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PLM Software suite during new product introduction.

How product lifecycle management software suite can be utilized during a new product introduction project.

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Tämän opinnäytetyön tarkoituksena oli selvittää kuinka PLM ohjelmaa Teamcentteriä ja sen ala-ohjelmia voidaan hyödyntää uuden tuotteen esittely-projektin aikana New Product Introduction -tiimeissä. Tavoitteena oli myös selvittää mitä hyötyjä näistä on projektin aikana, ja millaisia mahdollisia ongelmia näiden käytössä voi esiintyä.

Lisäksi työn tarkoituksena oli uusien ala-ohjelmatyökalujen käyttöönottaminen ja toimivuuden varmistaminen nykyisessä PLM-ympäristössä. Tätä lähdettiin toteuttamaan luomalla prosessi, jonka avulla voidaan myös jatkossa tehokkaammin ratkoa ja seurata PLM ympäristön ongelmakohtia ja parannusehdotuksia. Tämä luotiin sen tarpeellisuuden ja välttämätömyyden vuoksi, jotta PLM:n ympäristön parannusprosessi voisi jatkua hallitusti myös tulevaisuudessa.

Ala-ohjelmien testaus toteutettiin valitsemalla muutama ala-ohjelma ja testaamalla tiedonsiirtoa näiden välillä. Samalla pohdittiin niiden käyttökohteita, saatavia hyötyjä ja pyrittiin myös tutkimaan, kuinka tätä luotua dataa voitaisiin käyttää mahdollisimman monimuotoisesti, riippumatta osastosta tai NPI-projektin vaiheesta.

Avainsanat: PLM, NPI, Teamcenter, PDM, MPP

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Thesis abstract

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The goal of the thesis was to investigate how a PLM software Teamcenter and its suite programs could be utilized during a new product introduction project in different NPI teams. The aim was also to investigate the benefits and challenges that using PLM software could cause. Another goal was to introduce and test new suite programs that had not been used before, and to ensure that they work in the current PLM environment.

To achieve this, a new process was made for the commissioning company which will in future help to solve problems and introduce helpful changes in a PLM environment. This was done as a response to a corresponding situation and due to its necessity to further progress on this field.

Keywords: PLM, NPI, Teamcenter, Manufacturing process planner, New product introduction,

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Abbreviations

PLM	Product lifecycle management
NPI	New product introduction
PDM	Product data management
TC	Teamcenter, PLM software
MPP	Manufacturing process planner
EWI	Electric work instructions
BOP	Build of process
BOM	Bill of materials
BOE	Bill of equipment
DFMA	Design for manufacturing and assembly
PMI	Product and manufacturing information
NX	Siemens owned CAD software.
PS	Process Simulate
AW	Active workspace
MES	Manufacturing execution system
ERP	Enterprise resource planning

1. Introduction

Roughly a year ago, Wärtsilä contacted Seamk with hopes of finding someone to test a new software that they were planning to investigate. I got nominated from Seamk to look into this further.

This thesis is only focusing on the start of a product lifecycle also called the beginning-of-life (BOL). This BOL phase includes the steps from the commencement of the new product all the way to its release into manufacturing. BOL includes the steps initial design, detailed design work, and manufacturing. (Stark John, 2011)

The other parts of a product lifecycle will be introduced but they will not be studied too deeply in this thesis work.

Disclaimer: The thesis will frequently use the word suite. This is refering to a program collection, such as Teamcenter, and smaller programs connected to it. In the context of this thesis a suite program is a generalized term for software that belongs into a larger system, such as Teamcenter. The idea behind suite programs is that they are designed to interact with each other.

The objective of the thesis is to serve as a guideline in PLM and NPI projects. The big questions aimed to answer in this thesis work are:

How to utilize PLM software during a new product introduction (NPI) project, and which suite programs could different members of the NPI team use?

What kind of benefits can PLM software provide in this kind of context?

What kind of difficulties can arise from using PLM software suite and how to ensure that the PLM system that the company is using will be beneficial in the future?

Another goal of the thesis is to give a reader a good understanding of what PLM is, how it often works, and why would we want to use PLM software. The thesis is aiming to explain how NPI-projects proceed and how PLM software can be used during the project.

The aim here is to give the reader a good understanding of what is PLM, what does it include and how PLM software can help in a new product implementation.

This work was commissioned by Wärtsilä DCV, the department of Wärtsilä which operates in Vaasa, Finland. Wärtsilä is known as an engine & technology manufacturer for marine and energy industries worldwide. During the thesis work there was collaboration with Ideal group, Siemens PLM and with Wärtsilä employees.

2 Product Lifecycle Management.

2.1 PLM in general

PLM stands for product lifecycle management. It is the process of handling and using data about a product during its lifecycle. (Shilovitsky Oleg, 2016)

The PLM evolved from early Product Data Management (PDM) systems in the late1990s. The evolution was incremental. When companies realised that the lifecycle of their products was in some cases more than decades, they understood how important maintenance was for them. This in turn made the already existing PDM users to start shifting more towards a PLM focused approach. So, these data systems could serve not only manufacturing but also maintenance. The early adopters of this kind of product lifecycle management were car manufacturers, military and aerospace sectors. Nowadays PLM is no longer limited to these industries only. (VTT, 2006)

In the early 1990s when CAD -systems were in their infancy, the focus in the design departments was on the product. But over time shift in the paradigm happened and the focus moved from just managing the data of the product (PDM) to managing the entire lifecycle, that the product (PLM) would eventually pass through. (VTT,2006)

2.1.1 The phases of the product lifecycle

The steps that a product goes through in PLM can be divided into phases. These can be categorized as follows: 1. conceiving, 2.design, 3. production, 4. maintenance and 5. decommission. The conceiving step it is the pre-planning. During this phase of project, it is important to figure out the initial aspects of what the product is going to be in future. These initial aspects should define the product to make sure that the ideas and goals are clear and understood. (Stark John , 2011)

Design step is the step for the designing of the future product. The main function of this phase is to design the product according to the requirements received from the conceiving phase, validate the design, design the assembly process, validate the assembly process and design the tools that are necessary for manufacturing. Next comes Production, bringing ideas and designs into real life. This means the actual assembling of a product and manufacturing the parts and tools required. In the production phase, the product is assembled and tested. (Stark John, 2011) (WIDB)

Service section would contain all after sale procedures after the product has left the factory and been delivered to a customer. This usually includes the already mentioned maintenance. This can include repair services, customer services or manufacturing and providing spare parts. The aim of the service is to keep customers satisfied with the purchase and to retain customer engagement. (Stark John, 2011)

Decommission is the last step of the product lifecycle and it includes the disposal of the old and obsolete product. This step focuses on the downsizing and eventual removal of the equipment once needed to manufacture the product. The topics that are important here are the reusability of old equipment and other End of lifecycle activities (EOL). This step is incremental and happens at different times for different sectors. For example, the manufacturing team might stop their process after one year of manufacturing, but the maintenance team might offer repair service for the products for twenty years. (Stark John, 2011) (WIDB)

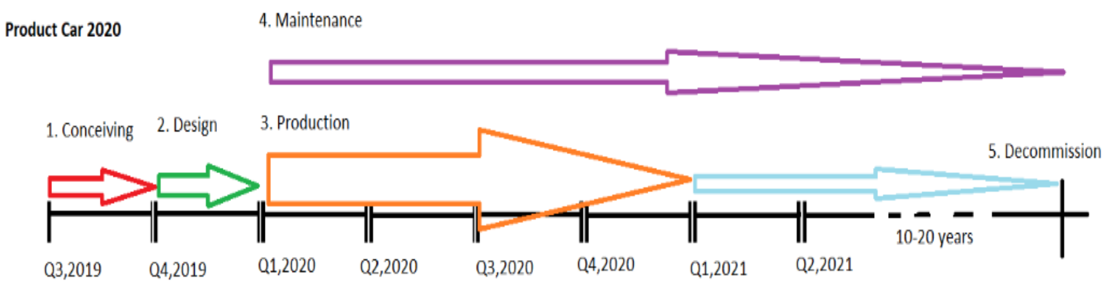

Figure 1 Products lifecycle (WIDB)

Figure 1. shows the simplified lifecycle of a new product, car. At first the car is conceived and designed. From a simplified timeline perspective, the production and the maintenance can be thought to start at about the same time. And at the end of

the production phase of the car starts the decommissioning process. This happens gradually, first ends the production and much later the maintenance.

