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Preliminary report for a PLM project

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Abstract

A need for a better document management system was becoming imminent within Stresstech, and Product Lifecycle Management (PLM) was selected as a preferred approach. There was a real need to plan things first to ensure an easier purchase and commissioning process later.

The objective was to plan the entire process from the current situation to an optimal product data management environment and form a set of development projects to be suggested to the company management. The projects needed to be realistic and the execution would have to be possible without major external resources. The efficiency of the execution had also to be as good as possible to prevent a possible failure of the whole process. The focus of the projects was both on the project value and change management because tracking only the budget and deadline would not have worked with complex projects having a vast scope.

The starting point was formed and there was room for employees to comment and give suggestions about the aspects to be improved to achieve the goal. This was transformed into a description called *PLM Vision.* A vision was formed, introduced and there was room for comments. The vision would function as a description about the desired state and it could be used during the whole process to check that everything would be on track.

The transformation from the starting point to the vision was covered through three development projects. Each was required for a successful implementation and they were planned in a way that a concurrent execution was possible in many phases.

Having the vision and development projects planned was only the starting point. It was meant as a good foundation to maximize probabilities for a successful implementation and efficient Product Lifecycle (data) Management after the projects will be closed.

Keywords/tags (subjects)
PLM, Lifecycle, product data, product workflow, development project

Miscellaneous (Confidential information)
Appendixes 3, 4, 5 & 6 are confidential and have been removed from the public thesis. Grounds for secrecy: Act on the Openness of Government Activities 621/1999, Section 24, 17: business or professional secret. Period of secrecy is ten (10) years and it ends 9.11.2027.
Appendices form over 30% of total page count.

Contents

Figures

Tables

1 The baseline for a PLM Implementation Initiative

1.1 Rationale

Product Lifecycle Management (PLM) is based on Product Data Management (PDM) system at the core, but it also takes into account the fact that there are also other systems in use and product data needs to be able to flow between systems and processes. It sounds like a promising approach that would solve both data management and system integration issues when deployed correctly. PLM is complex, but it is required to handle modern complex supply chains and the constantly evolving environment. It is not easy task and requires multiple changes within company in order to achieve a functional system and there can be lot of rebellion against changes due to multiple different reasons.

A need for a PDM system was identified within Stresstech and there were fears that purchasing another data system would help with the product data management but it would also cause major problems if not properly integrated to the existing systems and the end result would be worse than the current situation.

The purpose of this report is to both form a theoretical baseline for further reference to be used during the implementation phase and offer improvement suggestions for the management about how to transform from the current situation into a fully controlled and efficient product data environment with as little change friction within the organisation as possible.

Stresstech is an over 30 year- old company consisting of the Stresstech Oy main office in Finland, Stresstech GmbH in Germany, Stresstech USA and Stresstech Bharat Pvt. Ltd. In India. The company manufactures instruments for Non-Destructive Testing (NDT). The instruments handle the grinding quality and the process control is based on Barkhausen Noise. The residual stress instruments are based on an X-ray diffraction. In addition, there is also a destructive hole-drilling by Electronic Speckle Pattern Interferometry (ESPI) application for measuring stresses. All measurements can be conducted also within the in-house accredited measurement service laboratory. (“About Stresstech” n.d.).

1.2 Definition of PLM

PLM is an activity of managing products through their life cycles as effectively as possible. Products that do not yet exist and products already shipped to customers are hard to control. PLM offers transparency about the product during the whole product lifecycle, for example to managers (Stark 2005, 2). It was created for the product management needs when the environment gets more complicated and the number of products grows constantly (Stark 2005, 24).

PLM is a holistic activity that addresses many components. For example, in addition to products there are:

- customer
- organizational structure,
- working methods,
- processes,
- people, and
- information systems.

Everything starts from the customer and product. Products bring customers, so the product should be in the spotlight. A lifecycle of a product can then be defined and after that, one can figure out all different people, subcontractors etc. that are needed for developing or supporting the product. (Stark 2005, 20).

1.3 Benefits of PLM

Benefits of PLM are no simple issue. It is common, that effort is made in different lifecycle phase than benefits appear. Looking at the people doing all the effort it might not be worth it if they don’t understand benefits that appear elsewhere in company. And same benefits can be achieved with different improvement activities. (Stark 2005, 45–46).

One can classify benefits with multiple different ways. For example:

- Improves the effectiveness, efficiency and control of products throughout the whole lifecycle,
- increases company revenues,
- cuts costs,
- does things better, and
- manages the product data better.

(Stark 2005, 46–53).

PLM enables a company for example to

- harness the opportunities of Globalization,
- outsource the product development,
- have a collaborative product development and support,
- have a multi-cultural and multi-lingual work environment,
- re-engineer existing processes,
- increase the shareholder value,
- mass-customizing consumer products,
- improve communication,
- improve the supply chain,
- acquire new information systems,
- have a clear strategy with computer systems,
- harness possibilities brought by the Internet,
- focus on the product lifecycle,
- easily trace products and batches etc.,
- audit the product development and improve performance,
- have less complex computer systems,
- handle large volumes of data,
- manage knowledge,
- store silent knowledge from retiring workers,
- have multiple versions of the same basic processes,

(Stark 2005, 97–102).

1.4 Risks in PLM Project

It is claimed by Stark (2005, 53), that over 50% of initiatives will fail. Table 1 below describes some possible causes for failures.

Table 1. Risks in PLM projects (Stark 2005, 52).

Improper starting of the initiative. Scope or funding unclear
Picking preferred solution before starting the initiative
False assumption, that simply purchasing new information system will give good enough results and take care of issues.
Improper planning, implementing systems before evaluating what is really needed.
No tracking for project progress.
Calculating Return On Investment (ROI) with unrealistic assumptions in order to make ROI look better.
No clear authorization for the project from the top management.

Failed involvement of middle managers. Feeling of losing power and resistance to the project.
Failed involvement of all participants. A single department dictates the system and no consultation from other departments. Only a small team working on the project dictates all details without consulting, rejection from other persons.
Unrealistic expectations from marketing talks. Hiring a charismatic business guru is probably not a good idea. Believing vendor promises about the feature being in next release can mess things up.
No clear responsibilities. Unclear roles. Forgetting to build working relationships with the key managers.

It is easy to fail the initiative. This preliminary report tries to find out how to overcome all possible problems but these all should be noted within each development project during the execution.

2 Requirements for a PLM project

This chapter focuses on the theory about PLM, an efficient project model and the general lifecycle phases of a general product. There are themes overlapping in different chapters but it is an intentional way to view important themes from different perspectives.

2.1 PLM in General

PLM is a holistic approach for innovation, developing and introducing new products and product information management from an idea to the end of life. PLM -systems enable technology to integrate people, data, processes and business systems. PLM systems provide the backbone of product information both for companies and their extended enterprise. (“What Is PLM | PLM Technology Guide” n.d.).

CIMData considers PLM as a strategic business approach applying a constant set of business solutions to support collaborative creation, management, dissemination and the use of a product definition information. The fundamental concepts of PLM are:

1. *Universal, secure, managed access and use of product definition information,*
2. *Maintaining the integrity of that product definition and related information throughout the life of the product or plant,*
3. *Maintaining the integrity of that product definition and related information throughout the life of the product or plant.*

(“关于 PLM - CIMdata” n.d.).

There are also modular solutions available that scale based on the company size and need such as Dassault Systems ENOVIA (“ENOVIA™ Mid-Market PLM Solutions - Dassault Systèmes®” n.d.).

A big amount of data is created during a product’s lifecycle. Many people need to access the data. The data needs to be available to anyone needing it. An unauthorized access should be prevented. The environment can be complex if it is logical throughout. If there is a feeling that the environment can be controlled, it enables making improvements to it. (Stark 2005, 51–52).

PLM should be the responsibility of the CEO. All tasks can be delegated further, but the CEO is the only person who is in charge of products during the whole lifecycle. Different departments are in charge of a product only for certain lifecycle phases. (Stark 2005, 7–8).

Information Technology Infrastructure Library (ITIL) deals with similar problems at software development. It has an approach through the configuration management. The configuration management includes managing separate incidents, changes, releases, capacity, service level, availability and service continuity management. (Klosterboer 2008). As one can see, there are many overlapping themes only with different names and details because of different environments between traditional product and software development.

2.1.1 Some Problems With Product Data

A lot of time is wasted on searching information within organizations. Information might be outdated, which causes problems. Or then there are multiple different locations where the information could be located. The worst case is that there are both paper and digital information available and it is not clear where the information one is after can be found. Designs might be accidentally duplicated because earlier designs could not be found when needed, which causesd a lot of duplicate work and

wasted time. Modern systems generate more and more data and the situation easily gets worse day by day. Knowledge Management can be implemented, but as long as the product data is not under control, it will not help. (Stark 2005, 79).

An uncontrolled data entry can cause problems. A mistyped attribute or a misnamed file usually means that information cannot be found. Having different data systems causes problems every time one needs to move information from one system to another. It neither is a manual operation or an automatic process. Manual operations have a risk of human errors. (Stark 2005, 80). The automatic process costs money and it is hard to adjust if changes are needed.

One big problem is that the data is out of phase between different systems. CAD has a valid Bill of Materials (BOM), but the Enterprise Resource Management (ERP) system does not. ERP users do not know that they have incorrect data, and problems can occur, and money is wasted. Project and resource management and production planning becomes hard or impossible because information is not linked to correct up to date versions for example. (Stark 2005, 80)

Multiple sources of the same information can be maintained between different systems. In the worst case nobody has got an idea about what is the master copy. Changes probably do not go through all systems and some stay out of date. If the production has wrong information, wrong parts will be produced for example. Working with subcontractors makes things even worse than with the in-house resources. (Stark 2005, 80).

Uncoordinated engineering changes leave a possibility for unnecessary changes. Design cycles grow long, wrong versions of design data cause problems at multiple fronts. The actual working time required for the change might be a few hours but getting changes done might take days. Change control systems might be bureaucratic, complex and slow. This causes the change process to appear inefficient and people try to avoid it, which causes undocumented changes, and documentation falls out of sync with actual products. (Stark 2005, 80–81)

Missing suitable formal communications cause misconceptions and confusion. Informal communication chains are used instead, and confusion about information validity occurs. Obtaining simple information can take days. The control of

configurations might break down. Nobody knows why differences between as built and as designed BOMs appear. (Stark 2005, 81–82)

All issues above are somehow related to product data and/or product workflow. Product data is all data related to product and processes for manufacturing the product. Product workflow is workflow of the activities that produce or use product data. Product data comes in multiple different forms. Some of it is generated in-house and some elsewhere. Product workflow runs across the product's lifecycle and includes for example welding instructions for a specific part. In theory, product workflow starts with initial product specification and ends with retirement and recycling of a product. But product workflow is rarely linear. Some activities run in series and some parallel. (Stark 2005, 82–83).

2.1.2 Efficient Workflow

A traditional product workflow with a long list of consecutive operations is inefficient. Running it has big expenses, it is slow, has a lot of bureaucracy, takes longer than expected and the delays are multiplicative. There is a lack of management understanding, poor communication, no structure and low quality. A traditional workflow and communication problems are described in Figure 1. The biggest communication problems occur between different functional organizations. By reducing unnecessary steps, errors and changes, it is possible to modify the workflow to be cheaper and faster. A ready product is a function of a product workflow when looking at its cost and quality. Most companies manage individual steps in the workflow but not the entire workflow. An overall point of view and the ownership of the whole product lifecycle are required and problems need to be correctly understood in order to achieve an efficient workflow. (Stark 2005, 84–86).

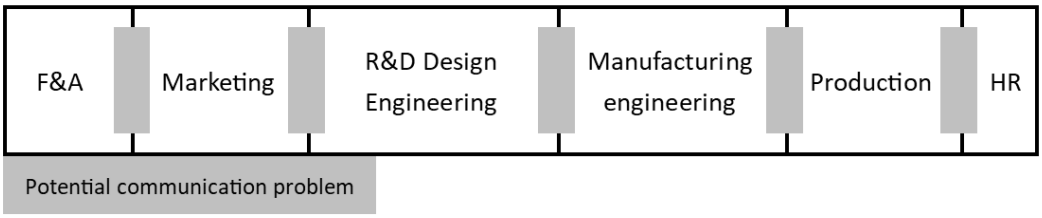

Figure 1. Traditional product workflow (Stark 2005, 84).

2.1.3 Product Data Components

Product data is not maintained by itself. Anything that is not properly maintained will slide into a chaos eventually. (Stark 2005, 86). The product data components are explained below in Table 2.

Table 2. Product data components (Stark 2005, 86–92).

Component	**Explanation**
Definition	Product data describes all data related to a product and processes that are used to define, produce and support it.
Scope	Wide range of different information is included in product data. All different types are used and managed differently. Different types can be for example: • specifications, • schedules, • project plans, • geometry, • formulae, • calculations, • computer programs, • photos, • manuals, • drawings, • sketches, • video data, • comments.

Media	Product data is stored on different media.
	• Traditional media
	  ○ Paper
	  ○ Aperture cards
	  ○ Mylar film
	• Electronic media
	  ○ Microfilm
	  ○ Magnetic tape
	  ○ Different storage devices
	  ○ Different storage techniques
	  ○ Different electric media
	Data management always depends on media used and its special requirements.

Type and format	Product data has many different types, for example:

	• Text data,
	• Numeric data,
	• Graphics data,
	  ○ Vector graphics,
	  ○ Bitmap graphics,
	  ○ Raster data,
	• Voice data.
	Programs are also one type of data to be managed. Programs can be linked to products or processes.

Representations	Even when media, type and format are similar, there can be difference in representations by programs used for example. Line can be defined either by two points or single point and vector.
Data exchange	Data exchange means operation where data is transferred from one representation to another. This operation might cause loss of quality.
Structure	Product data can have structure as in BOM, lists describe structure and relationships and the data needs to be managed.
Options and variants	Options and variants are usually unavoidable. Descriptions of each option needs to be managed and customization increases possible number of options which requires more management effort.
Versions of information	Same information can have multiple different versions. Need of version required depends on need, it can be either latest version or any other. When asking for latest version there should be some way to be sure version received is actually the most recent available.
Versions of systems	Systems such as computer software gets regularly new versions. The risk of not being able to open older version files should be addressed.
Identification and classification systems	These systems are built to keep track of product data. Every drawing, test or any other product data component needs to be able to be identified.

Status	There can be multiple phases product data can be in. In-process, in-review, released, as designed, as built, as installed, as maintained etc. The more mature the data is, the less frequently it is modified. There are different rulesets depending on which status the data is in.
Change	The most product data undergo a lot of changes during the product's lifecycle. Change management adds complexity to the product data management process. There are multiple operations in storing changes.
Sources	Data is created in multiple locations. The source where data is from should be managed.
Users	There are multiple different functions, and each function can have multiple different users that require access to product data. Unauthorized personnel should not be able to access product data, so managing the access rights is not a simple task.
Uses	People will create, modify, delete and refer on data based on tasks they are working on. The background and computer skills can vary a lot between different persons doing similar things.
Locations	Product data can reside in different locations. Either in single location (same building as production plant, server room nearby, on different continent, etc.) or as a distributed system. Or within a cloud service providers system.
Departmental organizations	Multiple departments need to have access to product data. There can also be functions across multiple departments that require certain access.

