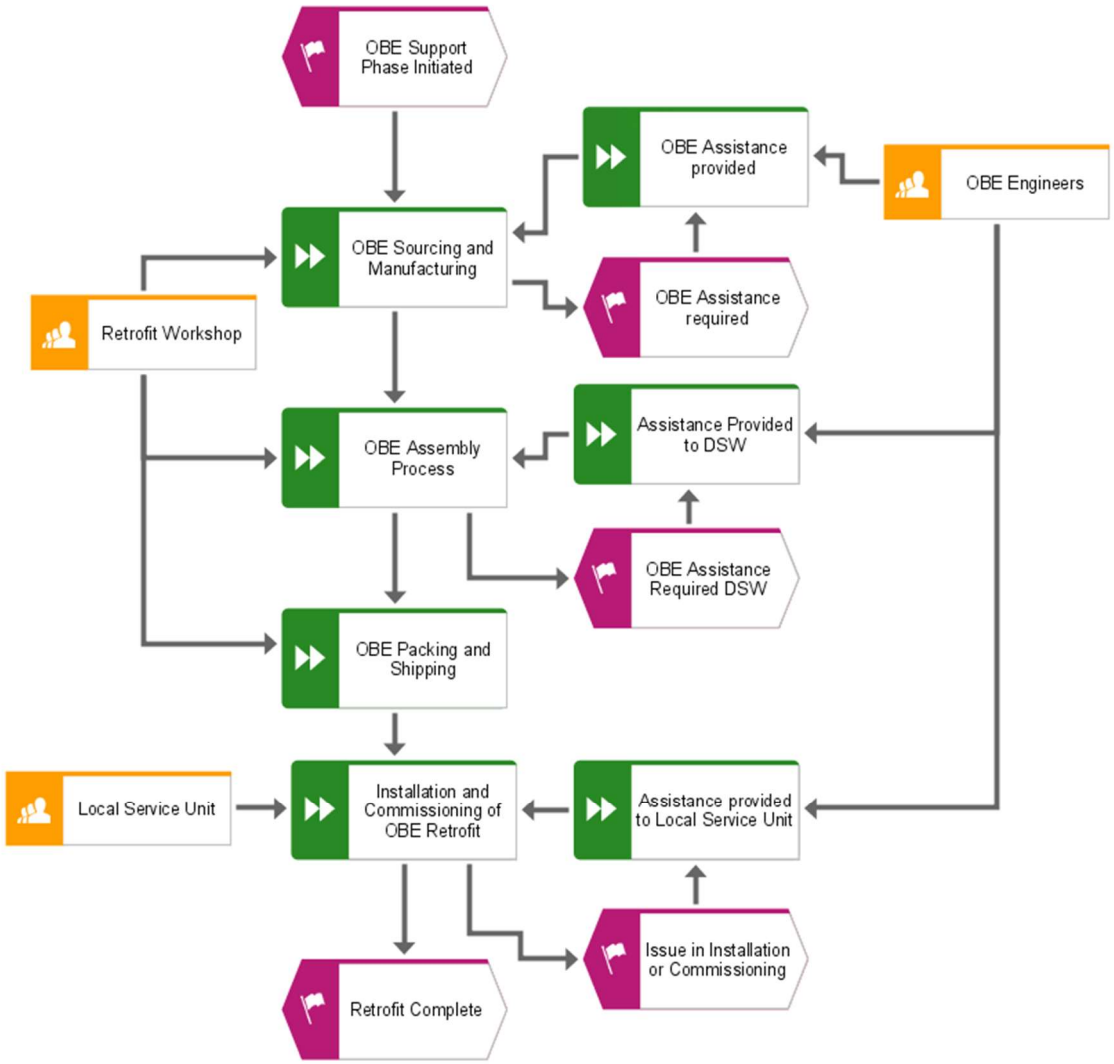

Figure 5-13 Support Phase To-Be [12]

5.5.6 Evaluation of As-Is vs To-Be

An elementary view of how the improvements could impact on the OBE design engineers was taken by comparing the amount of tasks attributed to them in the As-Is compared to the To-Be. As shown in Table 5-1 the To-Be task, despite having checklists added to their tasks, has 4 fewer tasks to perform due to the reduction of their role in the Pre-Engineering phase. This assumes that every task is only performed once with no feedback loops and Support is required in all three phases of the support process. in the ideal case, the improvements made would drastically reduce the chance of reworks or providing assistance which would make the difference between the two even greater.