A recent example of this was with Microsoft when they ended their support for windows 7 operating systems. In other words, Microsoft ended their maintenance for the product windows 7. Users can still use the product but the manufacturer, however, is not going to support this any longer with updates or customer service. This example also serves the purpose of contrasting an immaterial product with the car example, showing that the lifecycle structure can apply even to immaterial products and services. (Microsoft Support)

Only a few days after the closing statement, Microsoft had to make one more update to win 7. It seems that what they thought would be the last update, left some unintended consequences and they had to fix them. This shows that ending a product lifecycle can be a bit tricky and things do not always go as intended. (The Verge)

2.1.2 PDM

Often heard in similar context is the abbreviation PDM for Product data management. The word PDM is usually associated either with a PDM system or software. These are the operating models by which the functions of PDM will be met. According to Upchain.com PDM is a category for software that is designed to manage and control product data while it goes through the lifecycle of a product. The function of a PDM system is to collect the data regarding the product into one central location. This data is often instructions, parts or CAD 3d models. PDM software also enables version control for the data. (Upchain.com)

Product data management software is a fundamental part of the PLM software. The objective of PDM software is to collect and store the files and metadata in connection to the design of the product. This has the same working principle as PLM to store all data in one main server, where the data is accessible for all the members of a team. PDM software is used by engineers to make and manage the CAD- files, drawings and 3d models of the product. PLM holds the capabilities for launching new products, effectively changing the existing ones and tools for managing the end of the lifecycle for the product. Nowadays the line between PDM and PLM seems to fade out little by little and it can be difficult to tell them apart and differentiate. Upchain.com states that the difference between PLM and PDM is that the PLM oversees the process and digital environment. PDM on the other hand oversees managing digital data and its movement within the PLM system. Or more simply PDM system is a part of PLM system. (Upchain.com [2])

2.1.3 Difference Between PLM, PLM system and Products lifecycle.

For starters it is good to realise the difference between a few of the most commonly ways PLM as a word is used. First is the PLM. Products lifecycle management. Every action taken towards this goal of managing a product over its lifecycle is PLM. Next the PLM systems or software. Such pieces of software as Teamcenter are PLM systems. This means they are systems used to enable or perform PLM actions. These could be thought as platform enabling action. PLM can be action or a software/system (Siemens PLM)

As the last one there is the product lifecycle. It is important to note that this is the lifecycle that is being managed in PLM. This means the cycle of the 5 steps: 1. conceiving, 2. design, 3. production, 4. maintenance and 5. decommission. (Stark John, 2011)

2.2 PLM working principles

As with the PDM systems the PLM systems use a collective data principle. In short, this means that all the produced data will be gathered in one place. When all the data is in a central location and accessible to all effective handling of data is possible. PLM software also enables this data to be used during the entire lifecycle of the product. (Autodesk.com)

In this collective data principle all data is collected to one central location. This location may be a local hard drive on the server of a company, or a bought cloud service from a 3rd party vendor. All the data that users generate, be it reports, 3D models or other files, is saved on the central storage server. (NPD-solutions)

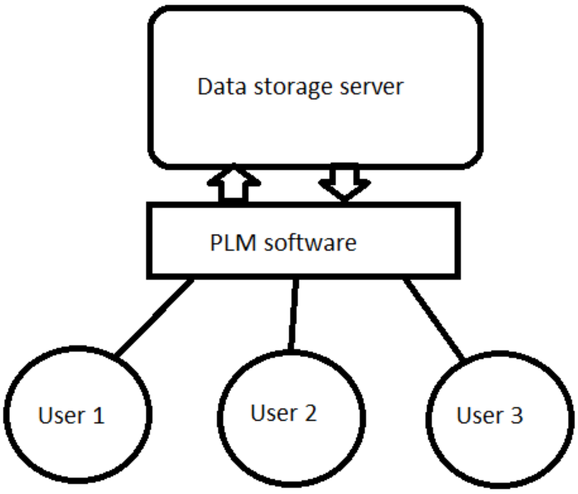

Figure 2 PLM software structure, simplified

In this approach, a user interacts with the PLM software and the software forwards the data to a server. When the user needs to access the data from the server the PLM software will be the intermediary and forwards the needed information, like shown in figure 2. (NPD-solutions)

Behind the PLM environment there is need to make things more efficient to save money and time wherever possible. Having a more effective PLM environment can help to make the procedure more effective. (Siemens PLM)

How data is handled in PLM

After understanding that the data of our product will be stored in the central data base, it is important to understand how the parent and child levels usually work in PLM software. A top down design for a product can be seen in figure 3.

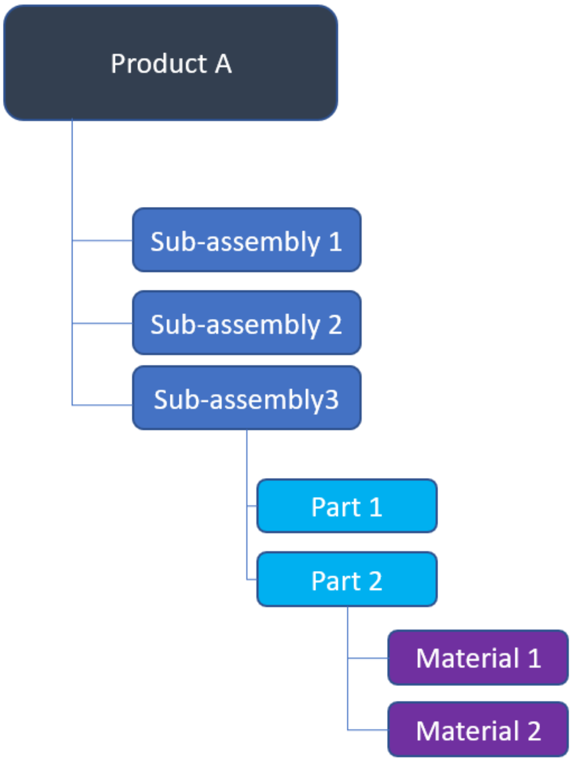

Figure 3 Product data structure (Siemens PLM, Teamcenter)

In this kind of structure, the highest level is the product, so all the items below it belongs into the product assembly. This is an example of a top down design. Below the product-level are child items. And below these child items are their own child items. And this pattern continues if there are item levels in the structure. In this kind of a structure there are now four levels, corresponding to the structure. It is good to know that the information of the product will be stored on different levels of the structure, depending on the situation. And if some data has been stored on the sub-assembly level, it is not possible to find that information when looking at the Part level. (Siemens PLM, Teamcenter software)

In the PLM structure, it is important to recognize the differences between parent- and child levels. The rule here is that a parent level includes all the child levels below it. Child levels are independent from each other, but still belong to the same parent level. What is the parent and child object depends on which section or item is currently being looked at. (Siemens PLM, Teamcenter software)

There are many benefits for this kind of an approach. For one it gives the ability to split the workload between users and offices or even nations. One person might work with the part and another with the sub-assembly. When the new part is done it gets updated into the sub-assembly. (Siemens PLM)

2.3 Benefits of PLM software

PLM software have been made to control complexity regarding products and processes, to divide it into smaller pieces that are easier to digest. This chapter will investigate what kind of benefits using PLM systems can provide to us. And more precisely what kind of functionalities are imbedded to PLM systems that are not so commonly found on other places.

2.3.1 Centralization

One of the most Important features in PLM systems is the inherent centralization. This Collected data approach provides that the data is available for everyone within the company regardless of location or time. This allows international companies to divide the personnel, so the physical location of the office doesn’t matter anymore. This way the data can be brought to the person with the corresponding knowledge and skill to work with and enables the work to be done efficiently. (NPD-solutions)

Another feature in centralization is that only the most relevant Items will be showed to the user. This is accomplished by revisioning tools imbedded to the PLM system. This means that when change must be made for part, you are not creating entirely new part with individual tracking number, but rather a revision of existing one. After this new revision is made, the “smart revision ruling” can look at the item structure and pick and show the newest or the most relevant version of the item. This means that the revision item is child object for the part. What this ends up doing with smart revision ruling system is that all the users are in normal circumstances working with relevant and up-to-date data. (Siemens PLM)

- Part
    - Part revision A
    - Part revision B
    - Part revision C (newest revision)

With smart revision ruling this means that the new data will come and replace the existing one rather than being totally separate new piece of data. Revision ruling means the settings that the PLM system uses to display the items. Depending on the settings some things can be hidden so they won't cause further confusion and it makes it look simpler. The revision ruling normally shows the most relevant version of part or item. This tries to ensure that the work gets done on the newest revision of the part, by hiding the old ones. This makes the structure look simpler and there is smaller chance for confusion (Siemens PLM)

Another big help that PLM software can provide is the capabilities to keep the data relevant. There is a known problem in the industry called data obsolescence. This means that before the data, for example 3d model, has been used in all the required steps such as validation and simulations, newer revision of that same 3d model comes out. Making the old part and the simulations and test's done obsolete. (Siemens PLM)

Another big help that PLM software can provide is the capabilities to keep the data relevant. There is a known problem in the industry called data obsolesce." This means that before the data, for example 3d model, has been used in all the required steps such as validation, newer revision of that same 3d model comes out7. This makes in-progress work and some of the work that was already done are now obsolete. And they must be made again. Revisions and other tools within PLM software can help with this kind of problems. (Siemens PLM)

2.3.2 Workflows

PLM systems can include customisable workflows. This could be thought as system driven to-do-list. Allowing to control the workflow processes. But they are usually confined within the PLM system but can include extensions integrations with email systems. In this kind of workflow structure, the organizing element has been pre-planned and made into computer program. Pre-decided ways by which the system decides the participant roles and tasks. (Siemens PLM)

For example, we can have a validation process for new design. First, the designer makes the new part or revision. After that the designer assigns the part to the work-flow. This means that the new part goes into the workflow and appears for the man-ager whose job is to look at the design and approve that it is correct. Next the flow continues to next person. This can be for example the manufacturer who is going to make that new revised part. But like with many things in PLM, it is customizable to fit the current needs. Workflows can be as simple or as complicated as needed, but these can be tailored to fit the company's needs and working procedures. (Siemens PLM)

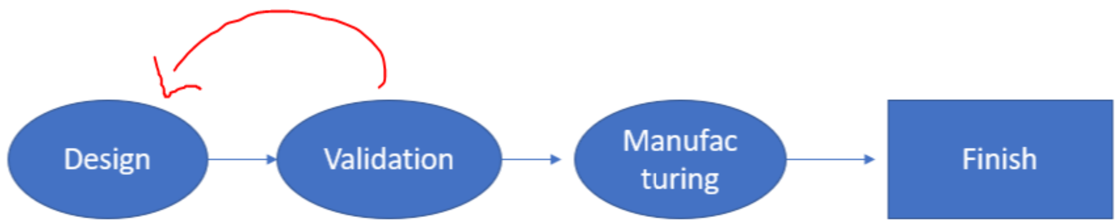

Figure 4 Simplified workflow

In this simplified representation shown in figure 4, the workflow goes as follows. If design gets validated it goes straight to manufacturing. If the design is not validated it gets rejected and goes back to the drawing board. Designer makes the changes and the part goes to validation again. This cycle continues until the part is approved.