Views	Views can be used to limit the amount of product data shown. Views should be configured in a way that only necessary data is shown. Views increase during products lifecycle.
Computer programs	Each computer system has its own approach for data management. Programs usually focus on activity-specific functions, not into data management so those only create product data but do not manage it.
Computers	Types of computers used to process product data can vary. Operating system, operating system versions, network configurations, etc. This is why manual techniques for data management is hard.
Data definition	Same items of product data can be defined differently between different departments, which causes conflicts and confusion about the product data.
Duplicate and redundant data	If one does not trust systems and keep their own repositories of product data. This leads into a situation where different groups have different versions of product data, which should be identical. A company usual has the most of product information stored multiple times into different locations. Having a reliable system to provide required data easily and quickly could be one way to circumvent this need.
Vocabulary	There can be different terms to describe the same thing and the same terms to describe different things. Each department has their own jargon.
Data ownership	People usually have contradicting opinions about who owns a specific piece of data. People with the ownership of data are reluctant to transfer the

	ownership elsewhere and probably unwilling to accept responsibilities of maintaining the data properly and making sure the data is available to others.
Volume of data	A big amount of product data is generated quickly with computers. Data storage needs to grow at the same pace to keep up with the amount of data created.
Security	The security rights change during a product's lifecycle. In addition, the rights can differ between different projects and products. E-mail for example is not good a way to secure product data.
Archiving	Product data needs to be kept for a long time. Some storage medias are not suitable for a long term data storage. Data should be capable outliving the systems that generate the data originally or process it later. A company needs to be equipped to handle product data created by currently obsolete software.
Corporate asset	All product data within a company represents its collective know-how. It is a major asset and it should be used as profitably as possible.
Islands of data	Different computer programs use different file types and interoperability is usually impossible. If other program is capable opening a file, it might not be able to extract all the information that is stored into the file that the original program can access. Many programs do not tell how the data is stored and how it is structured. So, each software can be one island of data.

All product workflow activities create or use product data. A product workflow is closely linked into product data. The product workflow consists of activities and the data is transferred between the activities. If the transfer is not automated, searching and transferring information can take a big portion of time spent for the entire activity. The more people there are to create and use data, the harder it is to do a manual data transfer. When automation is added to transfers, the workflow should be improved first to enable an efficient information flow. If that is not done, one can end up with an inefficient automated information flow and workflow. (Stark 2005, 93–94).

One might falsely presume that the information flow goes only from the beginning of a new product into product retiring. Some of the definitions can though be reused and previous product data can be reviewed to be created even better. This kind of more flexible information flow makes the product data hard to manage. The product data must be kept in control. There can be legal requirements to be able to trace the origins of any product problems with detail. Computer based systems have a concept called master data that defines where the main data is that will be traced as a slave to another system. It is easy to have irreversible conflicts for example if there are no ways to merge both master and slave data changes fluidly. The quality of the product data must be high meaning that it must be reliable, available when needed and accurate. This can only be done through company culture encouraging good quality data and penalising poor quality. Error creation and propagation must be prevented. Data management should span both the existing data and the data that will be created in the future. The data should be secure against an accidental deletion of one's changes made. In addition, moving data between different places must be handled reliably. Any suspicions must be able to be answered with an credible answer that assures people having doubts. (Stark 2005, 94–96).

2.1.4 PLM Vision

Execution overlaps with chapter 2.2 Project. This part goes through only the matters that are tightly included in PLM. A more thorough view of the execution is formed later. This chapter covers only PLM specific themes of projects.

Making a plan for PLM implementation starts from the mission and objectives. After that, a vision is created. The strategy is created based on the vision and finally a plan is made. The vision must always be company specific. It is based on the assumption that a company wants to handle its product lifecycle activities as effectively as possible. The vision must make sense to everyone. It must be believable and realistic and at the same time next to impossible to implement. The vision must be communicated to everyone likely involved on or affected by product lifecycle activities. The content must be clear and understandable. And all whom it may concern must be able to relate themselves within the vision. A consensus is also required. A shared vision helps everybody proceed towards the goals. Building a vision requires part time working by a team of people over a period of few months. It is a low cost activity that requires no acquisitions and it is a much cheaper operation than the actual implementation of PLM. (Stark 2005, 132–36).

The vision must fit into the company vision, mission and objectives. One step towards the vision is to understand the scope, range and content of the product lifecycle activities. The development of vision, strategy and plan requires consideration of everything that may influence product lifecycle. Both high level executives and people working with low-level activities with the product lifecycle are required for a better vision. The vision needs to provide a clear and complete description that can be communicated without an information loss. A lot of thought must be put on identifying all relevant parameters. Without a vision everything just drifts somewhere and there is no agreed destination where to aim. (Stark 2005, 136–144).

2.1.5 Strategy

After a vision has emerged, the next step is focus on the strategy. The strategy should describe how the organization should look like in five years and how the resources will be used during the product life cycle. The reference point for the strategy could be obtained from military strategies because of possibly unreliable case study descriptions from the industry. Autobiographical descriptions might not be that accurate description of a realistic process. Military strategies are in a large scale and they can accommodate some individuals who do not aim to the common

goals without being distorted. There are common themes in the military strategy through the time and a certain number of repetition. Strategies are always dependant of external circumstances and a successful strategy can become a disaster if the environment changes. A strategy must be simple, and it must be described in a few words. That is the only way they can be communicated successfully to people who must implement them. Changing the strategy during the implementation is not suggested. (Stark 2005, 163–170).

Military strategies have simple principles. 11 of the most important principles are:

- Keep the basic objective in mind, do not be distracted.
- Offensive strategy is required in the long run to achieve victory.
- Co-operation between different resources is required.
- Concentration of effort into a weak point.
- Use a minimum effort required to achieve the goal.
- Strategy should be flexible and be able to evolve depending on how things evolve.
- Surprising enemy.
- Securing against enemy surprises.
- Simplicity because complex strategies are hard to communicate and execute.
- Keeping morale up.
- Administration and logistic support.

(Stark 2005, 171).

Manufacturing the strategy has evolved through the years. From a single piece production into a just in time logistics mass production. Manufacturing strategies should change always when manufacturing resources and/or technologies change. Company strategies are usually copy paste solutions that are combined into various combinations that suit each company best. The basic principles for PLM strategy according to Stark (2005, 179) are:

- *Focus on the product,*
- *involve the customer, listen product feedback,*
- *remember the planet and mankind,*
- *simple slim-line organization,*
- *highly skilled people,*
- *use of modern technology,*
- *coherent PLM vision, strategy and plan,*
- *continually increase sales and quality,*
- *reduce time cycles and costs,*
- *watch the surroundings,*
- *maintain security.*

The strategy is created in five steps. First the information is collected. Based on the information, possible strategies are identified. The best strategy is picked, and it is communicated. Finally, the strategy is implemented. The vision describes the company future, so the information collected should address the current situation both within the company and around the company. Strategy identification should always have multiple possible strategies because it will increase the probability of finding the best strategy. Strategy elements should be described in detail. List of strategies are analysed and compared with a set of questions or for example with the SWOT -analysis and the best one is picked. The selected strategy should be communicated to everyone who will either be affected or involved. People need to be fully aware of it and they must be able to understand and implement it. (Stark 2005, 195–215).

2.1.6 Execution

Bringing change requires time. And PLM brings a lot of changes. All the changes must be effective through the whole organization. The changes PLM brings are not concrete compared to purchasing a PDM system or new machinery that has different tooling compared to old ones. “reduce time-to-market by 35%” is not easy to grasp on. But still there needs to be full a understanding about how the change is required. (Stark 2005, 217–220).

One of the most important components of PLM are Product Data Management (PDM) systems. They manage both the product data and product workflow. PDM is a multi-user and multi-organization environment. Without a PDM system there are only small odds to have a successful PLM implementation. (Stark 2005, 233–243). The financial justification for PDM comes from a more efficient workflow that reduces overheads and makes it possible to get products faster to markets (Stark 2005, 310–12). A more detailed financial justification is described in chapter 2.2.

2.1.7 About PDM

Failed PDM implementations have multiple different groups of barriers. These include system, people, project team, process, organizational structure, funding, information, installation and everyday use. A PDM system and system vendor can

have problems such as an incomplete system functionality or malfunctions, an unresponsive system and a system being unavailable a significant amount of time. These issues can surface any time from the start-up phase to the daily use phase. A company selling a PDM system can go bankrupt for example. If something like that happens, a company has learned from their experience and have established practices for data handling. Newer systems also usually have more advanced features. (Stark 2005, 333–34).

People as a barrier can be at any level; from the top management to users. The top managers can be distracted even when PDM system benefits are clear to them because they have also other things in mind. There might be fear of losing one's own position because of PDM between middle managers. Changes in the organizational structure usually reduces the power of functional departments. (Stark 2005, 334–336).

A project team should work like a team but there is a big risk that they work like a bunch of individuals. It is important that the whole team knows their role and it is not only purchasing a PDM system from a vendor but also having responsibility to support the system after the implementation. Users might attack the team because the system does not work as promised for example. If consultants are used, their responsibility ends as soon as their bill has been paid , so they should not be in any bigger role within the group. (Stark 2005, 336–338).

2.1.8 Processes and PDM

If the processes are not understood, PDM will not support the product data flow. All processes should be identified, clearly understood and if there are multiple alternatives, one of them must be decided. It is important to keep processes lean to achieve the goals of less overhead and faster reaction times. The organizational structure might have to be altered. PDM does not belong to a single department. It might be unclear who oversees the system. If each department can function freely within their own responsibility areas, each department will have the ownership of their product data and data structures in addition to working practices will vary between the departments. (Stark 2005, 338–340).

It is possible that some departments do not want to fund a PDM system because they are not sure if they will reap the benefits from it. Some may want to reduce spending to an already installed system if the benefits are not immediately apparent. There can be a temptation to spend into some newer technology instead with big expectations about the benefits for a small effort. Issues with information can arise from creating data or the system does not support some data types. Information is a source of power, so some people might not want to give up their power for a computer system. Within a system, there should be clear characteristics to data stored that can be searched and found easily. (Stark 2005, 341–344).

It is likely that there will be issues in the installation phase of the project. Either the system does not work as intended. The system might be buggy or there is no documentation or examples showing how the system is supposed to be used. In addition, there can be problems with money, time and people. To minimize issues, there should be accurate estimation for time and money required for the installation. Funding or labour can be withdrawn even when it is promised earlier on. A lack of training people or more important tasks that prevent working on installation can also be an issue. Work of the project team does not stop when the installation phase is ready. Preparations are required to face possible issues with the system functionality, lack of training and support, lack of funding, and failure to make the necessary organizational changes. During installation, people probably have a lot of patience but when the system is in everyday use, requirements ramp up. (Stark 2005, 344–47).

2.1.9 More Efficient PDM

PDM has four stages of evolution. Activities for getting to the next stage differ greatly. But in general, it is a process with five steps. First, the current situation needs to be understood. The second step is to understand the situation desired. Next, a strategy is selected to get from the current situation into the desired one. The fourth step is developing detailed plans and the final step is the implementation of the plans. Stages are greatly simplified to give a general view, in reality the criteria are more complex. A first stage company usually develops individual products starting always fresh and show a great interest in the performance of products.

Second stage companies have developed product modules, but the products are individual and only some reused parts between products. Third stage companies focus on customers, have at least identified and started development of platform products and have direct contacts between product developers and customers. Suppliers are involved in product development teams and there are metrics to manage the product development activity performance. Final fourth step companies have strong focus on customers, involve suppliers early on, flat cross-functional organizational structures, regular contacts between product developers and customers and a widespread understanding of the product development process. (Stark 2005, 367–377). A tool for viewing the current situation within a company can be found in Appendix 7.

2.2 Projects in general

Projects are activities that have defined deliverable, something that is created during the project. It has a defined end date and budget. The project has a lifecycle, it uses a wide range of resources and it will involve people with varying contribution during different project phases. (Roberts 2007, 6–7).

A project in an ideal situation can be considered as a temporary management environment that is created to deliver specified results according to well defined business justification (Roberts 2007, 10–11).

Projects have two different dimensions. There is a framework that supports individual projects and actual projects and define for example the resource allocation and possible support mechanisms for projects. The following chapters are separated under the framework and execution accordingly, for more clarity even when everything is closely connected in reality.

2.3 Project Framework

2.3.1 Project Value, Risks and Optimizations

There should always be a realistic value for a project instead of simply executing the project on schedule and on budget (Berman 2007, 1–2). When project execution introduces changes, the change should be adapted by stakeholders in order to get good results from the project (Berman 2007, 7). Getting approval and buy-in for the project from the top management can be expected to be hard but it is essential for the success of the project (Berman 2007, 9).

There are two different ways to solve problems a project faces. One is problem solving one problem at a time when problems occur. Another is a risk-based approach. An effective project management is done with the latter approach. It is better when one tries to anticipate problems and reduce risks already before any problems have surfaced. That way there are more solutions available to solve possible problems and there are less surprises. (Roberts 2007, 3–5).

There are multiple risks that can hinder the outcome of a project. Missing the vision or a poor communication of the vision can cause problems. There can be a powerful will to maintain the current status quo. A project can be considered being successful too early and real changes do not have enough time to anchor into the organization culture. There can be a lack of planned short-term wins or those are not delivered. The project steering group is not powerful enough or the organization does not have any sense of urgency and they do not understand why changes are needed immediately. (Roberts 2007, 4).

A successful project management starts by asking questions. What are the things that matter? Where can the biggest benefits be reaped at with the smallest amount of resources? The benefits of a project must be sold to all different groups separately. Having a list of benefits available when objections arise is helpful. A good project management allows right people doing good quality decisions at the right time. Participation from different groups can be encouraged to achieve mutually beneficial results. Milestones must be clear and understandable, and justification of initiative must be regularly reappraised. Emphasising risks and preparing for them

help to reduce the impact of risks that actualize during a project. Even the unforeseen problems should be managed. Quality must be agreed on and all change should be always managed. Clear roles and task allocation helps to prevent overlapping operations. (Roberts 2007, 4–5).

2.3.2 Governance and Effective Project Management

Purpose of a project is to produce benefits and add value. Benefits should be bigger than investment. Thinking about value might help when number of projects to achieve selected goal is decided. Within single bigger goal, having same governance within each project is important. And value should be considered at broader perspective as combined value of all projects. That is because some projects might only develop framework and thus only generate costs and other projects that reap the benefits from framework developed by generating income. (Roberts 2007, 8–12).

Effective project management requires beneficial environment for commissioning, management, funding, specification, building, testing and delivery. Project needs sponsors and owners. People who will make sure that project is promoted. (Roberts 2007, 12). More detailed description of roles can be found from chapter 2.3.4 Project Organization.

Project management requires systemized approach. Well defined approach to project management also called as methodology. Methodology is usually a document describing processes, responsibilities and deliverables and it is only supporting project management. It can be misunderstood as too bureaucratic or too restrictive, therefore it should be always considered properly before deciding about using it or ignoring it. Systemized approach usually consists of:

- overview of methodology thoroughly enough,
- list of roles and responsibilities,
- procedures or steps required,
- results describing what different steps must produce, templates for outlining the look and feel of the most common deliverables,
- examples about how completed template might look like,
- and answers to questions that are likely to arise.

There are industry standard methodologies available, but the most important requirements for methods are:

- references about successful usage elsewhere,
- robust and consistent without evident faults,
- clear, easily sold, communicated and easily understandable,
- must be able to promise real value in return for the investment,
- needs to scale between varying size, complexity and risk,
- needs to be relevant for all types of projects that will be executed.

(Roberts 2007, 13–14).

Organization structure that is supportive for projects make project management effective. People need to understand what projects are and understand project - related vocabulary. (Roberts 2007, 15).

Project managers need to have understanding about project management and sufficient experience of project management. Specialists that are experts within project scope is not enough because project managers oversee project schedules, costs and quality expectations. Project managers are probably the most important persons involved within a project. (Roberts 2007, 16).