Table 5-1 As-is vs To-Be

	As Is	To-Be
Planning / Pre-Eng	6	1
Design phase	8	9
Execution	8	8
Support	3	3
Total	25	21

5.5.7 [18]Simulation of KPIs

In order to determine if the KPIs and their relevant processes are a small simulation was run using GenIE a Bayesian Belief Network simulation tool. This effectively creates a digital twin for the business process allowing simulation and prediction of vital processes [18]. Estimations for the success rate values of each process were filled in for the lower row and then the subsequent values were determined based on probabilistic simulations in the belief network.

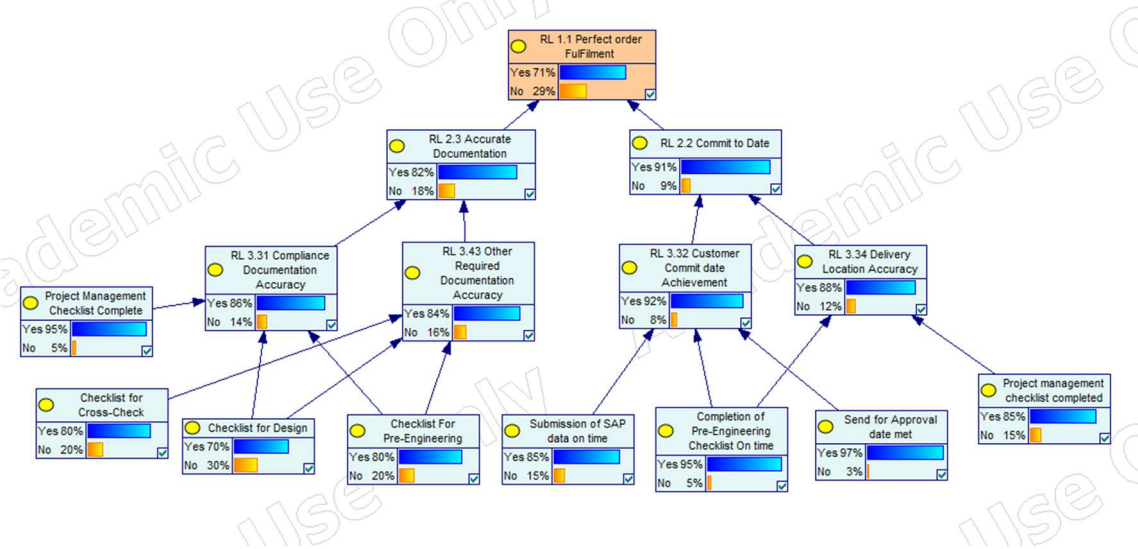

Figure 5-14 Bayesian Belief network showing achievement values [12]