Benefit here is that there will be time saved when this management of processes is done by automated system. Everyone can focus on the task's that need to be done, rather than spending time writing emails.

In manager language: Customizable workflows are a tool which can help you and your company to increase productivity, reduce products time to market and require less management. These things combined increase the revenue since more time will be used doing productive (revenue generating) activities and less time wasted. (Siemens PLM)

2.3.3 Expandability and connectivity

Once the database and the working procedures have been established, the next step is to have different kinds of tools imbedded to the PLM software, suite programs. These suite programs are connected to governing PLM environment and can read and enhance the already existing data in variable ways. (Siemens PLM)

One example of such in action. First you have the CAD program with which you create the product. Up next you can have simulation software where you can test the assembly process of that product and get some direction of how the product should be assembled in future. Or to see if the new product is compatible with the old tools, such as lifting tools.

These PLM systems can also be connected to manufacturing execution system (MES) or Enterprise resource planner (ERP) systems that the company already has in place. This kind of connectivity also allows the work that has been done at one part of the cycle to be read and sent to other parts of cycle. There is no need to do the same work twice when it’s possible to use the already made work. (Siemens PLM)

To create this kind of trinity of the company aproach. This figure is just to show the triangular structure of MES,PLM and ERP.

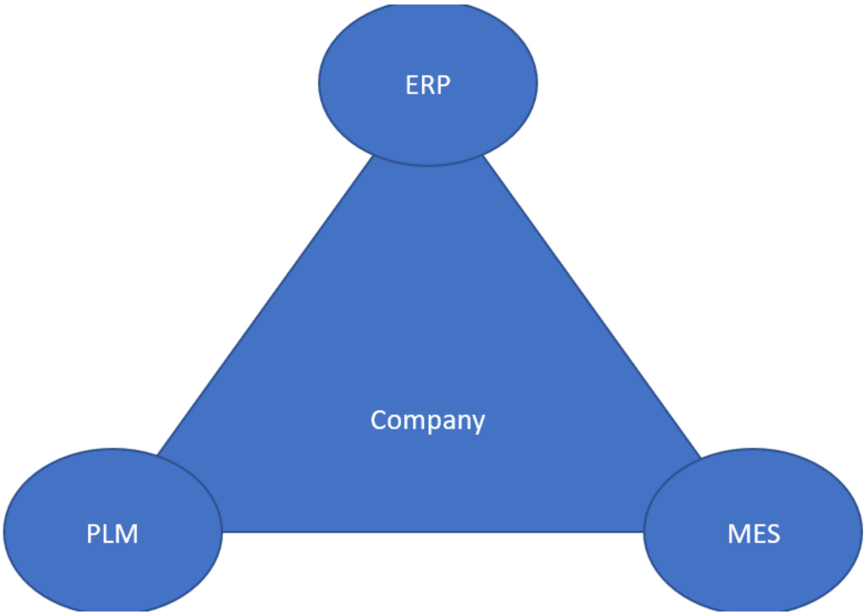

Figure 5 Company's business integration.

To have efficient business process PLM, ERP and MES must be integrated. They exist as distinctive and separate organizational entities, but they have a strong connection between each other, and even some superimposed roles. To have efficient system means that the data must flow effortlessly between all the entities. As shown in figure 5. (Schmich Matthias,2019)

To achieve this the company must go through digital transformation.
Like previously said the PLM can be managed without the use of PLM systems but without it the digitalization is not possible. (Schmich Matthias,2019)

With working system can enable the company to combine the available data and use it in new ways. For example, this can allow the creation of digital twin. With digital twin you can test the product in virtual environment without ever having to commission the product. (Schmich Matthias,2019)

3 New Product Introduction project

3.1 NPI

New product introduction or also abbreviated to NPI means the procedure it takes to bring new product to the market. This is a model how new product can be introduced. Or as a project of introducing something new to the marketplace. (WIDB)

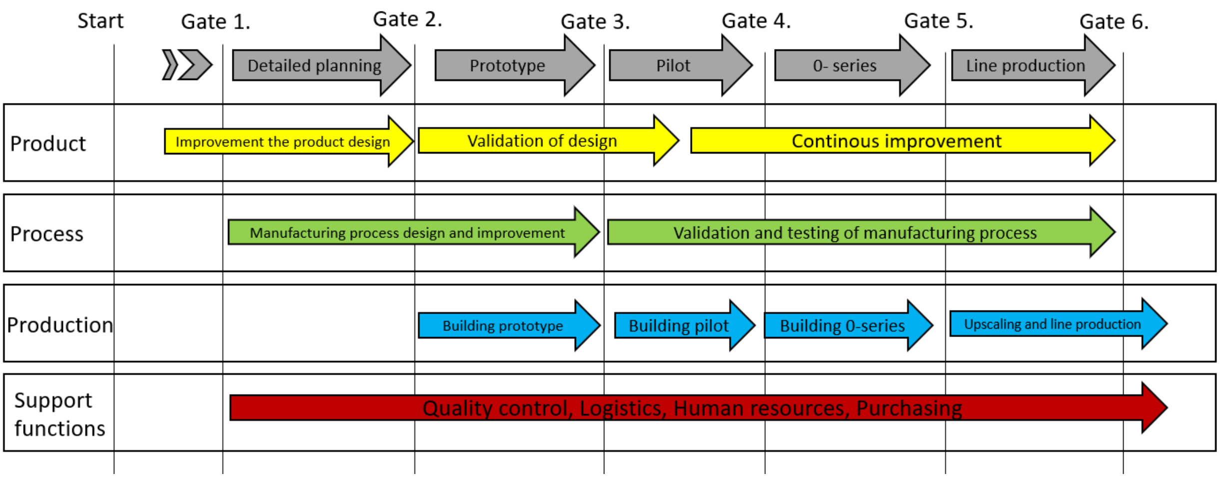

Figure 6 NPI project overview Ref. WIDB

Figure 6 shows the" big picture" in this NPI project overview. There are four major teams in this parallel process structure represented by different colours. Product, process, production and support functions. Each of these groups have different tasks to make this NPI project work. These groups work parallel of each other to maximise the usage of time. Other reason why this parallel structure is beneficial is that the teams can communicate with each other during the different phases and tasks. (WIDB)

For example: Part is being designed, and same time the corresponding process is being sketched. Process team sees that: if part would be little different, much easier way of assembly would be possible. Process team relays this information for the parts designer and the final part can then be designed knowing how it will be assembled in the future. This demonstrates the basic principle of design for manufacturing and assembly (DFMA.)

On top of that, in figure 6 little “step” indicators on top of the picture. Called as “gates”. This is referring to Robert G. Coopers “stage-gate” method. These mark the different phases that the NPI project usually goes through. These steps are usually given in context of time frame and requirements. These can be shown in dates, months or in quarters of a year, depending on the scale and schedule of the project. These steps can be also used to help coordinate the project. (Cooper Robert G., 1990)

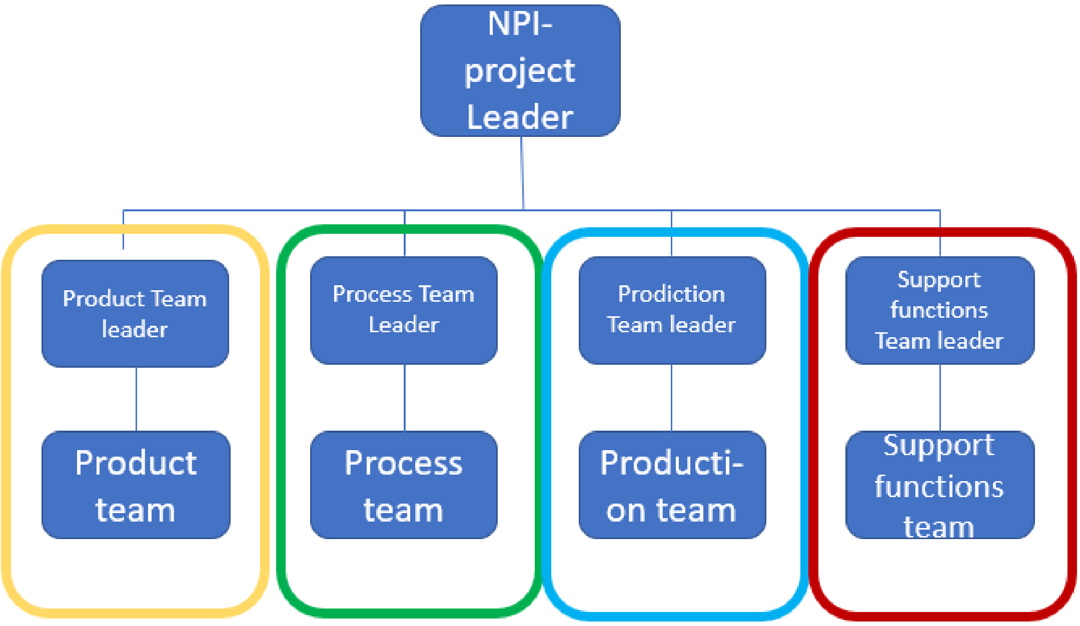

Figure 7 Simplified organization chart

Figure 7 shows example of chain of command in NPI project. One NPI project leader who is the coordinator for all the team leaders. Team leaders then guide their teams. (WIDB)