There are software-based support tools available for project management. They are providing sophisticated features to support projects. Software collects information about progress and generates reports and analysis that is shared. Project tools are limited mainly by data collection fitting within organizations working practices and possible laborious implementation of the tools. Using such tools should be carefully considered and expectations about delivered values and operational risk of instalment should be thoroughly analysed. (Roberts 2007, 19).

2.3.3 Managing Portfolio of Projects

Usually company has multiple projects ongoing at the same time. Portfolio of projects needs also to be managed. Multiple projects are competing from same resources within a company. No funds for all the projects, conflicts between projects, need for resources that affect normal functions of a company. Portfolio management requires multiple criteria to rank projects and execute only the ones that offer biggest rewards. (Roberts 2007, 15).

Traditional approach for project identification is by department. Every department have their own portfolio of projects. Departments are formed to execute business as usual, so project management becomes inefficient. Inefficiency comes from

interdependencies between different projects that are executed on different departments and successful projects require extensive co-operation between different, separate departments. Some project resources depend on other departments that have separate incentives. (Roberts 2007, 22).

One way to identify projects is to classify them by business objective. It requires change of company culture and it carries its own risks. This approach requires a companywide portfolio of projects to help with co-ordination and resource management. Portfolio of technically, strategically, and/or commercially interlinked projects are called programme. Programme is bit like project that has many sponsors, can be corporate disaster if it fails, is focused on business objective, has a wide scope and includes business-as-usual activity. This means, that not every development initiative must be a project and if project is born from a need of single part of an organization, it can be governed elsewhere where it is seen the most effective. (Roberts 2007, 22–28).

There should be both a date for identifying all relevant projects and resources should also be reserved to initiatives deemed worthwhile that become important when world changes after project identification. During identification either a portfolio of projects is created at first time or new projects are slotted into existing portfolio. New projects need to be selected, prioritized and commissioned actively during identification. In addition, basic information about potential projects must be known to help decision-making. Companies usually have metrics to outline potential projects. Metrics should be clear and available for all who it may concern. Metrics can also be called project outline. (Roberts 2007, 28–29).

Project outline typically includes:

- Sponsor who has driven the initiative,
- Title that can be either descriptive or code name,
- Objective that describes the purpose of the potential project,
- Benefits that can be expected from the project,
- Project scope,
- Project deliverable,
- Schedule with the most important dates,
- Investment required for the whole project,
- Investment needed for next stage of the project,
- Assumptions used during planning,
- Known risks for the project.

When every project has similar information available and when details are commonly understood, it is easier to pick the right projects. Havin well-articulated business plan helps with project identification. Business plan should also be balanced to indicate different categories: commercial, customer, process and learning. The whole business plan is divided between four categories and similar weight is given to each category. One needs to remember that all categories are linked, and statements should always be checked to make sure everything is consistent. Usual mistake is focus only on commercial projects, but it makes company unbalanced in the long run. (Roberts 2007, 29-34).

When business plan is well balanced, next step is assessing how project contributes to business strategy. Involvement of each project to specific strategy step can be evaluated. Effect is direct, indirect, partial or absent. Creating a matrix of involvement to each strategy point project by project gives information about which projects contribute to which strategy point. It is easy to draw conclusions about project portfolio support to business plan as can be seen from Table 3. When all the projects are added to the matrix, choosing between projects gets much easier. But this way is incomplete. It does not assess project risk and rewards at all. In addition, there might not be resources for all projects that seem relevant with criteria above and some need to be either postponed or cancelled. (Roberts 2007, 34–39).

Table 3. Project matrix (Roberts 2007, 35).

Strategy point (category)	Project #1	Project #2	Project #3	Project #4
Increase recurring sales (Commercial)	Indirect	Indirect	Absent	Absent
Faster reaction times to customer requests, 2 days faster (Customer)	Absent	Absent	Direct	Absent
Increasing internal quality by 10% (Process)	Direct	Direct	Indirect	Absent
Tailored courses for staff (learning)	Absent	Absent	Absent	Absent

Risk and reward can be calculated separately, and each project can be placed into risk-reward matrix. Table 4 has good example criteria for calculation. Each criterion that matches gives project one point and points are summed and project is placed to risk-reward matrix. In the matrix there are four different types of projects. Empty vessels that offer small rewards with low risk. Money pits that offer high risk and low rewards. Some projects might be so important, that they must be commissioned no matter of high risk and low reward. It is not outright permission to dismiss a project if it falls into this category. Low hanging fruits are projects that give big rewards with small risk. These are more preferred compared to empty vessels because of bigger rewards with similar risks. And the final type is make or break. These are controversial, and these are the projects that should have thorough examination of costs and benefits before decisions. When all work described above is done, all there is left is securing financial resources already discussed in project outline: cost of first stage and cost of the whole project. (Roberts 2007, 39–41).

Table 4. *Rewards and risks of a project* (Roberts 2007, 39).

Risk	***Reward***
The project will present significant technical challenge.	*This project is strategically imperative.*
The project will require significant procedural change.	*This is a regulatory or legally mandated project.*
The project will require significant organizational change.	*There is potential for long-term value creation.*
Implementation costs are expected to be high.	*Perceived expected financial benefits are high.*
The project cannot be implemented quickly.	*Expected value to customers is high.*
There is little appetite and/or capacity for this proposal.	*Expected value to employees is high.*
There will be significant impact on business as usual.	*This project includes a "wow" factor.*

2.3.4 Project Organization

In general projects should have an organizational structure that enables different people to have authority to make right decisions with the help of their experience, skills and knowledge. The structure should also be customized by the projects needs and there also should be means to satisfy expectations of people involved. The organizational structure should include all the required knowledge, experience and personal attributes to execute project successfully. (Roberts 2007, 42).

Highest level or project organization should be portfolio management team that manages portfolio of projects by criteria discussed on previous chapter. Each project has a steering group that is responsible for project success. Steering group authorizes project startups and significant changes within projects. Steering group persons should be able to be committed to successful project outcome, have authority to do decisions, can provide resources for the project and are experts with detailed knowledge of their own fields. Steering group should not be a committee and usually scheduled project steering group meetings are preferred. Steering group leader usually is project sponsor whose responsibility is to promote the project, have ownership of the project and thrive to successful project outcome. (Roberts 2007, 43–46).

Project manager oversees project co-ordination on behalf of project steering group. Project manager has limited authority and all decisions outside project managers authority should be done within steering group. There are project manager grades available that describe different level of project management skills and steering group is responsible that project manager has good enough skills for each specific project. (Roberts 2007, 43–50).

Project organization structure should have some checks to validate against risks. Successful structure enables effective project organization. There should always be separation between project ownership and day-to-day management. Clearly identified single project manager and other roles have been assigned to people who have authority to undertake responsibilities assigned to them. Organization should have authority to make decisions needed within the project and commercial, customer and developer perspectives should be included in project steering group.

All individuals should have been clearly assigned all responsibilities that are identified, and everyone needs to be comfortable with one's responsibilities. In addition, the most important stakeholders should be accommodated into organization structure. (Roberts 2007, 50).

2.3.5 Possible Support Mechanisms for Projects

Support, mentoring and coaching offered to support a project is good measure of company's commitment to project management. Investments in training do not help itself, it is only worthwhile if people work and learn together. There are multiple ways to achieve learning. There can be coaching events soon after the training to make sure that lessons are embedded to ways of working. Working lunch refreshers to refresh knowledge and skills. Skills forums to share experiences and raise standards. Newsletters to provide information about projects to broader audience. Road-shows that aim to maintain interest in project management relevance and invite participation. Intranet -sites that maintain the most current version of the truth. When requested, buddying can be effective. This means that a buddy is assigned to individual(s) that people can learn from. But if people don't find value in buddying, participation will cease. (Roberts 2007, 17–18).

Project assurance is a mechanism that enables checking project against effectivity of project management and potential to deliver the benefit defined earlier. Assurance can be either formal audit or other smaller scale check. In addition, talking about audit can increase fears and hide some problems under the surface. Purpose of project assurance is to increase likelihood of successful result coming from a project. Project assurance can be either health checks done within organization by expert people not involved within specific projects. Or audits, either internal or external. Audits are usually required when there are alerts about project being about to fail. In all cases, there should be competent people reviewing projects and able to propose solutions to fix problems that are found within the process. (Roberts 2007, 18).

Experienced companies have project support or assurance function. Usually they are combination of support and assurance either for specific projects or for a portfolio of projects. Otherwise these functions are as diverse as projects can be and specific functionality is dictated by needs. (Roberts 2007, 19).

Support and assurance function is good way to provide help during confusing and or demanding project work. This function has no typical structure because it is tailored to specific audience that have various and many needs. It is not necessary to have such function, but it can help by doing some work for project managers and or portfolio management team. The function should be outside any individual project as a general resource for organization. Such function generates costs, so it should be created only when there are for example experienced people to do it and sufficient authority within project steering group to direct it to desired outcome. It should be clearly defined who will be served and what are expectations. In addition to that, there should be multiple points addressed in order to achieve successful support function. (Roberts 2007, 207–12).

2.4 Project Execution

2.4.1 Project Planning

Stakeholder map is an easy way to identify everyone who may affect or be affected by a project. Structure of a map can be three levels: stakeholder groups, subgroups and individuals. Every line should be traced until an individual is found. Such individuals are good candidates for project management team. To help decide the composition of management team a stakeholder matrix is a good tool. Stakeholder matrix has two dimensions: power and support. Power is both authority derived from job title, persons knowledge and expertise. Support is a degree how much a person will back the project. Situations are not static, so matrix can be out of date quickly though. Matrix has four squares. People with high power are either terrorists or promoters depending on level of support. And people with low power are either hecklers or supporters. Terrorist should at least be seriously considered to be included within project steering group to let them take part and address their concerns more effectively. If there are no persons with high power, it should be seriously considered if project can secure all the resources it needs. It is also good to keep in mind, that people with low power can group up to gain power and influence. In addition, persons can either fall or rise to power. Therefore, matrix should be

updated regularly to reflect real situation. Project management structures are dictated by project needs so there are multiple different successful structures depending on the types of the projects. (Roberts 2007, 56–58). Matrix can be also useful when listing people that are targets for change. People with high support are either persons that can influence or people who have authority and position to make change. And people with low support are the target for the change. (Berman 2007, 112–114).

Within a company there can be resource pool. It is a group of people who are within single management structure and usually have common skillsets. This is one way to make sure that business-as-usual does not harm project execution. If company has only one person that can handle complex projects, it might hinder important projects badly. One way to overcome conflicts between projects and business-as-usual is called matrix management. It means, that people are managed both within line organization and different project structures. If management is used successfully, it allows delivering business-as-usual and projects better simultaneously. (Roberts 2007, 64–68).

Projects usually involve a combination of processes, organization or technology. Some projects involve all of them and all projects probably involve at least one of them. And all of those involve people. Projects change processes by changing how people work. Or organizations by changing co-operation procedures. Or new technology change things around. There is always starting point and goal, a desired state of things. This is why change management is essential enabler of project success. (Berman 2007, 89–91). Change management is discussed more thoroughly in chapter 2.5.1.

One way to help change process, accountability can be created. People should have incentives to achieve results and be accountable of unambiguous indicators. Assigning KPI to people requires detailed accountability plan. Indicators can be assigned to persons, groups or teams. Assigning to persons is always the best way but usually it is not realistic option. There should be action plan how goals can be achieved. Rewards and incentives are big motivators and those should be used to make sure project is successful. It can be bonus, but it also can be anything that is valuable for the team members. (Berman 2007, 137–147).

Drawing any fixed lines about what to plan is hard. Keeping project sliding out from planned state into chaos is also hard. First thing is to decide, what should be controlled during the project. Then all things linked to controllable things should be planned. Plan should also be refined when new information is available. There should be two different plans. One rough plan for the whole project and another that covers only one stage of a project. Contingency should also be had in case of initial estimates of how much work or time a project requires. It should not be automatically triggered or fixed amount. Each successful state should decrease contingency budget because total risks are reduced by each step. There should be some headroom for project managers within predefined parameters to continue project execution even when costs or deadlines change that require no authorization elsewhere. Having certain amount of flexibility makes things easier. (Roberts 2007, 70–74).

Project benefits should always be measured in hard currency to balance benefits against the resources project requires. The figure can come for example from increased revenues or profits, reductions from overheads, risk mitigation or enabling activity that delivers one of the above. While doing cost/benefit analysis it is important to make sure that predictions are as accurate as possible. Assumptions should be compared between other projects that are considered. Analysis should span multiple years and if required, cash flows can be discounted by current interest rates. Not all projects generate profit or hard currency benefits. Then there should be clear description how the benefits generated within project is realized elsewhere and turned to cash. (Roberts 2007, 74–79).

Effective risk management consist of identifying risks, qualifying, evaluation and mitigation. When listing risks, clear articulation is important to make sure everyone understands where risk arises and why it is important to mitigate it. Qualification means that likelihood and impact is estimated for each risk. Multiplying likelihood and impact values give a value for a risk. When all risks are evaluated that way, it is easy to pick the biggest risks and focus to those. In addition, it is possible to add financial value to each risk. It is good to remember that mitigating risks cause costs so it should be thoroughly considered. (Roberts 2007, 79–88).

Project outcome always has quality. It is simply comparing planned deliverables versus realized deliverables. Therefore, it is important to plan the deliverables well ahead. (Roberts 2007, 91–93).

When product deliverables are known, next step is to figure out what tasks are required to get them. With complete list of tasks, planning timetables and detailed costs becomes possible. There are multiple ways to get time and cost estimates. Top down requires whole project details and applies overall timescale and cost. This is good way to plan things in the beginning of a project. When project has been planned with more detail and project deliverables are divided into set of smaller products, bottom up method can be applied. It lists time and cost of specific smaller products. When comparing these two methods, they should give exactly same results. The Delphi technique tries to develop consensus about an estimate through meetings, questionnaires and surveys. Data gathered from experts is handled and eventually a consensus estimate is reached. This process is time consuming and should be used if project manager has little experience or range of initial estimates differ a lot. Analogy method tries to find similarities from other projects or aspects of a project. Through similarities an estimate is developed. Work distribution can also be estimated. It requires reliable data from previous, similar projects. Standard project technique requires also reliable data from previous projects. It is based on categorization between project size and complexity. Estimating new project size and complexity and comparing to similar previous projects gives estimates. (Roberts 2007, 111–117).

Projects involve human resources. Humans are unpredictable and risks arising from that fact should be taken in account. People will not be fully productive. Non-productive time should be allowed. Estimates might assume that all work is done with full productivity. Increasing amount of people working on a single task doesn’t always increase productivity. And people have different productivity rates. Estimate can be drawn from persons experience and speed. Every person has individual strengths and weaknesses, so it should not be assumed that all people are identical. Increasing productivity is only temporary. Letting people estimate their own work, being clear with assumptions, agreeing product descriptions, looking at metrics from previous work and negotiating penalty and or reward clauses can help project

manager to increase likelihood of more dependable estimates. (Roberts 2007, 117–119).

2.4.2 Project Initiation

Initiation phase is when projects management environment is created. In addition, best possible start is required for success. Initiation process needs to address scepticism about project benefits and viability. (Roberts 2007, 16).

Each person involved should be educated to know about project management, wider organization that provides support and understanding clearly language used in project management. Training can provide people skills and knowledge to do things better or differently. It might motivate people, but if principles and techniques are not applied, full benefit is not achieved. (Roberts 2007, 16).