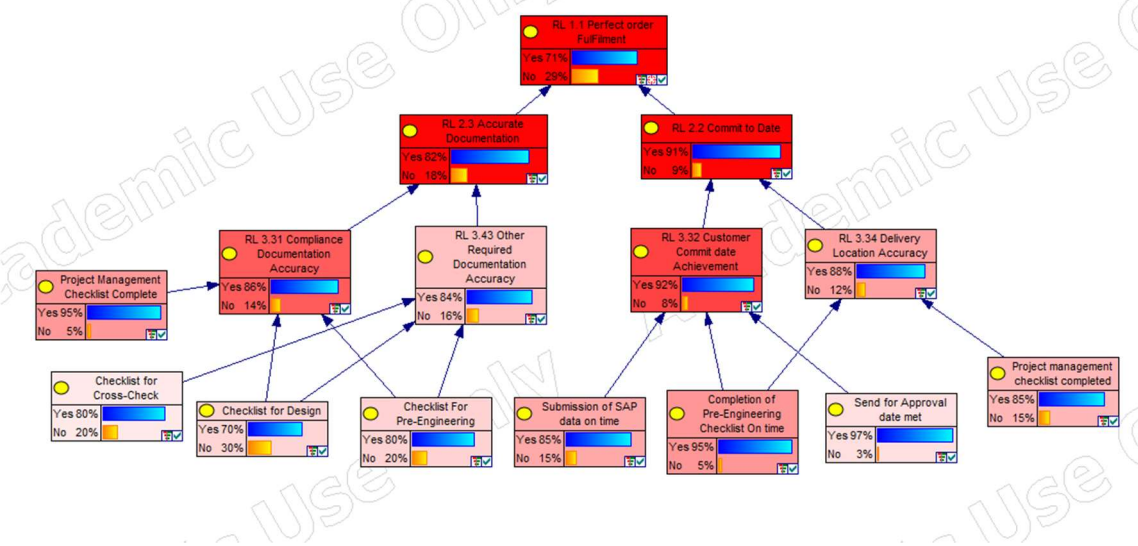

Figure 5-15 Bayesian Belief network showing sensitivity values [12]

The simulations were in line with what was expected and showed the expected importance of the Project management checklist on the accuracy, and the pre-engineering, and SAP submission time on the commit date achievement.

Summary

The overall goal for this thesis was to provide recommendations as to how the ABB Estonia Drives Retrofit order-based engineering processes could be improved from the customer and employee standpoints. The processes were evaluated from the use of value stream mapping and the application of Lean methodologies. The recommendations proposed should assist the team in providing superior service to their customers and help drive future waste reduction.

This thesis serves as the starting point for a new phase in the Drives Retrofit team in Estonia as it is expanding from being solely the OBE team to including Product Engineering, R&D and Sales support. Thereby, having strong processes and strategies in the OBE team will lay the foundation for these other processes.

A number of wastes were identified from the evaluation of the current work processes. The three primary wastes identified were searching for information and tools, waiting for information and clarification, and, overburden due to multitasking. The main contributor to these wastes was determined to be due to ineffective communication of requirements, information and issues.

The evaluation also identified that the current KPIs were not providing useful and timely information about the current state of the OBE processes. The KPIs were found to be subjectively measured and focused on the final result of the process with no indicators providing information while the process is in progress.

The thesis then proposes three potential improvements to the OBE processes. The first and most prominent is the Pre-Engineering phase which aims to decrease waste of searching and waiting for information by utilising those in the team who are talented in the disambiguation of requirements to locate and determine the information and tools needed. The common use of digital tools such as augmented reality, digital instruction and 3D assembly models was proposed as a method of increasing the effectiveness of communication between the engineers and their customers. The third process improvement proposal was the standardisation of the work processes and completion of process documentation such as checklists and Kanban boards in order to remove the unevenness of information flow and provide statistical information for the KPI evaluation.

The process diagrams were reformed into the new “To-Be” form with the changes considered.

The KPIs were also reformed under the SCOR11 framework and integrated to the new process diagrams. The new KPI's and processes were simulated using a Bayesian belief network in GenIE to provide an indication of how certain processes can impact on the overall performance of the OBE team.

In conclusion, this thesis has generated a positive impact in the OBE team, at the very least, the meetings and discussions about workflow and issues have triggered some critical thinking and engagement from the team. Some of the recommendations of this thesis are already being implemented at the time of publishing while others may be disregarded due to availability of new tools and processes or changes in the business. It is the opinion of the author that this thesis has laid the foundation for significant improvement in the Drives Retrofit OBE team.

Kokkuvõte

Selle magistritöö kõikehõlmav eesmärk oli pakkuda soovitusi ABB Estonia Drives Retrofit order-based engineering protsesside parandamiseks klientide ja töötajate vaatenurkadest. Protsesse hinnati väärtusvoo kaardistamise ja Lean metodoloogia rakendamise läbi. Väljapakutud soovitused peaksid abistama tiimi klientidele kõrgema teenindustaseme pakkumise ja eestvedama tulevaseid raiskamise vähendamisi.