3.1.1 Over lapping with PLM

When comparing the NPI project to PLM process it becomes evident that they for some part show the same thing. Product lifecycle management oversees the whole lifecycle. (Reminder from earlier products lifecycle includes = 1. defining the requirements, 2. design, 3. production, 4. maintenance and 5. Decommission.) Whilst the NPI is prevalent only at the beginning of PLM. NPI is prevalent during BOL phase. NPI is only present during the early phases of productions lifecycle, ending when the line- or mass production starts. The NPI project could be interpreted as a smaller part of PLM that takes closer look into the early phases. Like shown in Figure 8. (Stark John,2011)

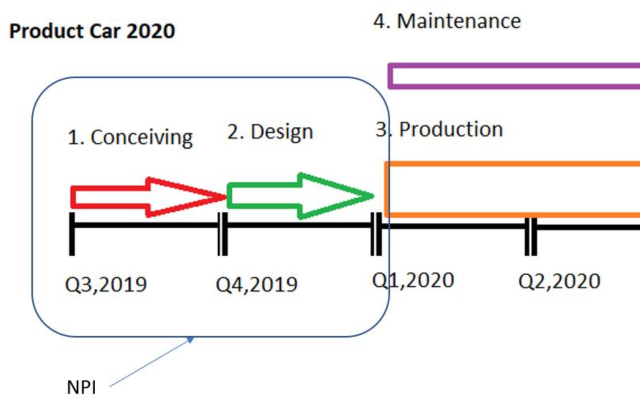

Figure 8 NPI within Products lifecycle

3.1.2 NPI and" Stage-gate"- method

When coming up NPI project it is good to realise that, as with many things, there are different routes to reach the same goal. There are different models how NPI project or more specifically new product development (NPD) can be done. One of such example models is Robert G, Cooper's Stage gate method as shown in figure 9. Simplified this means that there are gates and stages, the gates being made from quality requirements and stages represent the different stages of the products introduction. The project goes like the following. Before moving from "detailed planning phase" to "prototype phase" you must have had met the requirements for the given gate. The requirements must be always met before continuing to next phase of the project or process. Benefit of implementing such procedure to company is to systemize the new product introduction project. And when the NPI or New product development (NPD) has protocol to follow, the time to market is cut down significantly. To quote the man himself: "Stage gate systems simply apply process-management methodologies to this innovation process"- Cooper Robert. G. (Cooper Robert G., 1990)

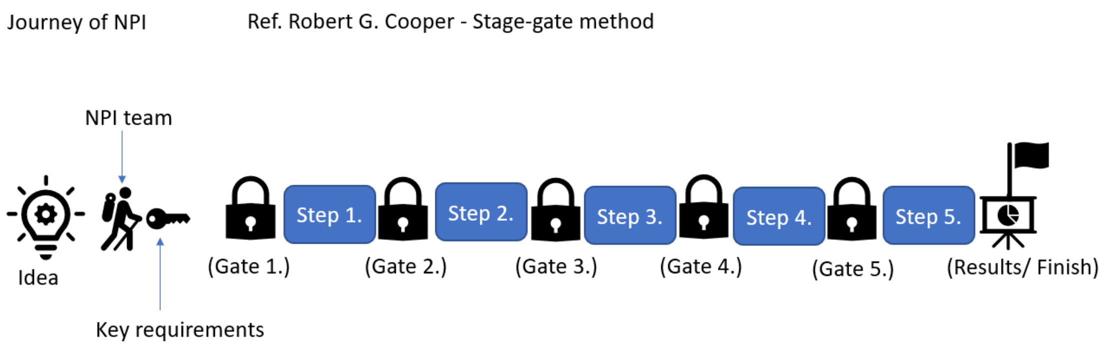

Figure 9 NPI journey, stage-gate method. Ref. Cooper Robert G.

3.2 The passage of NPI project.

The NPI project can be divided into production phases. These phases are pre-planning, detailed planning, prototype, pilot, 0-series and line/mass production. This is also the chronological order in which they appear in. These phases closely reference the manufacturing phases, with addition of designing phase at the start of the process. Like many things in this thesis, this depends on organization and the business case. (WIDB)

Like seen from the previous chapter, the NPI project was divided into "step's and gates" and these are used to categorize and track the progression. Steps closely referring to the manufacturing phases and the work that needs to be done in them.

For example, building a prototype. Physical activity that requires planning, collaboration and has clear end goal. Once this end goal has been reached, the next part is to look at the “gate” or the requirements that must be filled before we can progress to next phase, pilot. These requirements might be, to make changes to prototype model based on the findings during the building and testing of the prototype. So new improved version of the product can be designed for the piloting phase. (Cooper Robert G., 1990) (WIDB)

3.2.1 Pre-planning.

When starting at the beginning. This is the preplanning phase. This is the conceiving phase of PLM, same procedure, looked from two different points of view. Figure 10 shows the Pre-planning as the first phase of the NPI project.

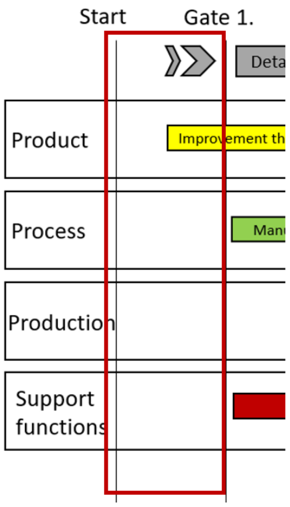

Figure 10 NPI Pre-planning

If the product is totally new, the proof of concept (POC) will happen on this first phase. This is the phase where nothing final is designed. Only the requirements and POC will be went over in order to realize if the product is worth doing. This section can also be the last if the meeting shows that the product that was planned is not worth doing it. If the initial screening shows that the product is not good enough, nothing will be done. However, if the Pre-planning shows that there is potential in this new product it will start to advance further. This potential can be new implementation of new technology or perhaps new product intended for some unmet niche market. During the preplanning it is vital to create the expectations and goals for the new product. Will it be the most efficient diesel engine in the world or the easiest to use smart phone? At this point it should not be the focus if these goals can be reached with certainty. (WIDB)

If the product makes the cut and the project starts to advance, the project leader and team leaders will be nominated and selected. These nominated persons will be responsible for the whole product introduction project. During pre-planning phase, team leaders assemble their teams. And the design team starts conceptualizing the possible new product. This can be to create few alternatives and test and simulate these alternatives to see which design is the best for the intended use case. (WIDB)

Gate 1. Before the project can advance to next step it needs to have met the requirements given. Requirements for this stage could be for example, to assemble the teams, decide leaders, and make a proof of concept. One of the requirements should be to figure out the requirements for the other gates coming up later in the project. And to figure out what needs to happen during the different phases of the NPI project. This helps to create the timeline and schedule for the project, and later on, helps to keep track of them. (WIDB)

3.2.2 Detailed planning

Step 2. After the clearance has been given that NPI project is truly starting and the first gate has been cleared, it is time to start the detailed planning. During detailed planning designers start to make data for the product and elevate it from being just a concept to actual product. This includes, the 3d data, drawings, certifications, simulation, analysis and other activities which create better picture of the product and its challenges. Goal is to create a product that corresponds the requirements passed down from the pre-planning. (WIDB)

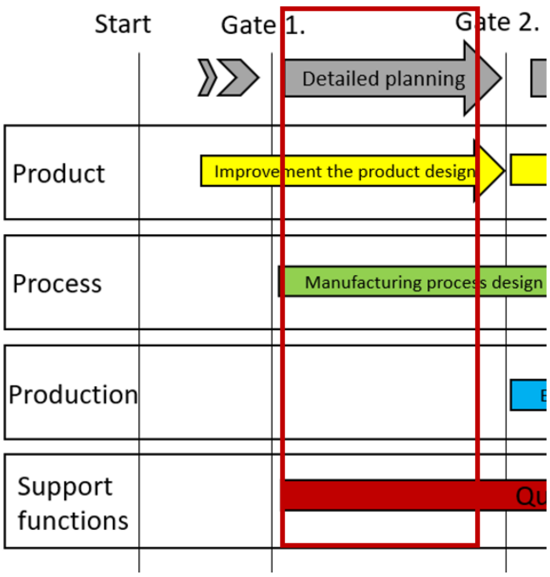

Figure 11 NPI Detailed planning

Same time as the designers are still working with the design of the product, the process team is already starting to create the order of the assembly. Thinking, how and in which order should the parts be assembled to ensure the easiest, fastest and safest assembly process. Two teams must have continuous collaboration since the design of part can determine when it must be assembled and vice versa. This parallel working can be seen in figure 11. (WIDB)

During this time the details of the design are constantly changing. These changes in the design can cause a snowball effect down the line. New designs can show up daily, so it is important that there is connection between the process team and the product team to stay on top of the constant change. Both teams will benefit from this. (WIDB)

Example: part 1 gets changed by the designer to be bigger to increase the performance, Designer looks that the part fits with the assembly. After that process team looks at the part and sees that the initial assembly way doesn’t work anymore because of the size increase. Process team then comes up with solution of how it can be assembled. It could be to assemble the part earlier when there is fewer other items in the way, or it could be to notify the designers that if the surrounding of the part would be changed the same order of assembly would suffice. (WIDB)

On top of that both teams can use simulation methods to test out the upcoming design. Idea behind this is to ensure that when the prototyping phase starts the product ready. By enabling the designing personnel to test some key aspects of the product has the possibility of showing some errors in early phase where changes are still quicker and more importantly cheaper to make. The overarching paradigm of this is that you can make better decisions when you have more knowledge of the situation. When giving the personnel the tools to see the product more in-depth allows them to perform better, and then provide better results. (WIDB)

Gate 2. Before the project can advance to prototyping phase, the requirements set for this phase must be met. These requirements might be to receive the most critical and early to assemble parts, so the manufacturing of the prototype can start seamlessly. And finish the initial product design. (WIDB)