Project should have clear starting point, well described structure that tells what happens between start and end and finally clear end condition. Description of key deliverables and approve points of a project can be seen in Figure 2. Project portfolio management handles pre-project operations and transfers a project to steering group to handle initiation, delivery and closure. Successful initiation requires well balanced project steering group, project manager, business case has acceptable margin between costs and benefits, customer requirements have been clearly articulated, solution design document addresses the requirements from the customer, project plan and other reports show how project will meet targets set in business case and all products of initiation stage has been approved by the appropriate authorities. (Roberts 2007, 133–134).

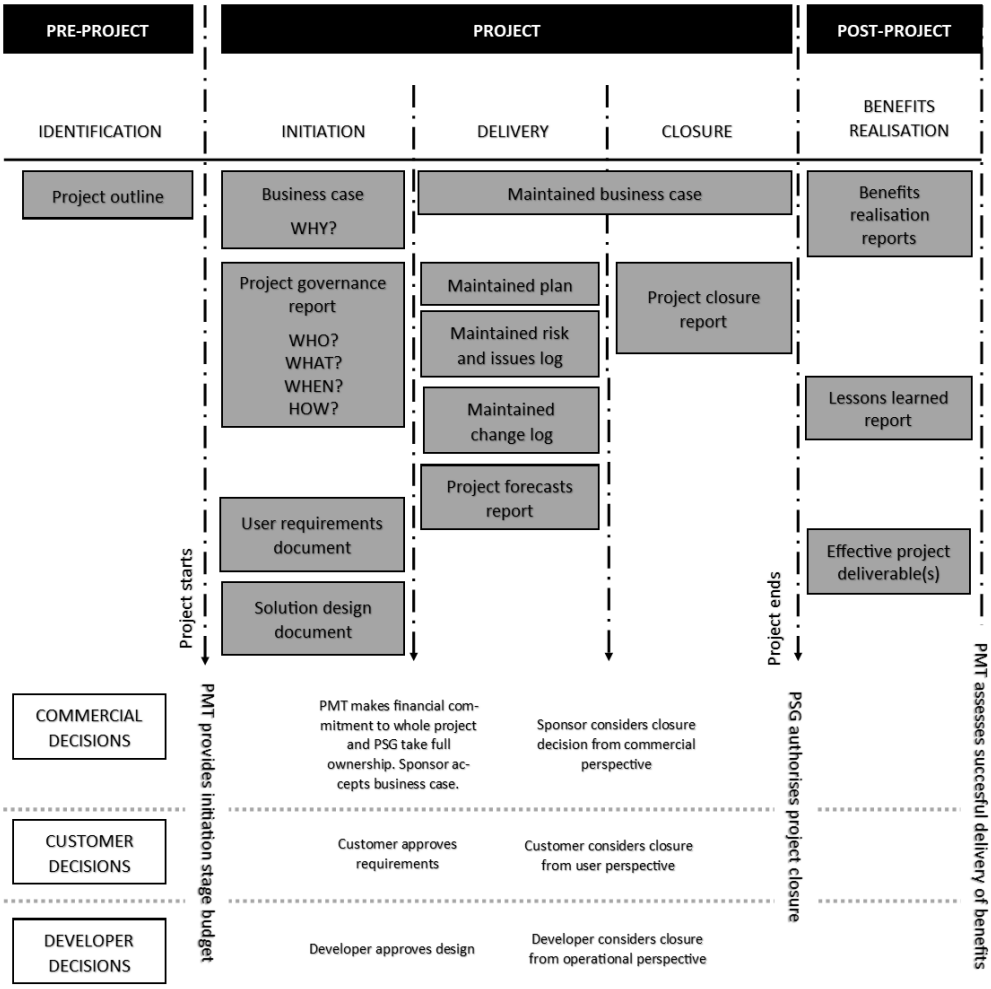

Figure 2. The project life cycle (Roberts 2007, 132).

A business case is the most important document of the project and it should describe what kind of opportunity or problem requires deliverables from the specific project. It must also point how the project contributes to the organization's strategy. Dependencies should also be listed and the criteria for describing a successful project is also required. There should also be a list of all alternatives to the chosen solution, including also an option to do nothing. And finally, a detailed analysis of the selected option that should include:

- All risks listed,
- Benefits listed,
- Lifecycle costs of project,
- Cost/benefit analysis telling how benefits outweigh costs,
- Key deliverables with deadlines when they are due,
- All assumptions made during development of business case,

- Plan to measure and deliver benefits,
- List of incentives offered to encourage desired outcome (if any).

(Roberts 2007, 134–145).

Project governance should also be documented. The business case answers to the question “why?”, and the governance report answers to “who?”, “what?”, “when?” and “how much?”. The starting point of the project initiation might be chaotic, but to increase the success rate of a project a success criteria should be established by the end of the initiation phase. (Roberts 2007, 145–167)

2.4.3 Project Tracking

After the project is finished, success should be assessed. A project can produce deliverable good enough quality on time and stay on budget, but it does not tell what the real benefits that project has enabled are. It should be part of the project lifecycle to have assessment of benefit realization. Actual benefits should always be bigger than investment. Some benefits are hard to quantify though. But it should be within a project scope to define how the benefits that are hard to quantify will be measured. (Roberts 2007, 19–20).

A project needs to have operational levers that are required to achieve desired results with the project. These levels are Key Performance Indicators (KPI), measurable variables that are related to process steps whose performance can be altered. KPI should be assigned to specific people to create accountability. By having measurable variables assigned to a person, multiple risks are mitigated. KPI can describe for example cost, time, quality, service or volume. And those can be absolute numbers, ratios or for example the number of process steps. KPI must always be developed for the needs of the specific project. One should always remember also to define how the Key Performance Indicators are supposed to be measured and calculated. (Berman 2007, 73–84).

After a successful initiation, the biggest task is to make sure that the project stays on track. A control cycle is described in Figure 3 and it illustrates how things can be kept under control. An effective escalation management is a good tool to keep things on track. It should be clear all the time who has control of the project and who is authorized to do what. The delivery phase includes detailed planning on how the

project archives targets, the delegation of tasks and monitoring of results. (Roberts 2007, 168–69).

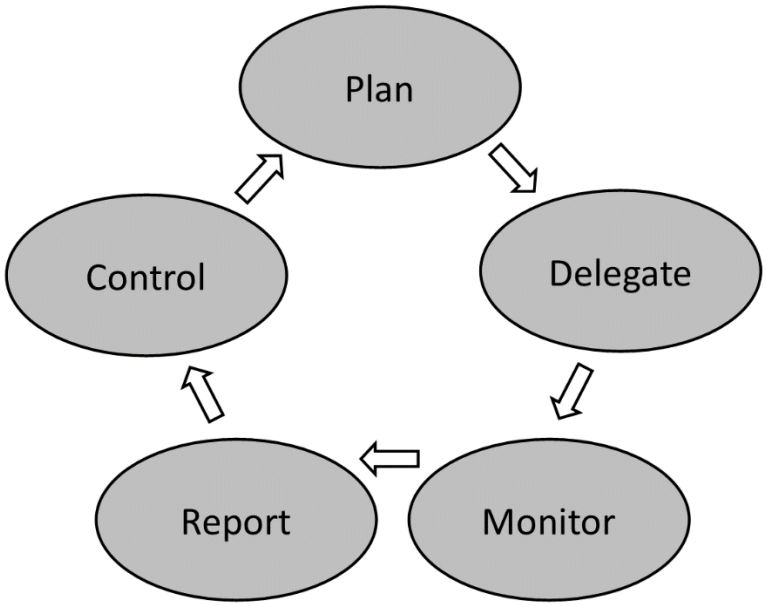

Figure 3. The control cycle (Roberts 2007, 168).

Tracking the progress of the ongoing project should not be forgotten. Tracking the process is a systematic approach and it requires a constant reporting mechanism, making the project metrics visible to the organization and the correction management process. There are two different reporting mechanisms available. The business case scorecard links the business case to the project objectives. It measures the project costs, financial impacts, delivery schedule and soft benefits meaning benefits that are hard to measure. The project value booking captures KPI values on a realistic and timely basis. As much information as possible is captured. The data collection should be automated if possible. (Berman 2007, 148–154).

2.4.4 Changes Within a Project

Change management within a project is also called as a change control to separate it from different kind of change management discussed above. It has three different elements. The first element is the authority of the project manager. The project manager needs to have authority to either approve or deny changes impacting the project. The second element is setting the environment supportive to a good change

management. There should be good communication to the entire project team setting expectations about how the changes within the project are handled. The third element is to determine if the change is requested and decide if it should be made. This way it is possible to track all changes, both accepted and declined. (Baca 2005, 2).

2.4.5 Execution and Closure

Closing a project too early can be tempting to many people. They might think that the rest of the project related things is worthless. But on the contrary, a successful completion gives a chance to learn valuable lessons and to make sure that everything was delivered as intended and the benefits promised can be measured. Closing a project is the responsibility of the project steering group. The project manager must generate a project closure report that should answer the following questions:

- *Does it provide sufficient information for the project steering group to close the project with confidence?*
- *Is the information accurate and up-to-date?*
- *Is all information internally consistent?*
- *Does it clearly outline a course of action for the benefits realization stage?*
- *Does it fully describe the roles and responsibilities of those who will take part in the benefits realization stage?*
- *Does it provide enough information about the governance of the benefits realization stage for the portfolio management team to approve the post-project management environment?*

Project closure report should include following content:

- Baseline documentation that successful completion will be measured against at,
- Project background outline that describes projects history and anomalies occurred,
- Detailed review of actual measurements against planned ones,
- Anything that remains unsettled,
- What management environment is required for post-project period,
- Recommended options to close the project,
- Outcomes project manager proposes.

(Roberts 2007, 222–224)

There should also be a report about lessons learned. It should gather and communicate as much information as possible to improve further management. The report might be worth little, but the review process can spark individual learning. (Roberts 2007, 230–231).

2.5 Efficient Change Management

2.5.1 Different Types of Change

Projects bring intended change. To maximize odds for a successful project, change management is important. Change can be separated into four categories: individual change, team change, organizational change and leading change (Murthy 2007, 28).

Individual change can be divided into four categories: behavioural, cognitive, psychodynamic and humanistic approach. Behavioural approach defines how behaviour is changed. It functions through reward and punishment. Reinforcing a desired behaviour can be done through a financial reinforcement like bonuses, non-financial, such as encouraging good behaviour, and social reinforcement, such as praises, compliments and a general recognition. (Murthy 2007, 28–37).

A cognitive approach defines how the results are achieved through a positive reframing. Change comes through affecting persons' self-concept and values. Changing values change beliefs, which change attitude which change feelings which change behaviour and thus the results are achieved. (Murthy 2007, 37–38).

A psycho-dynamic approach tries to understand how the inner world reacts to external changes. When changes occur, people go through a psychological process. A classical model by Kübler-Ross (1969) is denial, anger, bargaining, depression and acceptance. A more recent model from Weinberg can be observed in Figure 4. (Murthy 2007, 40–41).

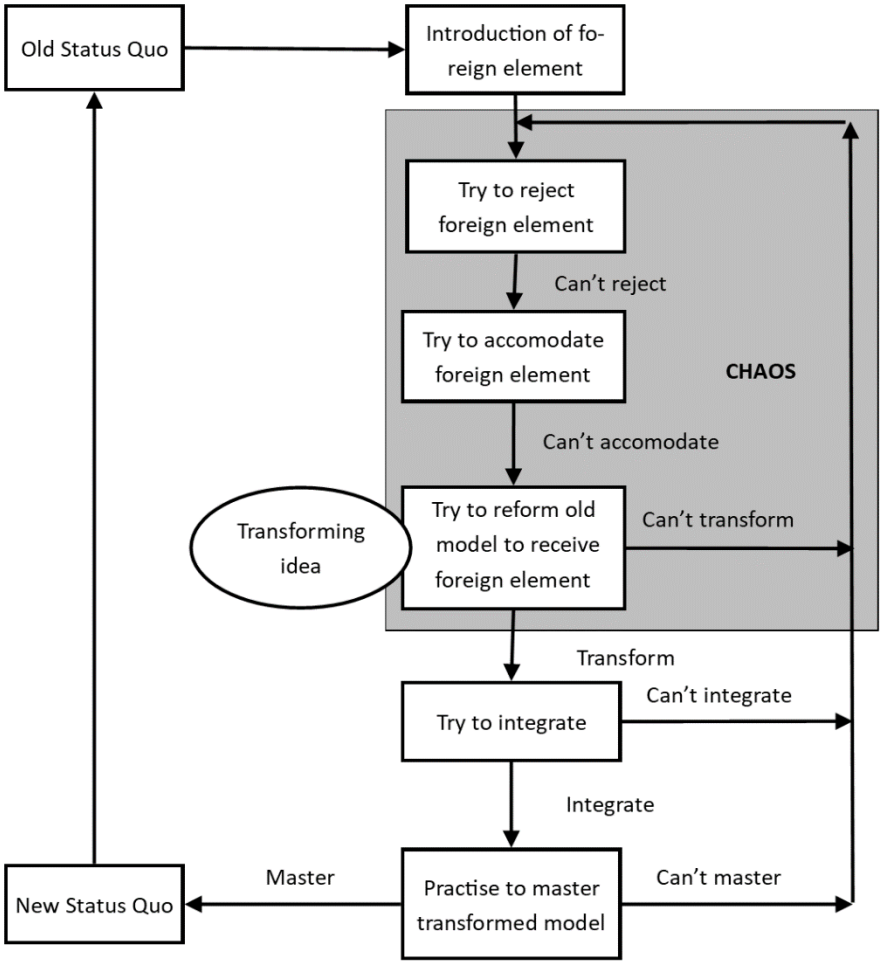

Figure 4. Change process (Weinberg 1997).

Humanistic psychology believes in development, growth and potential maximization. It can be unleashed by facilitating the environment, a supportive change agent helping process any negative feelings, moving from rigidity to a more fluid approach to allow more creativity and risk taking, and finally a greater degree of self-responsibility that enables more options to choose from. (Murthy 2007, 44–46).

Teams are group of individuals that work independently to achieve an organizational objective and own individual objectives. Teams face changes either of their objectives or of personnel changes. There are also multiple different states between forming a team and reaching a point where the team forms kind of unity through seamless teamwork. (Murthy 2007, 100–109).

2.5.2 Organizational Change

An organizational change has two completely different states: well in advance planned and unplanned due to unexpected events occurring. A planned change is always a preferred method. The simplest model of organization change is an unfreezing situation, making changes and refreezing the changed situation. It is criticized of being too simple a model. A more complex model by Moorhead and Griffin starts from the top management perceiving a need for a change. The problem is defined, and the problem-solving process is started. A change agent helps with problem-solving and the change is implemented. The transition is managed, and the results are measured, evaluated and controlled to make sure that the problem has been solved. (Murthy 2007, 76–80; Griffin and Moorhead 2011). Proactive companies for a change tend to be innovative, and it helps to generate new ideas and take risks with experiments. If innovations are not pursued, the situation changes to changes being urgent and business necessity. People that are used to changes usually accept them without frustration and demonization. But if there are continuous major reorganizations, it may damage morale and people spend a lot of time thinking about what will happen to them. (Murthy 2007, 135–173).

2.5.3 Reducing Friction with Change

Based on the observations of David Noer, the change process can be made more fluid by interventions in four different levels. The first level is getting the change process right. Efficient and effective management is required, including a communication strategy and process that are in line with the organizational values. It is better to communicate too much than too little. The second level is getting the emotional process right. There should be room and time for allowing expressions of feelings about the situation. The third level is focusing on the future. By focusing on the future, it is possible for people to recapture the sense of self-control, empowerment and self-esteem. The fourth level is embedding changes to the whole system. Ways to do it can be for example creating structural processes to treat and/or prevent survivor syndrome symptoms, clearly redefining the psychological contract between the employer and employee, and making sure all Human Resource

practices and management styles are in line with culture. (Murthy 2007, 112–14; Noer 2009).