See magistritöö märgib uue faasi algust Drives Retrofit tiimis Eestis, see laieneb ainult OBE funktsioonist sisaldama ka Product Engineering, R&D ja Sales Support funktsioone. Seetõttu, tugevate protsesside ja strateegiate olemasolu OBE tiimis on neile teistele protsessidele vundamendiks.

Praeguste protsesside hindamisel avastati mitmeid raiskamisi. Kolm põhilist tuvastatud raiskamist olid informatsiooni ja tööriistade otsimine, informatsiooni ja seletuste ootamine, ja rööprähklemisest tingitud ülekoormatus.Tehti kindlaks et nende raiskajate peamise tekitajana mängis rolli nõuete, informatsiooni ja probleemide ebaefektiivne kommunikeerimine.

Hindamine tuvastas ka et praeguse järgitavad KPI-d ei pakkunud kasulikku ja ajastatud informatsiooni OBE praeguste protsesside hetkeolukorra kohta. Leiti et KPI-d mõõdetei subjektiivselt ja fookus oli lõpp tulemusel ja puudusid indikaatorid, mis andnuks informatsiooni ajal mil protsess veel kestis.

Magistritöö pakkus välja kolm potentsiaalset parandusettepanekut OBE protsessidele. Esimene ja prominentsem neist on Pre-Engineering faas, mille eesmärk on vähendada raiskamist informatsiooni otsimise ja ootamisena, kasutades tiimis olevaid talente nõuete täpsustamisel, et kindlaks teha vajaliku informatsiooni ja vajaminevad tööriistad. Kliendi ja inseneride vahelise suhtlemise parandamiseks pakuti välja tavapärasema digitaalsete tööriistade nagu liitrealsus, digitaalsed juhendid ja 3D montaaži mudelid. Kolmas protsessi parandamise ettepanek oli tööprotsesside standardiseerimine ja protsessi dokumentatsiooni nagu kontrollnimekirjade ja Kanban tahvlite täitmine, et taandada informatsiooni voo ebatasus ja pakkuda statistilist informatsiooni KPI-de hindamiseks.

Protsessi diagrammid muudeti uuteks "To-Be" versioonideks koos kaalutud muudatustega. KPI-d muudeti ka kasutades SCOR11 raamistikku ja integreeriti uutesse protsessi diagrammidesse. Uusi KPI-sid ja protsesse simuleeriti kasutades Bayesi teoreemi GenIE programmis et võimaldada viidata kuidas kindlad protsessid võivad mõjutada OBE tiimi üleüldist tulemust.

Kokkuvõtvalt, see magistritöö genereeris positiivseid mõjusid OBE tiimis, vähimal määralgi sütitasid kohtumised ja arutelud töövoo ning probleemide üle kriitilist mõtlemist ja kaastaust tiimis. Mõned selle lõputöö soovitused on juba kasutusele võetud ja mõned muud võidakse kõrvale heita kuna saadaval olevate tööriistade, ja protsesside või firmas toimuvate muudatuste tõttu. Autori arvamus on, et see lõputöö on ladunud vundamendi võimaldamaks suuri parandusi Drives Retrofit OBE tiimis.

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Appendices

Full details of selected KPI metrics from SCOR11 [17]

	Level		Examples	Comments
	#	Description		
Within scope of SCOR	1 	Process Types (Scope)	Plan, Source, Make, Deliver, Return and Enable	Level-1 defines scope and content of a supply chain. At level-1 the basis-of-competition performance targets for a supply chain are set.
	2 	Process Categories (Configuration)	Make-to-Stock, Make-to-Order, Engineer-to-Order Defective Products, MRO Products, Excess Products	Level-2 defines the operations strategy. At level-2 the process capabilities for a supply chain are set. (Make-to-Stock, Make-to-Order)
	3 	Process Elements (Steps)	• Schedule Deliveries • Receive Product • Verify Product • Transfer Product • Authorize Payment	Level-3 defines the configuration of individual processes. At level-3 the ability to execute is set. At level-3 the focus is on the right: • Processes • Inputs and Outputs • Process performance • Practices • Technology capabilities • Skills of staff
Not in scope	4 	Activities (Implementation)	Industry-, company-, location- and/or technology specific steps	Level-4 describes the activities performed within the supply chain. Companies implement industry-, company-, and/or location-specific processes and practices to achieve required performance