3.2.3 Prototyping

Step 3. Next up is the prototyping phase. Prototyping is to create the early version of product and test the critical aspects. This way the obvious errors get noticed and the design can still easily be changed to be better and more suited for the intended use case. The prototyping will provide valuable “on-field” experience regarding the many aspects of product and use case. (WIDB)

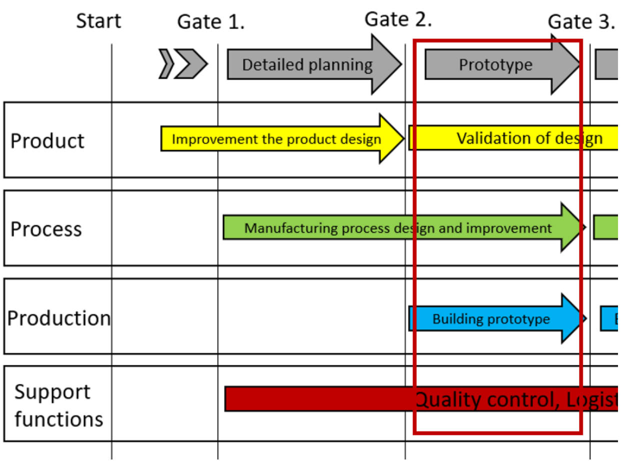

Figure 12 NPI Prototype

During the prototyping phase an active feedback loop from the production team to product and process teams is constantly going on. This can be seen in figure 12.

During the assembly process the early version of assembly order (BOP) will be made and tested. Once the assembly is going, receiving lot of new ideas and commentary about the process should be expected from the production team. This will then further shape the BOP for better. (WIDB)

The prototype product will be used to test many aspects of the product. After the product has been built, it is time to run extensive tests to see how it performs. All this data will be gathered and compared to the previous calculations and estimations. This can show right away if the performance related requirements were met. Prototype phase will also test the assembly process. To see if the order was logical and to see if there were some parts that were still difficult to assemble After the feedback has been collected, it is time for the product and process teams go back to the drawing board and implement the improvement ideas. (WIDB)

Gate 3. This gate before the pilot. Requirements to open this gate might be to finish the testing and test runs with prototype product and make the noticed changes and improvements to the products design. And then order the new parts to assemble the pilot. (WIDB)

3.2.4 Pilot

In pilot phase, shown in figure 13. When the changes to product have been made with the information learned from prototyping, it is time to create pilot product. Now that product works in the intended use case how it is supposed to. It is time to start building the product that will be the same or highly similar as the one you are planning to sell to customer. In prototyping the focus was on the product and does it work. The focus now in piloting phase has shifted a little from the product to more into assembly process and manufacturability. (WIDB)

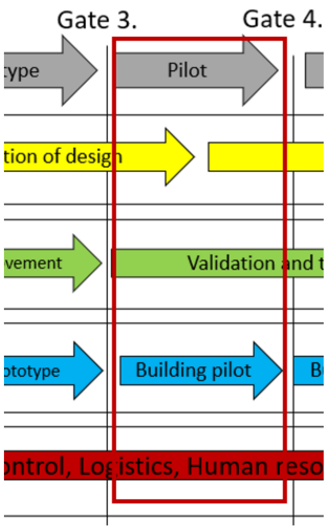

Figure 13 NPI Pilot

Now that the working principles behind the product itself have been verified. It is time to test other aspects that are essential for successful line production in future. These include testing and validating the assembly process, checking the needed tools, and training the assemblers how the product will be assembled and so forth. Piloting phase works similarly to prototyping. Current design parts get made, bought and brought in for assembly. Product team starts to assemble to product, and same time send feedback to the process- and product teams. After the product is assembled, it will be tested. Data gathered during all the assembly and testing process will be collected and used for reference later. After product is ready it is time for changes again. The feedback will be used once again to see what needs or could be improved and the changed. The aim should be how to assemble the product faster, more safely, more efficiently and cheaper. (WIDB).

After the design of the product has been locked the quick changes to it will no longer be possible. From this point onward the changes made into the product will be done with the standard procedures. These depend on the company and its modus operandi but will most likely been some form of “change notice.” (WIDB)

Gate 4. To advance on the next phase of the NPI, like previously, the needed requirements must be met. In this case, these requirements can consist of testing and verifying the assembly process in action as well as make the necessary changes that came up during the piloting phase. (WIDB)

3.2.5 0-series

In zero series, shown in figure 14, the first products to be manufactured on the production line environment after the pilot product. The meaning of 0- series products is to make sure the production line works as intended. That all the tools and machines are where they are intended, and the assembly personnel have the knowledge and skills required. 0-series could be thought as warm up period before the mass/line production begins. This is the time to make some final preparations for the production line before. If the location has changed between pilot and 0-series should the new details be discussed with the internal logistic departments to make sure everything works smoothly. Aim in 0-series is to constantly push the process to make it run smoother and faster. (WIDB)

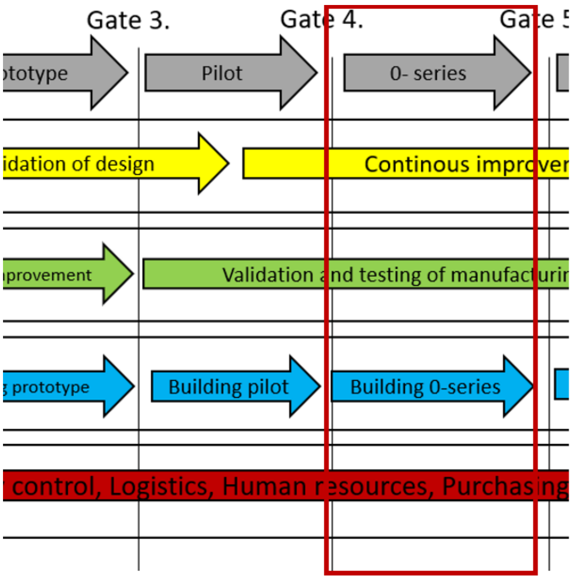

Figure 14 NPI 0-series

Gate 5. When the production line and the personnel are ready it is time to release the product to markets and start building the product for customers. Requirements for this gate are mostly to check and verify the upscaling of the process. This can be in a form of benchmarking results. (WIDB)

3.2.6 Line/mass production

Reaching the line or mass production is the goal of NPI product, shown in figure 15. After that is done, the product is no longer "NPI product "and start to behave as any other product in the company's system. This of course is highly dependent on the company's policy and systems. Reaching this point works like a passing of torch. The line production team has now a new product and NPI team goes on to develop next new product. This is the modus operandi if there is a separate team in charge of new products (NPI team) and other team in charge of line production products. (WIDB)

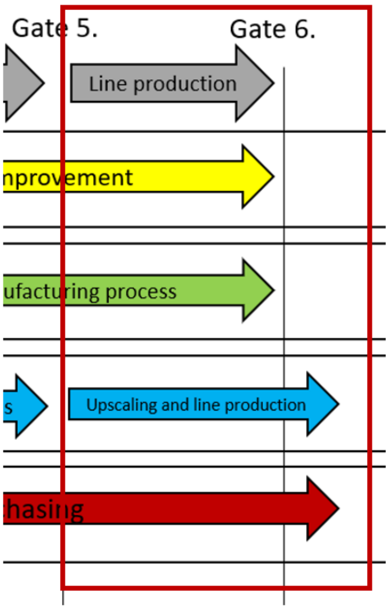

Figure 15 NPI Line production

Gate 6. after line production. In our case where the NPI team and the manufacturing team where two different groups. This happens after the "torch" has been given to production team from NPI team. At this part it is time to verify and all activities have been accomplished. Make sure that all the relevant information regarding the project has been documented and reported. It is also good to record the problems and solutions for those problems that appeared during the phases to ensure that they can be handled better in future. The last remaining thing is to close the NPI project and disband the NPI teams. This usually means moving them into new project. (WIDB)

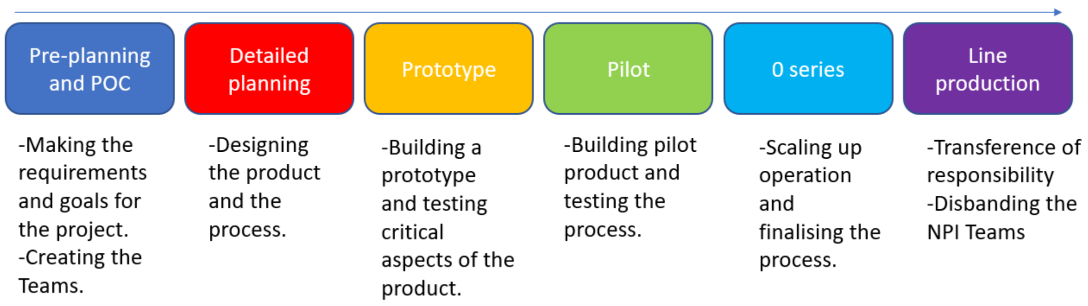

Figure 16 NPI project. Recap

Figure 16. shows the simplified recap of the whole NPI project. This figure shows the main tasks in each of the phases of the project.

4 PLM software, Teamcenter and its suite.

This chapter will take closer look into PLM software Teamcenter (TC) which is one of the available PLM software solutions on the market right now. Teamcenter was used because of its accessibility and that it was in use here in Wärtsilä. This section will not go to in depth into these suite programs and all the functionalities that they have. This is more of introduction of few of the many suite programs that the Teamcenter holds.

Note: there are lots of other PLM software and programs that do the same things and might even do them better from other software providers, but since they are not tied into Siemens PLM environment they will not be talked about. Not having access to these other PLM systems and talking about them would bring little value to the commissioning party. These are two example reasons why this is the modus operandi. Like stated previously this is just one way of doing things and is not necessarily the best one.