There are techniques to reduce change resistance. Education and communication enables people to see the logic of a change. Misinformation or a poor communication is a source of resistance. Letting people to participate makes it difficult to resist decisions. There can also be change agents that facilitate change and support it. Negotiating and giving something in return of the planned change reduces resistance. Manipulation by twisting and distorting facts to make them appear more attractive or co-optation by buying off leaders of resistance groups by giving them a key role in the change decision. (Murthy 2007, 67–69).

Change consciousness should be developed within individuals with a positive imagery and a bright future, and there should be enough supportive resources available. People can have different attitudes for change; from an aggressive resistance to an active involvement and somewhere between there is a neutral stance. People generally accept the change when the change brings:

- Job security,
- Monetary or other benefits,
- More status or authority,
- Personal satisfaction from more interesting tasks or more responsibility or authority,
- Positive changes to job nature, either more challenge or easier tasks,
- Opportunities to contribute into the change process.

(Murthy 2007, 91–95).

Main elements of creating readiness for change are:

- Planning and scheduling,
- Roles and responsibilities,
- Communication,
- Resources,
- Commitment,
    - Trust,
    - Motivation,
    - Involvement.

These all can be categorized within three categories: motivate people, create change acceptance and sustain momentum. The importance of a continuous communication cannot be highlighted too much. (Savolainen 2013).

2.6 Product Definition In General

There are multiple different types of products. The division is not strict, and many products fall between two different types.

Types are:

- Consumer durables
- one-off artistic works
- consumables
- stock items
- industry products
- industrial equipment products
- special purpose products, and
- an industrial plant.

Consumer durables are the largest category of objects. It includes for example domestic appliances, office equipment, automobiles, computers and furniture. One-off artistic works usually mean a limited edition of special designed products. Consumables are bulk content to be consumed, for example bottle water, newspapers, butter of soft drinks. Stock items are raw materials used to build other products. Industry products cover any items or assemblies that can be used to build own products. Industrial equipment products are machines that are intended to be used within industry. Special purpose products are for example jigs, tooling, fixtures or machinery customized for a special process. Industrial plants are a group of industrial equipment, products and devices that are connected together in order to construct a functional plant. (Rodgers 2011, 9–13).

In addition to traditional products, modern manufacturers are competing by having integrated portfolio of products and services. Offering services might be as hard as advanced manufacturing methods. But services should be developed alongside with technical strengths to ensure a long term competitiveness. (Baines, n.d., 2–3).

Product development with traditional organizations is carried out in series. It makes projects last longer and scheduling a single project similarly between different departments is hard to do and it is probable that scheduling does not go as planned. Iterative changes to products also take a lot of time, in some situations everything might need to be reset to the first department in line and everything starts from the beginning. (Stark 2005, 121–22).

2.7 Life Cycle State Classification in General

A life cycle states vary depending on the perspective. The manufacturer has a different view than the user. The manufacturer cares about the product vision, design, building, servicing and retirement of the product. (Stark 2005, 17–18)

The user cares about the product vision, definition, realization, operating and disposing or recycling the product. The vision might be completely different from the manufacturer's vision. It simply might be a thought about needing certain kind of product. Realization is the phase when a product is purchased. (Stark 2005, 17–18)

Different phases overlap. There is also an alternative view about the lifecycle: imagine, define, realize, useful life and end of life. The end of life is usually a hard concept for manufacturers. (Stark 2005, 18).

The phases listed above can naturally be dissected even further. In the following chapters there is more detailed dissection of each lifecycle phase.

2.7.1 Imagine

Imagine means, that there is an idea for a product(Stark 2005, 16). This phase might include for example Product Design Specification (PDS). It describes a problem that the product solves, and it splits the problem up into smaller categories. (Rodgers 2011, 85–87).

PDS is a dynamic document that must be updated if needed during the design process. One cannot simply copy-paste the same document between different projects and replace the text where needed, the document should always start from scratch. (Rodgers 2011, 85–87)

PDS requires information gathered from multiple research sources. The main method for gathering information is either surveying or observing people. Collected data can be analyzed, and patterns and insights can be sought from it. Simulations are also possible. Naturally, people whose opinions or behavior are the most interesting are interacting with products on a day-to-day basis. Studying people is not an easy task

and one should always remember courtesy and asking permissions for anything first. (Rodgers 2011, 67–68).

PDS has potential to include any information and intelligence within an organization. Going deeper into market research or similar methods for a new product creation goes a little off topic concerning this work. But one should be aware of possible requirements this phase dictates to PLM, and this should be within the scope of research. An example of PDS can be found at Appendix 1.

2.7.2 Define

A definition starts with the concept generation. There are deliberate thinking processes designed for an optimal concept generation. Some of the most successful techniques include:

- Brainstorming,
- Attribute listing,
- Analogical thinking,
- Idea checklists,
- Breaking rules,
- Lateral thinking, and
- Mind mapping.

(Rodgers 2011, 95–98).

There are also multiple drawing techniques that can help with exploring multiple different concepts. Drawings are also an efficient way to communicate designs to others. Freehand drawing requires an ability to use perspective techniques. There are thematic sketches that try to communicate how the product might look like and schematic sketches that define for example which components will be used or give detailed information for example about ergonomics. Rendering means that sketches are colored, and it tries to give an impression about how the product might look like in real life. CAD models can also be used for visualization purposes. In the best case scenario same models can be used directly with Computer Aided manufacturing (CAM). (Rodgers 2011, 99–107).

Technical drawings are drawings that are used for communication with persons responsible for manufacturing or construction. To get product manufactured correctly, standard drawing methods are available to prevent possible misconceptions. (Rodgers 2011, 108).

Prototypes can be either physical or analytical. Physical prototypes try to approximate the intended product, analytical prototypes describe the product in abstract mathematical format. Both types can be either focused or comprehensive. A comprehensive prototype is a full-scale fully functional version of the product. Focused prototypes are usually grouped in two different categories. One is “works like” -prototype and the other “looks like” -prototype. (Rodgers 2011, 122).

There are multiple different prototyping methods. Some of them are listed below for a possible future reference:

- Quick and dirty prototyping,
- Paper prototyping,
- Experience prototyping,
- Role-playing,
- Body storming,
- Empathy tools,
- Be your customer,
- Try it yourself,
- Scenario modelling,
- Scenario testing,
- Storyboards,
- Informance, and
- Rapid prototyping.

(Rodgers 2011, 123–27).

A product audience should be considered always when possible. A person’s ability, age or social background should not restrict product usage. An inclusive design means that the product is designed for everyone. Placing high physical demands for example can limit a group of possible users substantially. A universal design is an integrated approach that must be included into all stages of design project. It cannot be bolted on later. The awareness of user needs with different capabilities is needed and, in addition, methods how to accommodate them in product design. The methods can be for example:

- Capability assessment
- Capability simulators
- Ergonomics
- Exclusion audit
- Inclusive user involvement

(Rodgers 2011, 231–36)

Up to this point creativity should be as unbound as possible. The last step for definition is concept evaluation and selection. It is usually an iterative process where the best concepts gradually appear. Some concepts probably get combined and some are dropped quickly after starting the process. Previously developed concepts can also be developed during this phase if needed. Evaluation and selection should be done with a group and there are no strict rules and guidelines. A lot can depend on personalities. The point is to pick a concept that fills PDS: s requirements best. (Rodgers 2011, 126–27).

2.7.3 Realize

When there is a concept picked, next step is to figure out what exactly and how it will be manufactured. Detail design is iterative process that splits concept into different components. (Rodgers 2011, 127).

Design can be done either bottom-up or top-down. Bottom-up is more traditional method. Parts are modelled first and placed into assemblies and mated together. Bottom-up suits well with off-the shelf components that are not changed. Top-down approach means, that parts are created within assembly. Parts can automatically transform when changes occur. Top-down is more flexible method with possible design changes made possible by modern 3D-CAD software. (“2016 SOLIDWORKS Help - Design Methods (Bottom-up and Top-down Design)” n.d.).

Parts and assemblies are designed and modified iteratively until design is accepted. When the phase is finished, prototype evaluation can start. Everything starts with alpha prototypes. Alpha prototypes represent aesthetics and functionality, but not final manufacturing methods. Prototypes are tested, and changes are made iteratively until a version is accepted. Beta prototypes use also same manufacturing methods and materials that are intended to be used in final product. Prototyping is important phase. Then changes can be done fairly cheaply and quickly. (Rodgers 2011, 129–30).

Prototyping ends when a prototype is accepted. Next step is to make sure that all documents are up to date and drawings are released for production. Release drawings describe all possible details required for manufacturing the product. Before

release of document, it is important to make sure, that communication with manufacturing has been in order during earlier phases and products can actually be manufactured as per specification. (Rodgers 2011, 130–33).

Material selection and manufacturing methods go hand in hand. Person responsible for material selection and work instructions should have clear understanding about things in hand. And communication with manufacturers can't be emphasized enough. (Rodgers 2011, 133–51).

2.7.4 Useful Life and End of Life

It is unclear where to draw a line between useful life and end of life. Therefore, these two lifecycle phases are combined to single chapter. This chapter tries to describe key elements for decision making during useful life and give some context about when product could be at end of life. Using process industry practices with Stresstech equipment is overkill. But decision was made to get best possible practices from process industry that can be scaled down from the parts that don't apply. Process industry requirements for data management systems is also good starting point for getting requirements of this life cycle part for PLM implementation.

When customer has the product, all there is left is maintenance and eventually scrapping or recycling the product. "Maintenance contains decisions about all the technical, administrative and managerial actions during the life-cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" (Operational Decision Making in the Process Industry: Multidisciplinary Approach 2008, 16).

Overall Equipment Efficiency (OEE) can be derived from requirements to specific product. OEE is calculated with formula 1 and it is a product of availability, performance rate and quality rate. Availability is the time product is available for actual use and calculated as per formula 2. Performance is calculated by formula 3 and quality rate by formula 4.

$$OEE = Availability \times Performance\ rate \times Quality\ rate \quad (1)$$

$$Availability = \frac{Operating\ time}{Planned\ operating\ time} \quad (2)$$

$$Performance\ rate = \frac{Output}{Nominal\ product\ capacity\ \times Operating\ time} \quad (3)$$

$$Quality\ rate = \frac{Output - Rejected\ output}{Output} \quad (4)$$

Smaller the requirements with OEE, the cheaper the maintenance. Cost of maintenance can be taken account by calculating added value of maintenance as per formula 5. Costs include labour costs, material costs, common costs, overheads and allocated costs of maintenance. Common costs and overheads include maintenance planning, administration, training, data systems, rentals, capital costs and other invisible costs. Allocated costs include own maintenance, maintenance done by production personnel, external maintenance services and materials.

$$Added\ value\ = \frac{OEE}{Cost\ of\ maintenance} \quad (5)$$

(*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 70–71). Taking OEE in account as early as possible gives the most headroom for adjustment and choices for searching biggest possible added value.

Following chapter goes through decision support systems that can help with supporting and retiring a product.

2.8 Decision Support Systems

Operation and maintenance in process industry are important because of significant investments in physical assets. Better competitiveness has been sought out for example from increased capacity. But working practices on operational level are inflexible and task allocations are narrow. Know-how about best practices is strongly personalized and communication between persons or organizations is insufficient. Flexible task allocation would be required to react or prepare for external or unexpected changes. In current state reactions to abnormal situations are processed slower and focus is on repairing existing problems instead of avoiding future problems. Decision making performance is not monitored because of lack of methodology and support from technology. Current information systems have information scattered around and it is impossible to understand all the relevant

dependencies in a complex environment. Decision making moments might not be noticed at all. To change things, new kind of technology platform is needed. The platform should structure data and its uncertainty and information can be fetched seamlessly. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 17–18).

2.8.1 Holistic Approach for Making Decisions

Research reports have identified some mega-trends for paper and pulp -industry. Meaning of know-how, creativity and innovations, environmental issues, role of information technology, decreasing of labor, new markets and production plants, and more agile, flexible and protean production systems. But role of decision making is missing from the list. Decision making is linked to profitability by adding value through supporting operative decision making. Following questions might help with adding value:

- *Which kinds of decision making situations exist at the operative level?*
- *What is the role of the decision maker and information system?*
- *Which information is relevant to the decision maker?*
    - *What is the value of information?*
- *How can information be processed for and represented to the decision maker?*
- *How to train decision makers?*
- *When does a decision maker need the information?*
- *How to integrate different kinds of information?*
    - *How to work with uncertainty?*

(*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 18–19).

Creating a holistic conception and answering questions above requires a multidisciplinary approach. Abstract level structure is built to have same fundamental decision-making elements applicable in multiple different situations. Abstractive level also makes approach flexible. Information system requirements and decision process must be defined well to get results and improve profitability. Understanding human dimension and the fact that crucial decisions are always made by people is essential. Decision making should be distributed among network of actors with interconnected tasks. Normative approach to decision making is based on Statistical Decision Theory (SDT) that considers a decision as an optimization problem. Problem has multiple objectives and uncertainties. SDT consists of three

different elements: state, measurement and consequence. State cannot be directly acquired, but information about it can be measured and taken from earlier experience. Consequence is a collection of attributes by which success is judged. SDT has two separate models: measurement model and consequence model. Both take uncertainty in account. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 19–35).

2.8.2 Normative Decision Making in General

Normative decision making considers all decisions as optimization problems with multiple objectives and uncertainties. Decision task should be first formulated mathematically and then solved. In practice that is sometimes impossible. Not all tasks can be formulated mathematically and/or numerically solved within reasonable amount of time. Normative decision making is only for providing a framework for decision making elements. It also sets a long-term quest of continuous development of decision task formulation and finding methods for solving problems. The normative approach is based on SDT. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 23–24).

Operational goal setting should be a transparent, objective hierarchy that is derived from company vision and mission. But link between strategy and daily objectives can be obscured because there can be both coordination components and strategic components at every management level. In addition to specific process related goals there also can be objectives to coordinate activities throughout the organization. To have functional normative decision making, operational goals must be expressed clearly enough for serve as basis for rational decision making. Objectives can be both constraints and goals. Objectives are under continuous revision in modern companies. There might be major changes in company strategic objectives for example. Environment is highly dynamic, and changes must be adapted quickly. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 24–26).

By using abstract point of view, all operations can be structured into tasks. Each task has its specific decision-making process. This way entire operation of production is just a portfolio of tasks. This way possible changes to personnel or task allocation

does not affect the big picture that much. Task specifics define requirements for communication between personnel and capabilities of person responsible for a task needs to be taken account. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 26).

Task related decision making can be made multiple different ways. Usually it is group effort. One person in group can be designated decision maker and others have role of experts who give their motivated opinion to assist the decision maker to understand all possible effects of potential actions. Or then decision making can be genuinely multi-decision-maker process where decision making works by voting. Or then a consensus within a group can be achieved. But usually there is single person doing the decision and the rest of the group acts as experts. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 26–27).

Each task has a set of subtasks. Rough model for possible subtasks is listed hierarchically below. It is written on perspective of person responsible for decision-making.

- Detect the need for acting.
- Comprehend the present state of the operation.
    - Retrieve data about most recent development.
    - Retrieve data about similar situations that have occurred earlier.
- Comprehend the set of potential actions.
    - Communication with experts.
- Comprehend the consequences of each of the actions.
    - Communication with experts.
- Evaluate consequences with respect to given operational objective(s) and constraints.
    - Consultation if something is unclear.
- Choose the action that has best predicted consequences.
- Implement the action.
- Monitor the consequences of the action to detect possible further needs for actions.

(*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 27).