Figure 2 - SCOR is a hierarchical process model

Performance Attribute	Definition
Reliability	The ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process. Typical metrics for the reliability attribute include: On-time, the right quantity, the right quality.
Responsiveness	The speed at which tasks are performed. The speed at which a supply chain provides products to the customer. Examples include cycle-time metrics.
Agility	The ability to respond to external influences, the ability to respond to marketplace changes to gain or maintain competitive advantage. SCOR Agility metrics include Flexibility and Adaptability
Costs	The cost of operating the supply chain processes. This includes labor costs, material costs, management and transportation costs. A typical cost metric is Cost of Goods Sold.
Asset Management Efficiency (Assets)	The ability to efficiently utilize assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs. outsourcing. Metrics include: Inventory days of supply and capacity utilization.

Table 1 - The SCOR Performance Attr butes

Performance Attribute	Level-1 Strategic Metric
Reliability	• Perfect Order Fulfillment (RL.1.1)
Responsiveness	• Order Fulfillment Cycle Time (RS.1.1)
Agility	• Upside Supply Chain Flexibility (AG.1.1) • Upside Supply Chain Adaptability (AG.1.2) • Downside Supply Chain Adaptability (AG.1.3) • Overall Value At Risk (AG.1.4)
Cost	• Total Cost to Serve (CO.1.001)
Asset Management Efficiency	• Cash-to-Cash Cycle Time (AM.1.1) • Return on Supply Chain Fixed Assets (AM.1.2) • Return on Working Capital (AM.1.3)

RL.1.1 Perfect Order Fulfillment

The percentage of orders meeting delivery performance with complete and accurate documentation and no delivery damage. Components include all items and quantities on-time using the customer's definition of on-time, and documentation - packing slips, bills of lading, invoices, etc.

Calculation

[Total Perfect Orders] / [Total Number of Orders] x 100%

Note, an Order is Perfect if the individual line items making up that order are all perfect.

The Perfect Order Fulfillment calculation is based on the performance of each Level 2 component of the order line to be calculated (product & quantity, date & time & Customer, documentation and condition). For an order line to be perfect, all of the individual components must be perfect.

- An order is considered perfect if the products ordered are the products provided and the quantities ordered match the quantities provided (% In Full).
- A delivery is considered perfect if the location, specified customer entity and delivery time ordered is met upon receipt (Delivery Performance to Customer Commit Date).
- Documentation supporting the order line is considered perfect if it is all accurate, complete, and on time (Accurate Documentation).
- The product condition is considered perfect if the product is delivered/faultlessly installed (as applicable) on specification, with the correct configuration, with no damage, customer ready, and is accepted by the customer (Perfect Condition)

The calculation of line item perfect order line fulfillment is based on the Level 2 components:

- Each component receives a score of 1 if it is judged to be perfect.
- It receives a score of 0 if not perfect.

If the sum of the scores equal the number of components (in this case, 4) the order line is perfectly fulfilled.

Data collection

Data for the components that are used to drive the calculation of supply chain performance are primarily taken from Deliver and impact Deliver Enable process elements. These are primarily associated with the original commitment (Customer Order Processing – D1.2, D 2.2, D3.3) and the satisfaction of that commitment (Receipt and Installation (as appropriate) – D1.11, D1.13, D1.14, D1.15, D2.11, D2.13, D2.14, D2.15, D3.11, D3.13, D3.14, D3.15). In addition, the documents necessary for support of the supply chain process should be scored across the set of Deliver process elements. The Enable Deliver Process Element - Assess Delivery Performance (ED.2) should be updated from metrics derived.

Discussion

The performance of the supply chain is considered "perfect" if the original commitment made to a customer is met through the supply chain.