4.1.1 Teamcenter

Teamcenter is a PLM software owned by Siemens PLM. Teamcenter is the central software of this Siemens PLM software suite. Main task of Teamcenter in this PLM system is to work as a hub for the data stored. Offering wide variety of tools to handle data management in efficient manner. And being the central component around which the other suite programs attach to the system. (Siemens PLM)

4.1.2 NX

NX is the Siemens owned CAD and 3D modelling program. In NX you can use the data straight from Teamcenter and save the data right back into Teamcenter. This centralized data approach helps when there have been many individuals making the 3d models for parts and sub-assemblies, and it is time to gather all that 3d data into one main assembly. Once all the parts have been made can the assembly also be done within the NX. This process is also called the BOM creation. BOM aka bill of materials is a collection of all the items associated with the product or all the parts within the whole assembly. This can be done all within the NX program with connection to the data bank, Teamcenter. This is the main tool used by designers during NPI to create the 3D models and other data such as 2D drawings and technical documentation. When combined with the workflow management and data storage of Teamcenter, NX becomes quite efficient software. (Siemens PLM)

4.1.3 Manufacturing process planner

MPP for short, is the tool that the process team in NPI use to create the Build of process (BOP.) BOP is BOM divided into assembly steps. BOP could also be though as “Collection of Assembly steps that hold the parts of the product”. Like stated previously, idea behind making build of process is to think through the assembly order of the product. Once this assembly order (BOP) has been determined and validated, can this process data used further to get the full benefit of PLM software. This process data can be further used and examined in the many suite programs that are imbedded to Teamcenter. These include simulation software like Process simulate, where you can use digital twin of the factory floor, to simulate the assembly process. Time and process analyzing tools such as Gantt charts with both time estimates and measured times. Most important use case for this process data will be the manufacturing execution system (MES). From where it can be shared to production and logistic teams. (Siemens PLM)

4.1.4 Active workspace

Active workspace is the browser and website version of Teamcenter. This means that you can access the Teamcenter database by using mobile phone, tablet or other internet connected devices. Benefits in this is that the user doesn’t need download big and sometimes heavy software. And that the data in Teamcenter is practically accessible anywhere. This Active workspace doesn’t provide all functionalities when compared to desktop application often called in this kind of comparison “Rich client”. But for those who must use Teamcenter occasionally or who are not responsible for authoring or creation processes of the data, can Active workspace be good tool to view the data. Opposite of this is the Rich client which is the tool for those who create or manage the data. This separation to rich client and Active workspace can be seen in from figure 17. (Siemens PLM)

Lately Siemens PLM has pushed the role of Active workspace and constantly adding more and more functionalities to it. So, adding the data creation and management options to Active workspace. This might mean that in future their aim is to have most of the users in Active workspace. (Siemens PLM)

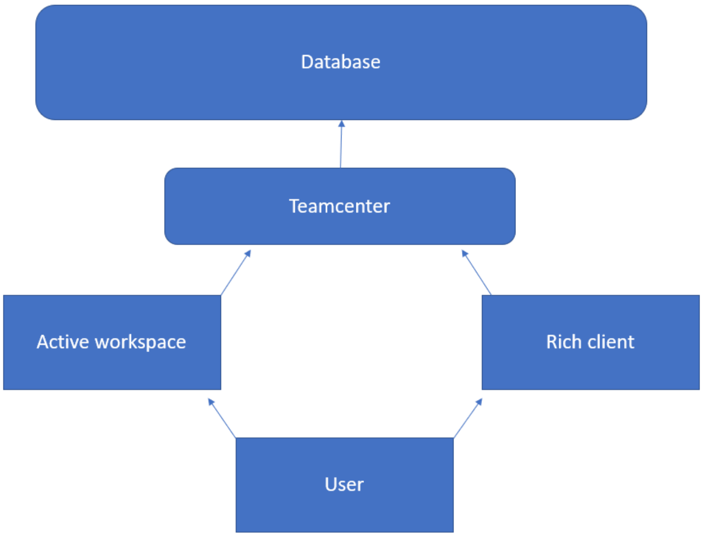

Figure 17 Active workspace structure

4.1.5 EWI

Electric work instructions is Active workspace (AW) based system for showing work instructions in a web browser format. Idea behind EWI is the ability to show the Production team manufacturing the product the work instructions in easy to access and in identical order as the manufacturing order. This gives ability to view the guides of the assembly progresses in the shop floor on any device. These guides are tied into Teamcenter so they can be updated and improved when found necessary. This is one of the instances where Active workspaces can provide useful functionality to shop floor personnel. (Siemens PLM)

EWI reads the manufacturing process and brings forth all the parts and tools from the BOP to be assembled. This can be companied with assembly simulations made by Cortona which is a simulation software or even JT-models (light weight 3d representations) So you can give the shop floor worker the information of what parts he needs, what tools and how to do it. (Siemens PLM)

Note:

There are many more functionalities in the Teamcenter and going through them all wouldn't be beneficial. But they all serve the same main idea. Trying to use the already existing data in more encompassing way. (Siemens PLM)

When looking at the suite programs and other features already imbedded into PLM software such as Teamcenter. At this point the questions usually end up around the subject of managing the data in effective way and getting some meaningful results out of that.

With tools offered it is possible to look the product from so many angles that it gives wide perspective for sure but, where is the line between time used and the value gained? Keeping this value perspective in mind is important because all these tools have a cost. And using too many tools might in the end come and eat up the profit margins of the product. It is a business. This means that cost and value are the main things that make the decision. Or take a lot of precious time, especially if project is on quick schedule.

5 Process improvement.

5.1.1 Background

During the past years Wärtsilä has increased their interest to these modern manufacturing technologies. Idea behind these is that the data made at one step will be used and enhanced in the next step and so forth. When I arrived at Wärtsilä to test these suite programs it quickly became evident that there were many things in the PLM environment that needed to be improved and many quality-of-life changes that should have been made long ago. On further inspection the situation was following. There were people using the PLM software. Back then mainly NX and little bit MPP. IM (infrastructure management) department which was ensuring that the systems were working. And when technical support was needed, the service provider was the go-to contact.

Previously all the issues with PLM environment where slow to progress due to in not being high priority for any of the parties involved. Everyone had their own tasks to accomplish and the issues with the PLM environment was only little side problem. This made the problem solving and improvement of the system quite slow. The persisting problems made it difficult to use some suite programs that were already costing money.

The improvement.

When I arrived and got this problem as my responsibility the plan of action was the following. What was done could be divided into three parts.

1. Creating a procedure that aims to solve these problems, getting higher priority, demanding time of others to do this. Creation of collaborative environment.

2. Solving problems. Creating and collecting & keeping track of problems and their progression.

3. Testing the flow. Testing the information flow in a situation described figure 18. This structure and these suite programs were chosen because they shared data

flow and Wärtsilä had not used all of these before and wanted to find out what kind of value these might bring.

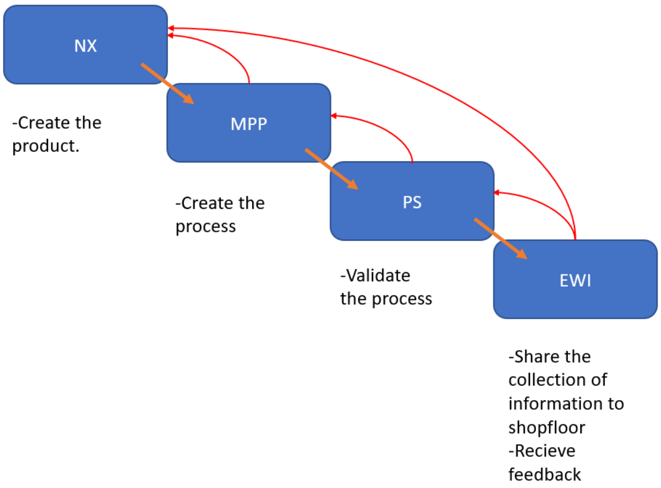

Figure 18 Data flow in Teamcenter suite programs (cycle)

5.1.2 Creating the system.

The biggest problem before was that it was no one's responsibility to investigate and try to push these issues forward. So, this was a first task for me. This led into creating our system for tackling these issues. I gathered a team consisting the key members from Wärtsilä PLM users, IM and from service provider. And with this team we started to consistently have weekly meetings and to tackle these issues that we were facing within our PLM environment. At First, we had overview of our current situation and created a "Challenge list" which would then work as our meeting frame and agenda list.

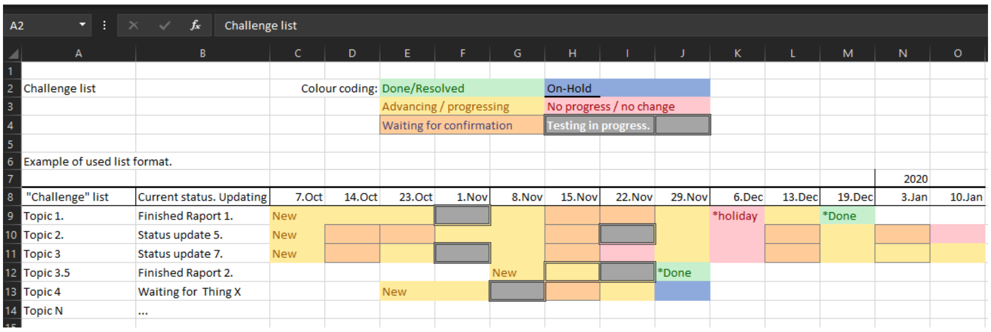

Figure 19 Screen capture of problems list, structure example

5.1.3 Solving problems

Now that the organ for solving these problems had been made the next part was to ask the users of the PLM system what kind of difficulties they have previously had and get user feedback for our problem list. These new ideas were added to the problem list or a challenge list. Problems on the list differed from being simple quality of life improvements, like being able to track certain data value much more easily to objects having wrong rotation in the 3D data, or things showing up differently in NX and in the imbedded 3D viewers of Teamcenter.