2.8.3 Support System

Operations' Decision Support System (ODSS) is a mathematical Information Technology based set of tools that assist operational personnel to carry out tasks better evaluating by filling operational objectives and constraints from strategic business goals. Human decision making can be rational, but rationality breaks down

easily. Breakdown occurs especially when there are multiple objectives or there is significant uncertainty about consequences. Present systems available have risks that can be realized both during implementing the system or while using the system. Systems can neglect new evidence that contradicts established beliefs, specialize the model for extreme cases, assume predictability of an event higher than it is, fail to recognize poor actions because outcome was good, or failed comprehension about uncertainty in expert knowledge for example. Uncertainty of knowledge might be omitted completely. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 28–30).

Most decisions are triggered by events. But in operations also not making a decision is a decision. Events can be divided into different categories:

- Event of new measurement data becoming available.
- Foreseeable external events.
- Unforeseeable external events.
- Foreseeable internal events.
- Unforeseeable internal events.

When new measurement data becomes available, all decisions should be re-evaluated because having more data makes guesses about system state more accurate. External events refer for example changes to external variables. Internal events are changes with internal variables when external variables are not changed. External variables are things that change what is produced and internal variables are internal ways that change how same end result is achieved. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 37–38).

Operation environments are always dynamic. New ways to react to change is required to react to new types of environmental challenges. Companies need to find new ways to operate. Organizational thinking helps with the task. Thinking is the only way to solve new problems in a way that solutions work with existing environment. Companies need to have economic and mental capacity to react and respond to uncontrollably behaving markets. In short reacting means that company is able to use its resources in optimal way. Organizational thinking is not simple problem solving. It is also the formation of the problem that needs to be solved. A bigger goal is required and motivation to achieve the goal is needed. Goal oriented activity is intended action. If organizational thinking is thought to be just problem solving, it is

impossible to comprehend how information systems could help with the task. In addition, false assumptions about Artificial Intelligence (AI) and information systems ability to replace human thinking. It is not correct. All programs and ways of using them is always outcome of human thinking. Capacity of systems are always dependent on creators' capacity. Therefore, there should always be human element when looking at information systems. New types of information system design processes is needed and human-machine co-operation practices are needed in order to achieve best possible results. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 76–77).

2.8.4 Limited Resources of Human Thinking

Decision support systems help to mitigate human errors. The more complex the process is, the minor mistakes can cause large risks that are hard to solve and expensive when realized. Errors in organizational thinking and information processing can be either active or passive. Passive means that people do not act when they should. Passive thought errors can be thought to be less serious than active, but it is false assumption. Sometimes acting late is simply impossible. Active thought errors are realized actions that lead to worse than original goal. It might feel unfair to label inability to predict complex situations incorrectly as thought errors, but it is only way to aim into as high level organizational thinking as possible. Complex chains of thoughts need to be analysed and correct factors need to be found that have possibility to cause problems. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 78–79).

Humans have limited working memory capacity. It is approximately 4-7 unrelated pieces of information. Pieces can be either single letters or whole words. There are strategies to overcome this limitation by strategies that try to embed as much information for example within single word as possible. Thought errors occurs because of limited working memory and forgetting something obvious. Good example is situation where there are thousands of possibilities, but humans consider only couple of them due to memory limitations. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 79–80).

There are two major problems in human decision making. Limited memory capacity and limited size of mental representation. Limited memory capacity limits human ability to construct big mental representations of decision situations. Abstractions needs to be created to have bigger themes processed. Only a couple of alternatives can be taken account and only some beliefs, desires or other attributes can be encoded. Limited size of mental representation gives false hope about what representations include. It can easily be presumed that representations include and involve all relevant knowledge. There are many reasons why representations have their faults and quality of decisions decrease that are discussed below. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 85–86).

Problem solving is cognitive process where people have goal, but no direct means to reach it. The goal often is to find the very goal for some activity. Design thinking is a form of problem solving. Its function is to create new information. Problem solving is required for decision making because decision making needs representation of decision alternatives. Design and problem-solving processes are manipulation of mental representations. To get a clear view about what kind of decision aids are required, contents of mental representations need to be inspected more thoroughly. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 80–81).

Mental representations have highly articulated structure. People represent conspicuously only a small part of possible actions. Architects for example are guided by small set of functional rules. And in paper machine design there can be more complex chains. For example, faster production by improved water removal that is achieved through increased press impulse and realized by having an extended nip in the machine. This mental representation of properties and elements need to be understood to understand the structure of mental contents. One needs to know where possible false assumptions can occur within the process. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 80–81).

When problem solving has finished, it has produced multiple options for decision making. Decision making is activity where there are multiple alternatives and all of them cannot be chosen at the same time. If consequences are certainly known in advance, decision is deterministic. If there are probabilities of outcomes, decisions

are probabilistic. Differences of these two situations needs to be taken in account. Tools are required to solve the problems with uncertainty. Tools collect, analyse and sample information and thus reduce uncertainty. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 81–82).

Quality of decision can be measured. It depends on information people have about environment and phenomenal processes affected by the decisions. If information about environment is highly probabilistic and phenomena are not well understood, quality of decisions decline. People have always their hopes, values, wishes, utilities, goals and other desires linked to decision processes. Different people have different beliefs about situation and expertise, expectations and available means vary significantly. In addition, there are different decision rules and strategies involved. The way information is presented to decision makers can also affect decision quality. Information can be presented unclearly and in emotional ways which decreases decision quality even when actual information is not changed at all during presentation. Task specific knowledge for example helps experienced operator to make more rational decisions quickly. There are a lot of factors about human decision making that is needed to be taken account of. It is important factor in decision making and all possible sources of decision errors should be understood while implementing decision support systems. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 82–84).

Humans make serious decision errors systematically. Humans are not ideal decision makers by default. The most typical external factors causing decision errors are anchoring and visibility. Incorrect information and emotions can also be affecting decision-making. Emotional preferences can create unconscious obvious bias by choosing always objects and people that feel attractive instead of optimal option. Overconfidence can also cause false assumptions in decision making. Overconfident people do not search for falsifying evidence or consider detailed hypotheses because they have already formed a theory that is not linked to real world at all and it can cause severe errors in decision making. Finally, there is also problem when making decisions in groups: groupthink. If there is an authoritative person in group, it is often the case that all alternatives are not considered because nobody wants to raise important issues on the table. This also can cause serious errors in decision-making.

(*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 84–86).

Human-machine interaction requires controlling complex technical processes and therefore it is good psychology application for decision-making and thinking. People have mental representations about behaviour of complex objects, for example airplanes. Predictions about how objects react is required to keep risks in decision making low. Human capacity is relatively limited and especially in new or odd situations risks of severe errors occur. Decision making is usually human operation because if it could be easily automated, it would be easiest to have machine do such operations. Machines cannot act as decision makers because machines don't have capability to decide what is relevant. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 86–87).

Human errors are inevitable. But it doesn't mean that those are not avoidable. Probability of errors can be reduced by rational psychological means. Educating people, making human-machine interaction simpler and moving complex task-elements to be performed by carefully tested machine elements. Teaching people cognitive strategies for interaction and functions of machine can be organized in an effective manner to simplify the decision situations for example. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 86–87).

In complex and dynamic environments intensive interaction between different stakeholders is required. That requires new kind of co-operation and collaboration. Operational decision making can be the result of interactions among persons contributing directly or indirectly to the decision making. Interaction can be either knowledge sharing and/or transferring point of view. Exchange of information in critical phases of processes requires mutually accepted concepts. In addition to common concepts, sufficient knowledge of work processes is required to be able to learn from the process events. Same goes to sharing experiences and knowledge in the work community to improve the work process. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 90–92).

2.8.5 IT Systems as Decision Support System

All decision tasks must have same abstract structure derived from formal decision theory. Uncertainty needs to be included explicitly within the process. There are general requirements that come from the users. Data structure needs to correspond the structure of decision theory. Generic functionalities analyse SDT structures and provide automated actions, suggestions and information for making actions. Full specification includes for example how data is presented to users, detailed specification for communication and mapping decision tasks to organizational roles. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 40–42).

IT systems needs to provide the functionality for decision-support and all data and knowledge required by the persons doing the decisions. Current Manufacturing Operations Management (MOM) Software available is probably not able to provide full decision-making support but if not, support should be under work because MOM is the best pick to build decision-support system in to. Table 5, Table 6 and

Table 7 illustrate requirements for decision support -feature and IT infrastructure. (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 98–100).

Table 5. Summary of the requirements of decision support in MOM (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 100).

Name	**Explanation**	**Relevance**
Support situation assessment	There should be functionality for collecting information and creating new information, which is useful for the decision-makers in their situation assessment activity. The information contains various types of data and knowledge.	This requirement is relevant to many situation assessment functions in DCS, CBM, MES, EAM and BI.
Support developing decisions	There should be functionality for creation, evaluation and selection of decision alternatives for various decision-making situations.	This requirement is relevant to many action planning functions in DCS, MES and EAM.
Support executing and monitoring actions	There should be functionality for execution of committed decisions for various types of decisions and monitoring the execution of these decisions.	This requirement is relevant to those action planning functions in DCS, MES and EAM, whose execution is performed or whose execution can

		be monitored via automation and information systems.

Table 6. Summary of the requirements of collaborative decision support in MOM (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 100)

Name	**Explanation**	**Relevance**
Support information exchange	There should be functionality for exchanging information among decision-makers in a way that is useful in their decision-making activities.	This requirement is assumed to be relevant to many functions in DCS, MES, EAM and BI.
Support knowledge management	There should be functionality for sharing knowledge among decision-makers in a way that is useful for them in their decision-making activities.	This requirement is assumed to be relevant to at least some functions in DCS, MES, EAM and BI.
Support business process management	There should be functionality for the decision makers to manage the business processes in which their decision-making takes place, in a way that is useful for the objectives of the business processes.	This requirement is relevant to many functions in MES and EAM.

Table 7. Summary of the requirements of IT architecture in MOM (*Operational Decision Making in the Process Industry: Multidisciplinary Approach* 2008, 101).

Name	**Explanation**	**Relevance**
Support data administration	There should be functionality to store and access various types of data that are useful for decision-makers in their situation assessment, action planning and collaborative decision making activities.	This requirement is relevant to most (or all) functions in DCS, CBM, MES, EAM and BI.
Support knowledge administration	There should be functionality to store and access various types of knowledge that is useful for decision-makers in their situation assessment, action planning and collaborative decision-making activities.	This requirement is relevant to those functions in DCS, MES, EAM and BI, where the situation assessment, action planning and organizational decision-making activities of the decision-makers can be facilitated with knowledge stored in information systems.
Support model administration	There should be functionality to store and access various models for data processing which are useful for decision-makers in their	This requirement is relevant to those functions in DCS, MES, EAM and BI, where models of data processing are

	situation assessment and action planning activities.	used.
Support integration between systems	There should be functionality to transfer data and knowledge between systems and means for invoking functionality of other systems to the extent that is required by the previously presented requirements.	This requirement is relevant to DCS, CBM, MES, EAM and BI. It is also relevant to ERP as a system with which the previous systems might be needed to be integrated.

3 Collecting data

3.1 Principles

Research needs to be planned. All starts by formulating multiple problems and picking one that suits best against certain selection criteria. The selected problem is transformed into researchable questions. When the questions are ready, there needs to be a title, conceptual model, defined objective of the study, investigative questions, hypothesis formulation, the definition of concepts and the delimitation of the study scope. (Krishnaswami and Satyaprasad 2010, 22–23).

The problem in general was to form instructions to execute development projects that finally combine into full PLM approach. There were multiple research questions:

- What are research projects that will be implemented?
- What things should be considered within projects?
- What problems need to be solved within projects?
- How can one know if a project is successful?
- What is the priority for the projects?
- Are there causalities for different projects?

The objective of the study was to figure out the starting point and form meters that can be used to track progress after changes are made within the company. Two different approaches for data collection was used in addition to a literature review. A general survey for the whole company and in addition group interviews for getting more detailed information within single department and company level were conducted. The survey was for both collecting quantitative data for measuring the starting point about data management that can be used for tracking improvements

and measuring the success of a project. Non-quantitative data can give insights about where one should focus while planning projects.

After data has been collected, it is analyzed. Quantitative and non-quantitative methods are usually used, but a statistical analysis is based on quantitative approach. A statistical analysis provides exact descriptions from large samples of data. Estimates and generalizations are also possible through a statistical analysis. There are different statistical measures. A central tendency can be measured for example with a mean or median, and a dispersion can be measured by range, deviation or standard deviation. (Krishnaswami and Satyaprasad 2010, 160–164).

3.2 Survey

Many problems with product data are with daily tasks. Managers might not be interested in them when they are facing bigger issues at the same time. But the right combination of low-level problems can cause higher level problems. A lot of time is wasted searching and not finding data needed. Product data might be mistyped for example. (Stark 2005, 79).

In order to figure out what kind of approach to PLM would be best for the company, a feasibility study is required (Stark 2005, 127). Thefirst thing required is knowledge about the current situation. A survey is a tool that has minimal resource requirements, low cost and a potentially large sample (Brewerton 2001, 105–106). The goal of the survey was to find out the general situation within the company and, at the same time, the biggest issues. The more respondents survey will have, the better view it gives of the current situation. So a survey seemed to be a perfect way for collecting information.

Surveys usually have background data question(s) that enable grouping answers accordingly. Sensitivity should also be kept in mind when collecting the background data. (Brewerton 2001, 106). If a survey claims to be anonymous but collects a lot of detailed background data, anonymity will be questioned and it might affect the responses. Grouping questions should be as inclusive as possible to make sure each respondent is applied. (Brewerton 2001, 107). While trying to get as honest answers as possible, it was important that anonymity was assured. The respondents' role in a

company is both detailed enough for possible further actions and broad enough for anonymity. There was also one option that can be selected if any of predefined groups do not match or a person does not want to respond to that question. Grouping was designed based on the company organization chart.

Attitudal information can be collected with multiple ways; five -point attitude scales, open ended questions, semantic diagrammatic scales, etc. Open ended questions give an ability to reply freely, short or long answers. But analysing the answers is hard. Quantitive data is limited to counts of thematic data. Semantic differential scales on other hand give straight quantitive data. It has two opposite extremes and a possibility to select one's own preference for example on a 5 point scale. (Brewerton 2001, 108–109).

Descriptive information should be asked at the end of the survey and if attitude measurement makes assumptions so there should always be some place for commenting any question of the survey (Brewerton 2001, 108–110)

The first compulsory question collected backgound data, it asked the respondent to define their role at the company. Possible roles were sales, design/R&D, manufacturing, service, and other. The second compulsory question asked about the amount of data locations the respondent could identify as a source of work related data. As discussed in chapter 2.1.1, multiple different locations make managing the product data hard. It had five options: 1-2, 3-4, 5-7, 8-10, and over 10. The third optional question asked to identify all locations of the second question. This way it is possible to map out all specific different data locations.

Compulsory questions four and five were attitudal questions with a 7 point scale. They were formed based on the project KPI discussed in chapter 2.4.3, and these questions can be used as a measurement for the effectiveness of PLM implementation within the company. The first survey builds a starting point baseline where later surveys can be compared to. The fourth question was about searching work related data and if it was easy or hard. The fifth question was about how easily all required information is found generally: always or never. As discussed in chapter 2.8, an optimal situation is that a system complements human operations, thus the

system needs to work in a way humans find easy. And finding product data easily is essential for advanced PLM, which is covered in chapter 2.1.1.