An order is defined as a collection of one or more order lines representing a request to deliver specified quantities of goods or to render specific services. The order can further be defined as a request (with a specific identifier as a reference) to deliver specified items or to render specific services with specific prices, dates, and quantities. Commitments are made to a customer at the order line level, where an order line is defined as a line representing a commitment on a sales order. An order line always references a product or service.

For an order to be considered perfect the following standards must be met:

RL.1.1 Perfect Order Fulfillment

- Delivered complete; all items on the order line are delivered in the quantities specified
- Delivered on time to the initial commitment date, using the customer's definition of on-time delivery
- Documentation supporting the order including packing slips, bills of lading, invoices, quality certifications, etc., is complete and accurate
- Faultlessly installed (as applicable), correct configuration, customer-ready and accepted, no damage, on specification

Orders canceled by the customer are excluded from the metric. Order changes initiated by the customer and agreed to by the supplier supersede initial commitments and form a new comparative basis for the metric.

Often for date and quantity issues (and occasionally product), a range rather than a strict value is used. This is acknowledged as a standard practice; in those situations the standard measured is considered to be met perfectly if the range specified is satisfied.

The term "customer-ready" for the perfect condition standard may imply a subjective component based on the customer's satisfaction. Although condition may not be as rigorously measured as time or quantity it should be considered as a component if available, especially since this attribute measures performance of the supply chain which is, of course, ultimately measured by its customers.

It should also be noted that a corresponding evaluation of suppliers' performances could be determined by extending these standards to each supplier's ability to source products.

Hierarchy	
RL.2.1	% of Orders Delivered In Full
RL.2.2	Delivery Performance to Customer Commit Date
RL.2.3	Documentation Accuracy
RL.2.4	Perfect Condition

Processes	
SCOR	Supply Chain
sS2	Source Make-to-Order Product
sS3	Source Engineer-to-Order Product
sM2	Make-to-Order
sM3	Engineer-to-Order
sD1	Deliver Stocked Product
sD2	Deliver Make-to-Order Product
sD3	Deliver Engineer-to-Order Product

Practices	
BP.159	Electronic Data Interchange (EDI)
BP.014	Demand Planning & Forecasting
BP.019	Demand Planning
BP.020	Demand Management

RL.2.2 Delivery Performance to Customer Commit Date

The percentage of orders that are fulfilled on the customer's originally committed date.

Calculation

[Total number of orders delivered on the original commitment date] / [Total number of orders delivered] x 100%

An order is considered delivered to the original Customer commitment date if:

- The order is received on time as defined by the customer
- The delivery is made to the correct location and Customer entity

Data Collection

Data for the components that are used to drive the calculation of Delivery Performance to Customer Commit Date are primarily associated with the original order processing step of 'Reserve inventory and Determine Delivery date' (D1.3, D2.3 & D3.3), and the satisfaction of that commitment through the shipment and customer receiving processes (D 1.12, D1.13, D2.12, D2.13, D3.12, D3.13).

Discussion

Order delivery performance from a timing perspective is based on original commitments agreed to by the customer. The acceptable window for delivering on time should be defined in the customer' service level agreement. Orders canceled by the customer are excluded from the metric. Order changes impacting the timing of a delivery that are initiated by the customer and agreed to by the supplier supersede original commitments and form a new comparative basis for the metric. The original commitment date can refer to a range, rather than a strict date and time, that is acceptable to the customer (e.g. advanced shipments). This metric has no "In Full" element, such that partial deliveries can still be considered as meeting the Customer Commit Date so long as all metric criteria are met. Measuring the frequency of accepting the customer's original request date, vs. commit date, can be an important measure of customer satisfaction.

Several SCOR diagnostic metrics exist that can be used to focus delivery performance improvement efforts. Some of these include:

- % Orders Scheduled to Request
- % Orders Shipped on time (not yet defined)
- Carrier Performance Reliability (not yet defined)

Orders may not be delivered to the Customer Commit Date due to breakdowns in the order fulfillment and shipment process (e.g. Transportation availability). Orders may also be delivered late due to carrier delivery performance / issues.