5.1.4 Verifying and testing the information flow

Continuous data flow between suite programs was the selling point which made Wärtsilä to be interested in these suite programs. In theory and in marketing materials this data flow works. However, the question that Wärtsilä had was how it is going to work in this customized PLM environment that they have right now. And what kind of complications this might cause this data flow. This whole loop could not have been proven to work previously, due to the existing issues.

This was the topic that I started to investigate during my time in Wärtsilä. When I arrived the first two steps of the loop were in use, but not utilized to the maximum potential, due to not using the later parts. The PS and EWI where not in use at all.

The first part of this verifying process was to install the required software and ask for trial licenses from the service provider. Installing of the Process simulate and linking it to Teamcenter was a relatively quick task. The EWI, however, was more complicated. Using the EWI function in an Active workspace requires that the active workspace is built upon a Jawa framework. Wärtsilä, however, did not have the Active workspace on this kind of a platform so the reconfiguration of the platform was required to enable the use of the Active workspace. After the platform change had been made, the EWI and the whole data flow between the suite programs could be tested.

The testing was to go through this loop with the same data. First using BOM, which is the NX part of the equation. Next up was to use MPP to create the BOP. In this phase the parts from BOM were divided to corresponding operations and activities to create the BOP. Then PS was used to test if this sub-assembly could be done in the order that had been designed. And lastly use EWI to view and share the data made in previous steps and to verify that the whole loop works. This loop can be seen in figure 20.

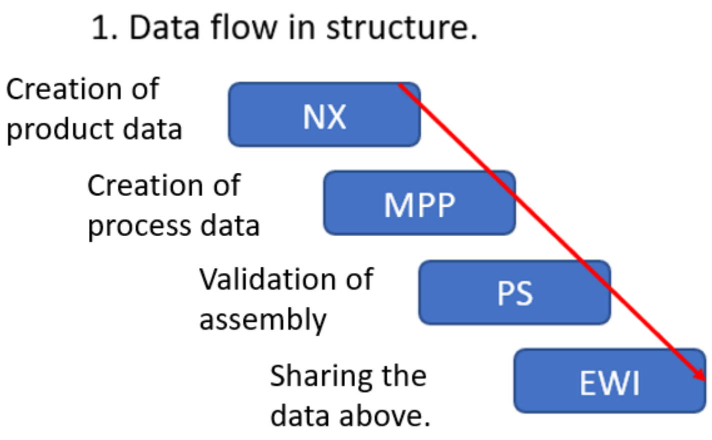

Figure 20 Verified data flow

A few things in this loop were not what they were expected be. With the versions that were used the simulations made in Process simulate could not be easily brought into EWI. The functionality of showing the simulations already made in PS also to the shop floor workers would have brought more value to this loop. It would be possible to fix this later but during the time of testing this could not be done without using third party applications. EWI could not show the simulations as they were, but there is an alternative way. The simulations could be recorded into a video with a screen capture software and this video could then be shown in EWI.

6 Demo video

One part of this thesis was to demonstrate how information flow between the suite programs works and how it could be demonstrated during the detailed planning phase of NPI when the product is undergoing the quickest changes. This was done by creating a demo video showcasing the steps in the data flow process. Video was chosen for the format knowing that more people would be interested in seeing a few minute-long video. The video showcases the data flow and working procedure during the detailed planning phase when the design is still undergoing rapid changes and highlights the challenges that rapid changes may cause.

The video itself will not be shared outside Wärtsilä due to it containing footage of their materials, parts, and items.

Video itself showcases the information flow between NX, MPP, PS and EWI. After the information flow has been showed a change gets made to a part and the dimensions of the part change. Lastly the video shows how the change affects rest of the flow and how it can be managed. This can also be seen from figure 21.

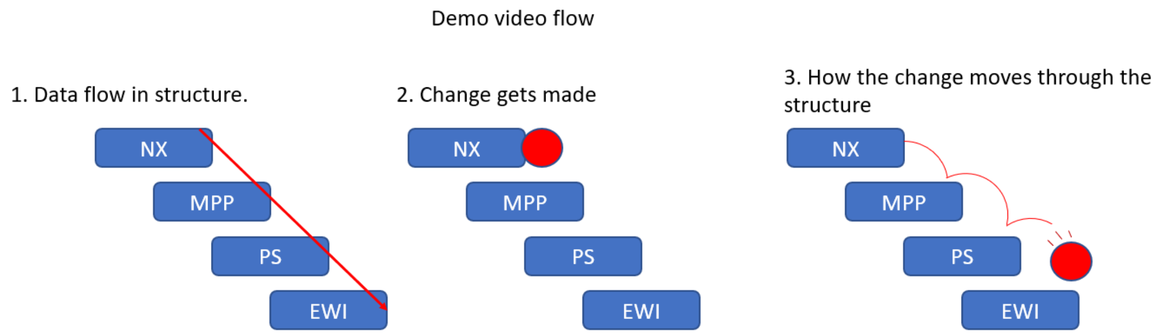

Figure 21 Demo video structure

The demo video could be thought as a continuation of the verified data flow between suite programs, but this time including the quick changes in detailed planning.

7 Possible problems

Like with many things that are complex in nature, problems will most likely occur. This is also the case with PLM software. This chapter will show some examples of PLM software features that might cause some problems. These come from various of different angles. A few of the most probable problems will be introduced and investigated. These are things that were encountered when starting to work with PLM systems and will probably be encountered by most new users.

7.1 Scale of PLM system.

Pieces of PLM software and systems are not small and cheap. These systems require their own servers, cloud storages and lots of people working and maintaining them in operational condition. This means that many small and medium size businesses do not have the resources to implement this kind of a system. On top of that, to maximise the benefit provided by a PLM system such as Teamcenter, requires many people working with the data to justify its high price with useful functionalities. Implementation, the running costs, operational and license fees all these costs, and if there is not enough value generated to justify the cost the system is not going to be worth the investment. This might and will deter smaller and medium size businesses from PLM systems and make them look for cheaper alternatives.

Customizability

If the PLM system is highly customized, that can lead into situations where some proposed solutions will not work. In case of problems it will be much harder to get help and to pinpoint the source of the problem. Trying to find a problem in a large customized PLM system can be difficult to pinpoint in complex system.

7.2 Necessary knowledge.

One of the down sides of the PLM system is the initial level of knowledge required to effectively using the software. This point remains valid for learning any kind of new software or thing in general. But in the environment with complex processes and products can this learning process take bit longer. Trying to make sense of the new digital environment can be hard especially without proper training or previous experience with similar systems. And often the technical manual is the last place people really want to look for answers. But usually the knowledge and skill come from colleagues. This however is only my perception. Without proper training PLM software can be hard to get into.

7.2.1 Closed loop, information flow

Tying closely to last point is the “closed loop of information.” The information can be lot harder to find when comparing PLM system to other software programs. Reason being that there is usually following structure. System manufacturer, local service provider and the end user. This means that the service providers get the knowhow from the system manufacturer and then forward that to the user/customer. This will quickly lead into situation where the information/know-how/ knowledge stays within this closed group. This information flow is shown in figure 22.

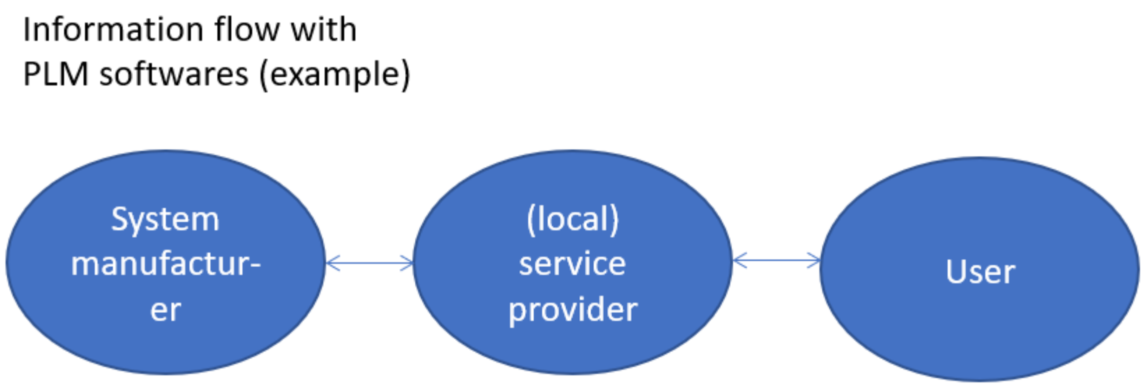

Figure 22 Information loop

When someone new comes along it is hard to get into that knowledge that is “trapped” within this closed loop. In case of urgent technical support, the best choice to find that information is to contact the local service provider.

This does not mean that the information wouldn’t be available. The knowledge is out there, but simple search in google might not give you the answer you are looking for. System manufacturers do offer forums and such platforms for user discussions.

Finding a solution for a current problem from forums can be bit of a longshot. Especially if the problem is acute.

PLM system your company is using might not be “out of the box solution” in other words the system is customized. This customisation might make the “forum solution” inapplicable. In cases like this, company’s own data base might be best place to look for answer, or to talk with colleague with more experience.

Recently more PLM providers are leaning towards the open source approach and in future the open source PLM software might be the next step in the gradual evolution.