The rest of the questions were optional and they were all open ended questions. Questions six and seven asked about what information was the easiest and hardest to find. This was done to collect attitudes and preferences about different practices used at the moment, and possibly revealed the aspects that require more attention or more urgent action. Questions eight and nine asked about data creation: what information was the easiest to create and what was the hardest. This was in order to involve people and give them room to tell their opinions, which is essential for successful projects as discussed in chapter 2.2. The final question was for comments, feedback, clarifications or similar. The survey form can be found in Appendix 2.

Quantitative background data (question 1) was included for data analysis. Data location questions (2 and 3) were included for an accurate description of the starting point. Quantitative question 2 was there to shed light about how many different locations there were for product data and qualitative question 3 anwered how common each individual location was.

3.3 Group interviews

Interviews are a flexible tool that can be done on any stage of the research progress. It can be used as a sanity check for data already collected. But it is hard to archieve reliable and valid results. Unstructured interviews specify only the topics that are in interest of the research. Answer options are not limited. The same interviewer should be used during all interviews for consistency. As much background information as possible should be collected and preparations should be done as thoroughly as possible. Interview privacy should be ensured and possible interruptions eliminated. The situation should be as relaxed as possible but the interviewer should always be in control. Objectivity and sensitivity should be kept in mind. Interviews give rich data, but are costly and time-consuming. Reliability is poor and the results are open for interviewer bias. (Brewerton 2001, 77–81).

The interviews were designed to be group interviews in order to cut costs and timespent. The first part of the interviews were divided into small groups by

department, from 2 to 10 persons excluding the persons in the management group. Some of the smallest departments were combined if they had a similar content of work when looking at the product lifecycle. Manufacturing departments had an additional attitude survey conducted through printed A3 and post-it notes in order to have a better coverage to questions intended as KPI for the whole PLM project.

All groups got briefing about the state of process, a summary of the survey results and there was room to comment freely about them. After that answers to two different questions within the same theme were collected. Manufacturing departments answered first to the attitude survey before the survey results were shown due to low amount of answers through survey. Two questions were:

- What are the biggest issues at the moment with product data, and
- What should be done to obtain a perfect product data management environment.

The responses were translated to use PLM vocabulary if necessary by the interviewer and collected to post-its and attached to a whiteboard that was divided into two sections according to the questions. The location of the whiteboard was announced to everyone during the interviews and people from all departments were invited to see the responses themselves. There was extra time reserved in order to make sure there is enough time for everyone to be heard and comment freely. Situation was kept as relaxed and unformal as possible to encourage more accurate answers.

The second part of the group interviews were held to bigger groups sectioned by the product lifecycle phase and operation(imagine, define, realize, useful life, end of life) and it at least tried to include everyone. The purpose of the survey was to find out all life cycle phases required to handle products and thus product data. This part started with a review of the whiteboard after all of the post-its had been categorized into general broader themes. PLM Vision and strategy were also announced to the whole group, and there was a possibility to comment them and ask questions before the collection of answers was started.

The interviews also had a hidden agenda not told to the participants. It both served as a test for a new project model suggested in the thesis and as a tool for a change management and change justification through employee involvement and lowering barriers between departments through increasing understanding and co-operation.

In addition, a PLM Vision that will be discussed later on was formed mainly based on the replies of the group interviews. The hidden agenda was revealed to the participants at the end of second interview.

3.4 Survey Results

After analyzing the survey results it was clear that the number of answers from manufacturing was alarmingly low compared to how big a portion of workers it included at the company level. Details can be seen in Figure 5. Answers by department. Questions 4 and 5 were asked again during the group interviews in a way that everybody could see what others answered within a single group. It might have introduced some error to the results. In addition, there might be multiple answers from the same respondents within the results.

As can be seen in Figure 6, most of the respondents know 5 or more locations for the data. A more detailed situation can be seen in Figure 7. There are 18 unique locations for the data mentioned separately. It is possible that some locations are not simply remembered when answering, therefore, the number of locations can be even more than 18.

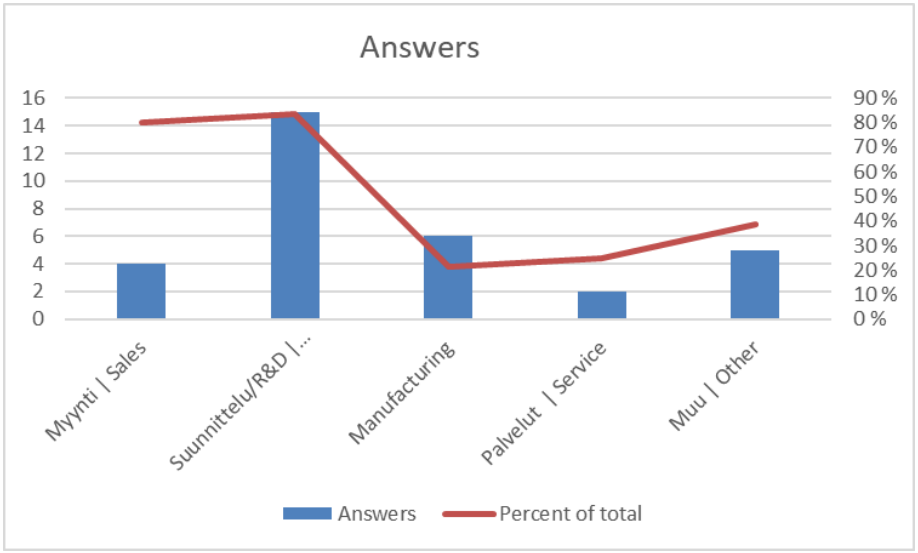

Figure 5. Answers by department.

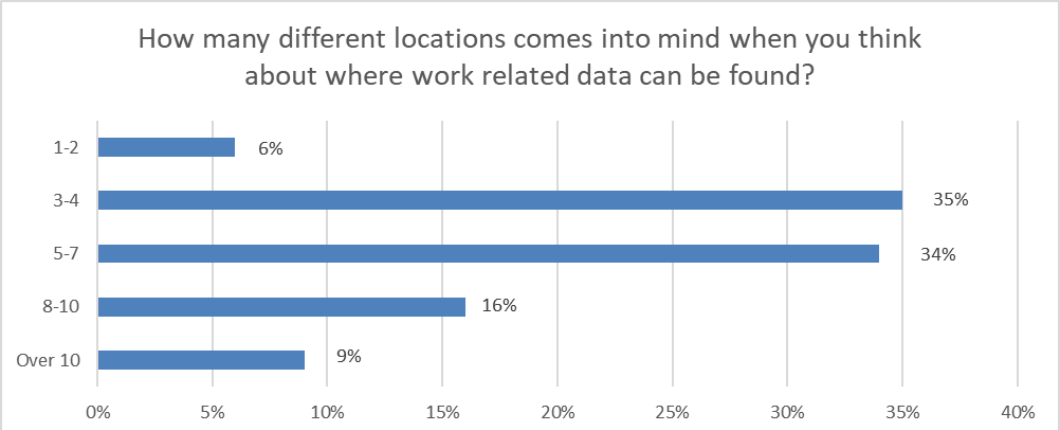

Figure 6. Number of different locations.

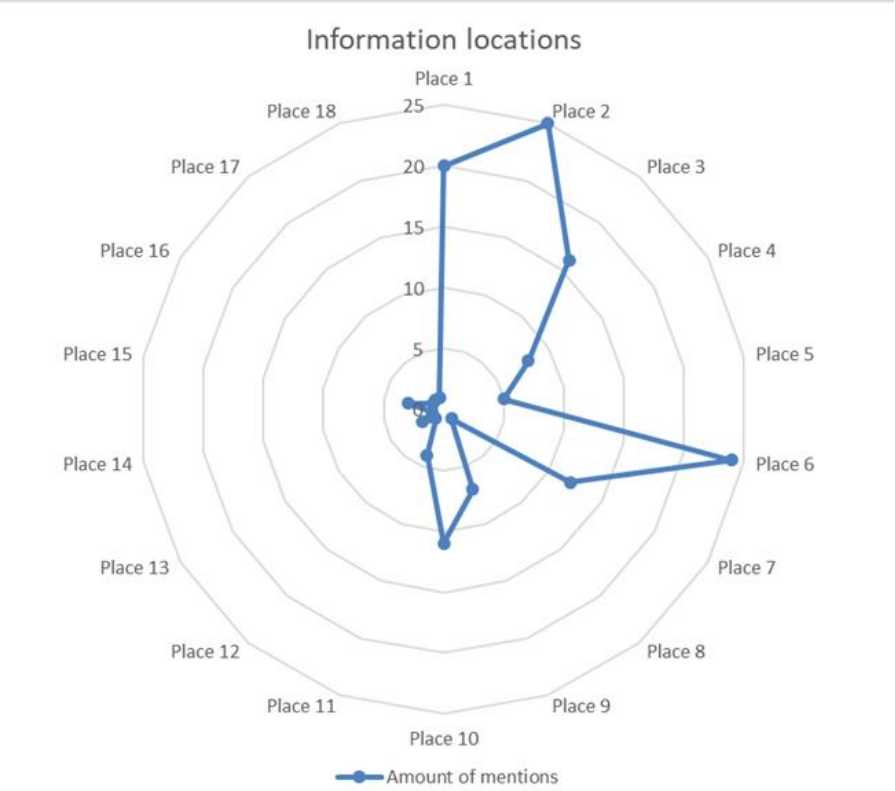

Figure 7. Information locations

When comparing Figure 8 and Figure 9, it seems that different means for collecting information have not changed the results at least much. Thus, combined results should be somewhat reliable, and they can be used as a baseline future situations will be measured against.

There are some differences between Figure 10 and Figure 11. It seems that the answers from manufacturing scatter a lot more between both extremes. It might be caused because of different roles on searching information or it might be because of

different collection methods used. Nevertheless, there were no major changes to the big picture, so this data can also be used as a baseline to measure improvements.

More detailed analysis concerning the baseline measurements and using further surveys to measure the improvement is discussed in the project plans attached.

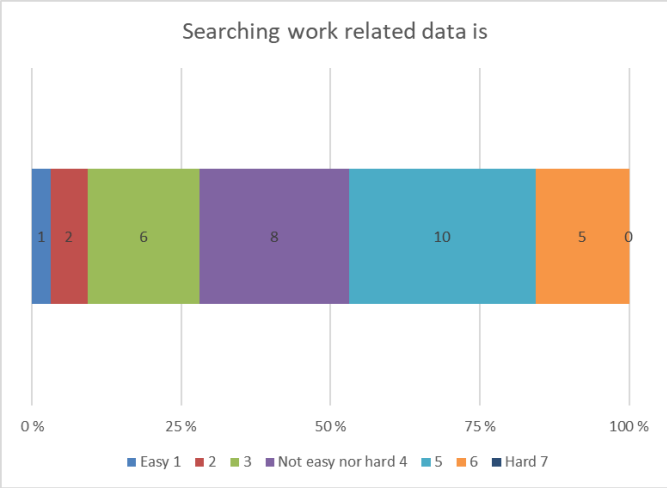

Figure 8. Searching work related data.

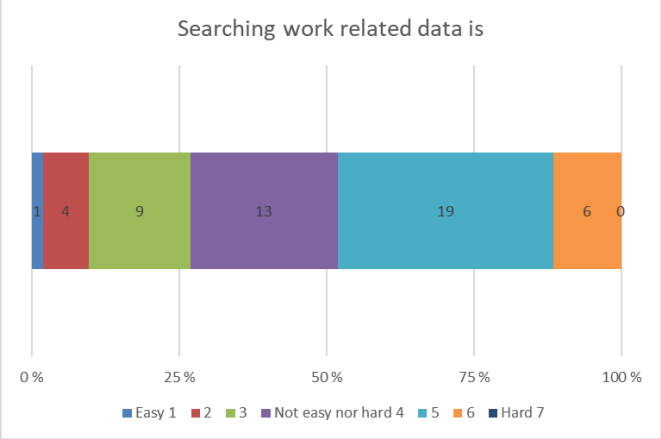

Figure 9. Searching work related data, answers from manufacturing added.

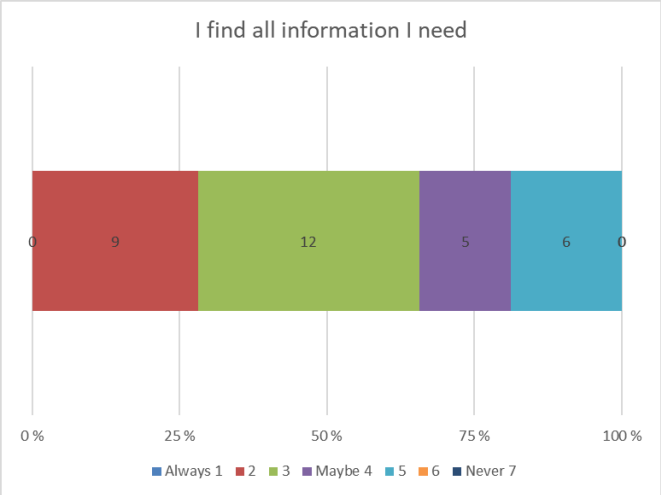

Figure 10. Finding information.

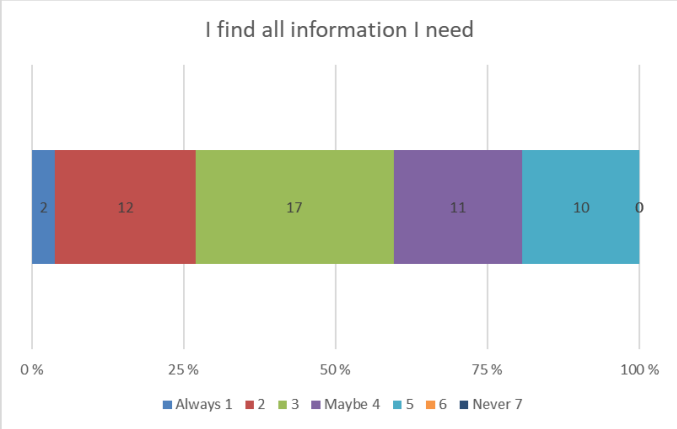

Figure 11. Finding information, answers from manufacturing added.

3.5 Group Interview Results

The responses of the group interviews were categorized under common themes.

Table 8 shows the common themes and the number of the responses in which the themes were present. This way it is possible to find out which themes should be addressed first. All answers were also included in PLM Vision, see Appendix 3. This way people were included in the process and it was a form of a good project management, see chapter 2.2 for reference.

Table 8. Results from group interview part 1.

Issues	
Theme	**QTY**
Decisions / responsibilities unclear	20
Information missing	33
No access to information	5

Suggestions	
Theme	**QTY**
Processes defined & refined	37
Holistic view and/or Common policies	30
Responsibilities defined	18

No common policies between departments	21	Proper instructions / learning	4
Location of information / same information in different places / contradictive information	19	Information available from single location when needed, information flows	27
Validity of information	8	Requirements for data management	16
Lack of training for x	7	Figuring out risks before they occur	5
Searching is hard	6		
Total answers to issues	**96**	**Total number of suggestions**	**78**

All total	**174**
Note: single point can include multiple themes! All answers and suggestions included in PLM vision.	

The second group interview had a section where people could comment and ask questions about the PLM vision and strategy. The questions about the vision and strategy were addressed and there were no further comments about them. In addition, a rough product lifecycle model was formed together that can be used as a starting point for development projects if needed. The results were included in the project plan in Appendix 5. Situation in the second group interview were different compared to initial interviews due to much bigger group size, and it might have discouraged people from commenting.

3.6 Benchmarking Interviews

In addition to internal data gathering, there were also two interviews. One conducted to an unnamed big company sales and product representatives and the other to a designer at an unnamed company that is part of a global group. The interviews were lightweight general inquiries about how well some dimensions of PLM were embedded in each company's strategy and/or every day operations.