Hierarchy	
RL.3.32	Customer Commit Date Achievement Time Customer Receiving
RL.3.34	Delivery Location Accuracy

Processes	
sD1.3	Reserve Inventory and Determine Delivery Date
sD1.11	Load Vehicle and Generate Shipping Documents
sD1.12	Ship Product
sD1.13	Receive and verify Product by Customer

RL.2.3 Documentation Accuracy

Percentage of orders with on time and accurate documentation supporting the order, including packing slips, bills of lading, invoices, etc.

Calculation

[Total number of orders delivered with accurate documentation] / [Total number of orders delivered] x 100%

An order is considered to have accurate documentation when the following are accepted by the customer:

Documentation supporting the order includes:

- Shipping documentation:
  - Packing slips (Customers)
  - Bill of lading (Carriers)
  - Government or Customs documentation / forms
- Payment Documentation:
  - Invoice
  - Contractual outline agreement
- Compliance documentation
  - Material Safety Data Sheets
- Other required documentation
  - Quality certification

All documentation must be complete, correct, and readily available when and how expected by the customer, Government and other supply chain regulatory entities.

Data Collection

Data for the components that are used to drive the calculation of Accurate Documentation are primarily associated with the Deliver processing step of 'Load Product & Generate Shipping Documentation' (D1.11, D2.11, D3.11), and 'Invoice' (D1.15, D2.15, D3.15).

The data collection step is part of Assess Delivery Performance (ED2) and Manage Deliver Information (ED3)

Discussion

This metric is calculated at the order level. The timeliness and quality of the documentation is measured from the perspective of the customer, Government, and other regulatory entities. Documentation may be late or incomplete due to the inability to prepare/process the correct documentation on time. Inaccurate or late shipping documentation may prevent the product to be loaded or shipped, increase the customs delay, and delay the customer's acceptance of the order. Inaccurate or late invoices may also lead to the inability to fulfill the customer request.

The definition encompasses On time and Accurate documentation. However, on-time documentation implies a scheduled ship date and scheduled invoice date.

Accurate documentation metrics are similar to what exists for SOURCE process metrics

Possible diagnostic metrics that can be used to focus Accurate Documentation improvement efforts include:

- % orders documentation (shipping and invoice) processed on time
- % faultless invoices

		Product by Customer
RL.3.34	Delivery Location Accuracy Percentage of orders which is delivered to the correct location and customer entity	• sD1.2 Receive, Enter, and Validate Order • sD1.4 Consolidate Orders • sD1.11 Load Vehicle and Generate Shipping Documents • sD1.12 Ship Product • sD1.13 Receive and verify Product by Customer • sD2.2 Receive, Configure, Enter and Validate Order • sD2.4 Consolidate Orders • sD2.11 Load Product & Generate Shipping Docs • sD2.12 Ship Product • sD2.13 Receive and verify Product by Customer

		Product Shipment
RL.3.31	Compliance Documentation Accuracy Percentage of compliance documentations are complete, correct, and readily available when and how expected by customer, Government and other supply chain regulatory entities. Compliance documentation includes material safety data sheets.	• sM1.4 Package • sM2.4 Package • sM3.5 Package • sD1.11 Load Vehicle and Generate Shipping Documents • sD2.11 Load Product & Generate Shipping Docs • sD3.11 Load Product & Generate Shipping Docs
RL.3.32	Customer Commit Date Achievement Time Customer Receiving Percentage of orders which is received on time as defined by the customer	• sD1.13 Receive and verify Product by Customer • sD2.13 Receive and verify Product by Customer

		Product by Customer
RL.3.43	Other Required Documentation Accuracy Percentage of other required documentations (besides of compliance documentation, payment documentation and shipping documentation) are	• sD1.11 Load Vehicle and Generate Shipping Documents
	complete, correct, and readily available when and how expected by customer, Government and other supply chain regulatory entities. This kind of documentations includes quality certification	• sD2.11 Load Product & Generate Shipping Docs • sD3.11 Load Product & Generate Shipping Docs