7.2.2 Overflow of abbreviations

Like you already noticed even from this thesis work, that there are tons of letter combinations. Some of these have only differ by one letter, so the possibility to misunderstand is high. When learning and just getting into the “PLM world,” learning the difference between closely the same abbreviations can take some time. When hearing BOM, BOP, BOE all in same sentence it will make you want to pause for a moment and process what was just said.

There is no questioning that usage of abbreviations saves time and takes less keys to press when writing. BOP vs build of process. 3 letters or 14. Information / time = intensity. More intense something is the harder it is to process. With abbreviating it is possible to increase the amount of information within less words or letters used.

Context is also important when using abbreviations. In a constant setting like workplace many of these letter combinations ossify and become part of the daily conversations. This needs time and doesn’t happen in a day. The ossifying process requires lot of repetition.

This becomes a problem when outsider, like new employee joins in. These normalized abbreviations will take some time to learn and during the learning process can be confusing. Solution for this is the need to have the courage to ask for confirmations. This is quite universal occurrence and is not only tied to PLM systems or new product introduction.

7.3 Other problems:

Performance. This appears when opening of 3d models and structures starts to take unreasonable amounts of time. This wasted time really hinders the usability of the system. This is caused by lots of other factors which all play a little part in this. For example: large structures, products with thousands of individual parts, server bandwidth, internet connection speed, computer specifications and so forth.

Most software and suite programs need licenses to operate in Siemens environment. This is of course there to combat unauthorized use. But then again when talking about implementing or testing something new will these licenses issue rise up and slow down the process. Example, you want to test software X, the providers usually will give trial licenses to test the software but getting that license will take from few days to few weeks, depending on the case.

Recap: Many of these situations mentioned previously are direct correlation of being new to the system and to the way it operates. Problems can also be caused by the customized system and how it should be operational for many years to come. The working procedures eventually change, and the PLM system should be able to follow this change. This is especially true if the lifespan of product is over decades.

The problems shown here a biased. These are the ones that I have encountered and ones that I have dealt with. They might not represent the widest of picture but will still shed a light on the downsides of PLM.

8 Results

When the thesis project began, the big questions the thesis work tried to answer were:

How to utilize PLM software during a new product introduction (NPI) project, and which suite programs could different members of the NPI team use?

What kind of benefits could PLM software provide in this kind of context?

What kind of difficulties could arise from using PLM suite programs and how to ensure that the PLM system will be beneficial in the future?

How and where the PLM software could be used during the NPI was the first big question that this thesis work presented. To summarize, the figure 23. should bring clarity to the points of an NPI project at which the software programs could be utilized.

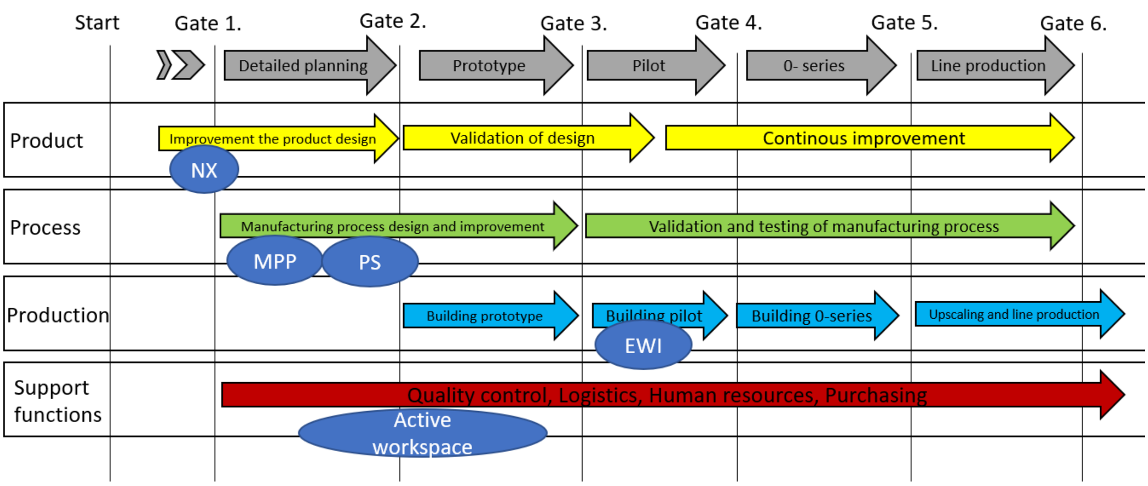

Figure 23 Software suite during different phases of NPI

From the start of the planning, the CAD software NX can be used to design and create 3d data for the product. When detailed planning starts, also begins the creation of the assembly process. This can be done with MPP and it can be tested with PS. When the NPI project proceeds further and it is time to build a pilot, can EWI bring good functionalities to help the shop floor personnel. For supporting functions, the Active workspace can provide a way to peek into Teamcenter data to help with their own respective tasks and to stay on top of the situations of other teams.

When this thesis began, it was suspected that the customized Teamcenter environment would cause some problems during the testing of this data flow. However, it did not have as big an impact as was first expected. Only one major part that caused trouble was the framework on top of which the active workspace was built. Changing this to match the EWI requirements was the only instance when the unsuitability of the existing PLM environment appeared to be a major problem. On top of that there were a few cases where some data types would not work with the suite programs. For example, there was an operation data type in the system and in previous use which would not work with the process simulate. This caused errors during the data import from Teamcenter (MPP) to process simulate. This was much less than what was anticipated in the beginning.

As for the benefits that PLM software can bring to NPI project, the big ones were centralization, workflow, expandability and connectivity. The most relevant of these in this thesis was connectivity. Enabling data flow between programs is of the utmost importance to make it possible for the PLM software to reach the full potential. This data flow can then successfully enable the collaboration of different teams in NPI. In this thesis this was first tested and later demonstrated on a Demo video.

The last chapter talked about problems that might occur when you start working with PLM software. Many of these were direct consequences of not being familiar with a PLM system, and others resulted from complexity which appeared in the form of complex products, processes and systems.

8.1 Recommendations and how to continue.

In my opinion there are still many things that would require deeper insight to make an educated decision on what would be the best course of action to take. One shortcoming of this thesis was concentrating only on how PLM software could be used during the early phase of the PLM ignoring the rest of the lifecycle. This was an acknowledged decision to prevent the thesis from getting too wide. Therefore, it could be beneficial to investigate how this already existing PLM data could be used for the later phases of the product lifecycle, for example, in maintenance business.

Product specific PLM systems is one topic that could provide interesting insight into alternative ways for handling product data. When creating a new product which has been given green light to go forward, one thing to investigate is the value that a product specific PLM system provides. This approach would end up making the system better optimized for the product. However, doing this would cut the connection to the already existing data, and mean that all the data must be made again.

This can also be a benefit, as with a smaller system the software should work faster. This might require more personnel in the PLM system upkeep to constantly configure the system as the product evolves. To make this feasible in a financial sense, this products specific PLM system should be opensource or much cheaper than the current system. This kind of product specific system most likely will be more laborious, at least in the beginning.

One other aspect that could provide some value during the NPI part of the PLM, would be to investigate other alternative software within the Teamcenter environment and to see how they could possibly enrich the data that was already in use during this process. For example: what could we do with suite programs like plant simulate and line designer? Addition of work areas could provide a new point of view for how things could be done, thus allowing the NPI teams to make more educated decisions.

Another direction that could be worth looking further into is the growing role of Active workspace. Like briefly mentioned earlier, Siemens seems to be updating the Active workspace quite regularly and in future it is likely that some NPI teams might be able do their tasks entirely from the active workspace side of Teamcenter rather than on the rich client. The least thing to do is to keep an eye on things and see how they evolve.

One thing that could and should be improved is how to include some of the logistic data flow within this same structure. Currently the logistic team will get the BOP structure through the MES system, but one example for future update could be logistic BOM. This logistic BOM would be the materials of the product divided into pallets and layouts. This change could help with tracking these pallets and bring them to the right place at the right time. A change like this could help with internal logistics and give the logistic team more tools to design the logistic side of the process in more detail. Similar systems are already in order, but they are not under this Teamcenter umbrella so the benefit of continuously updating data will be lost.

The last point about which I would want to know more is how Teamcenter functionalities compare against other PLM systems from other software providers. Are there other, for example, open source PLM systems that provide many same functionalities and for the fraction of the price. So, it could be beneficial to investigate how the PLM systems from for example OpenBOM and ARAS perform.

8.2 Self-assesment

One challenge that I had during the writing process was that when I started to write the theory part of the thesis the exploratory part had still not yet been completely decided. And it took me quite a while and many meetings with the overseeing teacher and with the representative from the company to decide what this thesis was going to be about. From the first meeting it became clear that this thesis would be about how the PLM software can be used, but the rest of the details was still quite ambiguous. So, if I could do this again, I would want to crystalize the idea and the wanted outcome as early as possible. This would then give the direction straight from the start and save some time consequently. This lack of direction came from a few defining factors. One was the fact that I was under NDA, which meant that talking about specific processes, items, or parts, could violate this agreement. This in mind it was decided that the things shown and introduced in this thesis would be shown as generalizations so the details could remain hidden. One was that we did not want to take a single problem we faced as a topic for this thesis, referring to the challenge list, since all these topics on the challenge list required collaboration between multiple parties, and this in turn could in a worse case mess up with the timing.

In other words, we did not want to tie the completion of this thesis to a schedule over which we had only a little control.

The work itself progressed as scheduled. The big questions that this thesis work was trying to answer were answered adequately and on top of that this thesis holds lots of general information regarding both PLM and NPI projects. With these in mind, I think that the thesis work can help to those interested in PLM and NPI projects and the work done during my time at Wärtsilä will prove to be beneficial.

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