The big company seemed to have PLM completely embedded in its operations. Product lifecycles were predefined, big customers can get a guarantee that they can purchase the same products for at least 10 years for example. Stock planning is done accordingly within the company and important components are stored within the company if suppliers cannot guarantee availability through the desired lifecycle. Configurations were described as Legos consisting of standard products and customized components that enable compatibility between different components.

Extensive product information can be found on the company's web pages and there is a configuration tool available that assigns a numerical identifier for specific configuration if it does not exist yet. The identifier is locked for that configuration only and it is an official way to refer to the specific configuration for now and in the future.

The other company was almost at stage 4 with PDM, see Appendix 7. The company had predefined lifecycles of products. Critical components were recognized during the product design. They ensure that spare parts can be purchased from stock at least 10 years after product retirement and there are arrangements possible even after that. PDM and properly configured production structures makes it possible to reuse as much old parts as possible. Subcontractors have access to PDM -system. Product data travels from component suppliers by phone calls or by email. Having long support cycles makes it hard to manage revisions and versions. They used to have a PDM system that was fully customized to their needs during the years of work, and it had advanced features compared to the current one. The new owner through acquisition wanted to have the same PDM within the whole group to enable component sharing with all companies in the group. The biggest problems that were experienced with the change were search functionality and too restrictive use rights that hinder possibility to work flexibly.

4 PLM Implementation

4.1 General

As described earlier, full PLM project takes years to complete. A successful implementation requires also a vision to make sure everybody is in the same boat and a strategy that defines how the vision will be achieved.

Information acquired in the survey and interviews were used to form the starting point for PLM -project and a basis for PLM vision. The vision and strategy were discussed with the management group and it was announced to people at the second group interview. Finally, three development projects were planned that describe a more detailed strategy for achieving PLM vision.

Stresstech products are mostly industrial equipment products and industry products. Criteria to differentiate product groups within each other's in-house is thus required and it has mostly been done. Products have three different categories: systems consisting of multiple products, products consisting of multiple components and components. Stresstech also produces services, such as measurement services.

4.2 PLM Vision, Strategy and Project Plans

As discussed earlier, the PLM Vision was based on the replies in group interviews and literature review. The strategy was based on literature references for an efficient strategy. The vision desrcibes a desired state of product data management in the future and it functions as a goalpost where to aim at during the process. The strategy gives instructions on how to get into a desired state. The vision and strategy can be found in Appendix 3. The strategy was used as a baseline for project plans that act as a more detailed strategy for achieving a PLM vision.

After realizing the complexity of PLM implementation, it became obvious that to reduce risks, it was necessary to make sure, that development projects have a supportive environment for execution. Developing processes and similar is almost a daily task within a company, but co-ordination requirements between all departments is just too big a task for existing frameworks to ensure success. A project plan for implementing a new kind of development project model within the company was initially created to work as a template and illustrative document at the same time. The project plan can be found in 0. The project can be funded from free cash flow, therefore, financial risks are low.

The rest of PLM implementation was formed as development project plans according to new project model requirements. It was divided into two parts. The first part is to improve the product workflow as a preparation for purchasing a new system later. The project plan can be found in Appendix 5. The second part is the actual purchase process of PDM/PLM system and commissioning the system successfully. The project plan can be found in Appendix 6. The product workflow project can probably be funded from free cash flow but purchasing a PDM/PLM system requires additional funding, which increases financial risk.

The product workflow was selected as the first actual project for PLM initiative because of a low-cost implementation and controlled process development bit by bit. This way people can learn while doing improvements to the product workflow and they start to form opinions about efficient and inefficient practices. At least in theory it should enable almost a direct purchase and commissioning of PDM/PLM system when there are already detailed descriptions about processes and requirements. Workflows can be automated already during the initial commissioning and this way the cost of new system can be justified by faster returns on investment. Projects include benchmarking, taking into account Operational Decision Support System methodologies and theory portion of this report in general supports both projects by collecting extensive background information for project manager(s) and other participants.

5 Conclusions

There are significant risks to both single development projects and the PLM implementation. The Themes are so broad, that even the smallest risks can cause big enough problems that cause a loss of motivation and projects end up being dropped. This report was formed to be as simple and minimal as possible with minimum requirements after taking an account risk mitigation. It is always possible to pick the most rewarding parts for an easy profit and forget the harder ones. But it means that some issues with product data will never be fixed and costs remain easily hidden. Fighting with product data issues is probably never rewarding for the employees and it causes distractions to normal operations.

Using Appendix 7 as metering tool is really challenging. A single person does not probably know the answer to all of the questions and when it is answered through groupwork, there might be significant disagreements about how questions should be interpreted. In order to ensure as accurate answers as possible, serious consideration should be taken before deciding participants.

With a full support from the top management and capable persons accountable tothe project management and execution who understand the underlying themes within these projects should be enough for a successful implementation. Projects can

be executed efficiently with support from all directions and a company gains more efficient manufacturing processes along with a more efficient data management.

The themes discussed in this report form a complex holistic picture and there definetily are major gaps on many sectors. The thesis was done with a deep inside knowledge about the company but there might still be something important lacking due to sheer complexity of themes discussed. This is why discussing with people during a further execution is highly suggested in order to spot possible issues before something goes wrong. And this is why competent project manager and other people executing actual projects is an absolute must. And polyphonic collaboration with all the people affected by the changes should not be skipped.

The most surprising aspect was the observation that majority of aspects involved in PLM that have been mentioned in literature also surfaced within group interviews spontaneously. Simply coordinating whole company to work together towards common good might have resulted in similar results even without any backup from the literature. This should be considered as a good incentive to always ask comments from people. The asking process takes only a little time and it might offer even major insights about the best way to tackle some problems.

Having more resources and time for the work would have enabled more thorough report and project plans. On an other hand there needs to be enough breathing room for actual project manager and planning can not be done fully on behalf of people actually responsible for project execution. In addition better involvement of whole Stresstech Group would have been possible if there was possibility to travel to meet more Stresstech Group workers.

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Appendices

Appendix 1. Example of PDS

Product: Fictional "X-Cross" Kids' Bicycle		
Date: April 21, 2010	**Issue: 2**	**Creator: Will Ernesto**
The performance demanded of any product should always be fully and precisely defined. **1. Performance** **1.1 Must be easy to operate** **1.2 The product should withstand rough handling.** **1.3 Operating conditions [see Environment].**		
All aspects of the environmental conditions that the product is likely to come into contact with, and have a bearing on, need to be considered and investigated at the outset of the project. Environmental hazards may occur during a number of stages in the design and development. **2. Environment** **2.1 Resistant to adverse weather conditions.** **2.2 The product should perform in the temperature range -4°F (-20°C) to 158°F (70°C).** **2.3 The product should be resistant to corrosion from salt water.** **2.4 The product should withstand a shock load of 5000 lb (2268 kg).** **2.5 The product should be able to withstand vandalism.** **2.6 Dust and dirt should be easily cleaned from the product.**		
The service life of the product and how this is to be measured needs to be stated. **3. Life in Service** **3.1 A minimum of 10 years is required for this product and 15 years is desirable.**		
You should be aware of the maintenance issues surrounding the product at all stages of its life, including the need for spare parts or special tools. **4. Maintenance** **4.1 Screws, bolts, and washers used must comply with British Standards.** **4.2 Parts that require lubrication must be accessible.** **4.3 The replacement of spare parts must be easily done.**		
Establish targets for production, supplier, contractor, and retail costs as early as possible. Checking competitor or like products will help. **5. Target Product Cost** **5.1 The product is aimed at the mid price range. Retail cost is £95.00 and target cost for manufacture is between £30.00 and £35.00.**		
Establish targets for production, supplier, contractor, and retail costs as early as possible. Checking competitor or like products will help. You will need to conduct a comprehensive analysis of competing and like products; this will typically involve literature searches, patent, and product searches. **6. Competition** **6.1 Raleigh BMX** **6.2 Hood BMX** **6.3 Apollo Urchin**		
It is likely that the product being designed will need some form of packaging even if this is merely to protect the product while it is being transported from one place to another. The cost of packaging can have a significant impact on the final cost to the customer. **7. Packing** **7.1 Size must be kept to a minimum.** **7.2 Cost must be kept to a minimum.** **7.3 Weight must be kept to a minimum.** **7.4 Must be waterproof.** **7.5 Must be easily unpacked by the customer.** **7.6 Company logo must be clearly shown on package.**		
Do you envisage the products' delivery by land, sea, or air? Consider the type of truck, pallet container, or aircraft. **8. Shipping/Transport** **8.1 Packages will be stored 10 to one box.** **8.2 ISO containers will be used to carry the boxes.** **8.3 Transportation will be by sea then road or rail.**		
Consider how many products you wish to manufacture, which will affect costs and schedule. **9. Quantity** **9.1 10,000 units to be produced annually initially.** **9.2 Long production run expected.**		
Where is the product to be made and what facilities and expertise will be available? **10. Manufacturing Facility** **10.1There are no constraints on the manufacturing facility.**		

Appendix 2. Survey

Tiedonhallinnan kartoitus / Data management survey

Kyselyä käytetään pohjana tiedonhallinnan kehitysprojektien luomiseksi. Pitkän aikajänteen kehitysprojektien tavoitteena on parempi tiedonhallinta joka käytännössä tarkoittaa sitä, että tiedon etsimisen sijasta voidaan keskittyä työn tekemiseen.

This survey establishes base for development projects. Long term development projects have goal to develop data management. Which in practice means, that instead of searching data we should be able to focus doing our work.

a

1. Rooli yritysessä / Role at company *

Huom! Palvelut sisältää huollon, mittauspalvelun, asiakastuen, .. | Note: Services include mainteinance, measurement service, customer support, ..

- ◯ Myynti | Sales
- ◯ Suunnittelu/R&D | Design/R&D
- ◯ Manufacturing
- ◯ Palvelut | Service
- ◯ Muu | Other

Ensin kerätään taustatietoa tiedonhallintaan liittyen. | First we collect backround data for data management.

2. Kuinka monesta eri paikasta löydät työhön liittyvää tietoa |
How many different locations comes into mind when you think about where work related data can be found? *

Huomaathan, että tiedon sijaintien lukumäärä riippuu työtehtävistä, yhtä oikeaa vastausta ei ole olemassa | Please note, that data locations depend on what you do, there is no single correct answer

- ◯ 1-2
- ◯ 3-4
- ◯ 5-7
- ◯ 8-10
- ◯ Yli | Over 10

3. Vapaaehtoinen: Kerro mitkä nuo yllämainitut sijainnit ovat | Optional: Please disclose what those locations are

Seuraavaksi kysytään mielipidettäsi tiedonhallinnan nykytilasta. | Next we ask your opinion about current state of data management.

4. Työhön liittyvän tiedon etsiminen on | Searching work related data is *

	1	2	3	4	5	6	7	
Helppoa | Easy	◯	◯	◯	◯	◯	◯	◯	Vaikeaa | Hard

5. Löydän kaiken tarvittavan tiedon | I find all information I need *

	1	2	3	4	5	6	7	
Aina | Always	◯	◯	◯	◯	◯	◯	◯	En koskaan | Never

Seuraavaksi selvitetään mikä nykytilanteessa koetaan vaikeana ja helppona. **Osio on vapaaehtoinen mutta vastauksia toivotaan.** | Next part asks about what is considered easy and what is considered hard at current situation. **Answering is optional but suggested.**

6. Mikä tieto on helpointa löytää? | What data is easiest to find?

7. Mikä tieto on vaikeinta löytää? | What data is hardest to find?

8. Mikä tieto on helpointa luoda? | What data is easiest to create?

9. Mikä tieto on vaikeinta luoda? | What data is hardest to create?

Ja loppuun tilaa avoimille vastauksille, palautteelle, kommenteille jne. | And last, open answers, feedback concerning the survey, other comments, etc

10. Vapaaehtoinen: kommentit/palaute/selvennykset | Optional: comments/feedback/clarifications

Appendix 3. PLM Vision and strategy

Appendix 4. Project 1: Development Project Framework

Appendix 5. Project 2: Product Workflow Improvements

Appendix 6. Project 3: Purchase of PDM/PLM System

Appendix 7. PDM stage questionnaire

PDM Stage Questionnaire

Mark option that applies with cross (x)

Stark, John. 2005. *Product Lifecycle Management : 21st Century Paradigm for Product Realisation* . Decision Engineering. Springer. P.378.

A. About the company

1. How many of the main business processes of the company are defined?
All ☐ More than half ☐ Less than half ☐ Check answer!

2. On average, how much training do people in the company reveice each year?
> 15 days ☐ 5-15 days ☐ < 5 days ☐ Check answer!

3. How often are customers included in product development teams?
Usually ☐ Rarely ☐ Never ☐ Check answer!

4. How would you describe the company's organizational structure
Flat ☐ Between ☐ Pyramid ☐ Check answer!

5. How would you describe the company's organization?
By product ☐ Mixture ☐ By function ☐ Check answer!

6. What percentage of people in the company understands that product development is a process?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

7. How receptive is the company to advanced techniques and practices?
Receptive ☐ Unreceptive ☐ Check answer!

8. How does the top management value product data?
Strategig importance ☐ Little or no value ☐ Check answer!

9. What is top management policy towards Information Systems?
Competitive advantage ☐ Outsource when possible ☐ Necessary evil ☐ Check answer!

10. To what extent is Total Quality Management (TQM) implemented? (everyone is committed maintaining high standards)
Fully ☐ Partly ☐ Not at all ☐ Check answer!

B. About product development

11. How much contact do product developers have with customers?
Most have lot ☐ Many have some ☐ Most have none ☐ Check answer!

12. What percentage of developers can describe the complete product development process?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

13. What percentage of developers work in cross-functional teams?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

14. What percentage of development projects uses Concurrent Engineering? (simultaneous execution of different development project steps)
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

15. How is the activity of managing product data viewed by product development management?
Strategic activity ☐ Low-level activity ☐ Check answer!

16. How receptive are the managers of the product development process to advanced techniques and practices?
Always very ☐ Sometimes ☐ Usually unreceptive ☐ Check answer!

17. What is the level of integration of engineering computer systems?
Most are ☐ About a half are ☐ Few are ☐ Check answer!

18. What is the average age of product developers?
Under 35 ☐ 35-40 ☐ Over 40 ☐ Check answer!

C. About PDM

19. How often is product data exchanged electronically with customers and suppliers?
Usually ☐ Often ☐ Rarely ☐ Check answer!

20. How often is product data transferred electronically inside the company?
Usually ☐ Often ☐ Rarely ☐ Check answer!

21. What percentage of product data is managed by PDM?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

22. What percentage of product developers understand the reasons using PDM?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

23. Is the approach to PDM by department or company-wide?
Mainly company-wide ☐ Mainly departmental ☐ Check answer!

24. Is engineering change management electronic or manual?
Mainly electronic ☐ Mainly manual ☐ Check answer!

25. Is all data under the control of PDM?
Yes, all data ☐ No, a lot is ☐ Nope, only little ☐ Check answer!

26. Which PDM applications are in use?
Structure & complex workflow ☐ Basic data & simple workflow ☐ Basic data or simple workflow ☐ Check answer!

27. What percentage of product developers use PDM?
81-100% ☐ 51-80% ☐ 0-50% ☐ Check answer!

28. How many part numbering systems are in use in company?
1 ☐ 2 or 3 ☐ 4 or more ☐ Check answer!

29. To what extent are lifecycle practices in use?
A lot ☐ Some ☐ None ☐ Check answer!

30. What is the level of integration between PDM and CAD/MRP/ERP & similar systems?
Full ☐ Little ☐ None ☐ Check answer!

31. Since when has the PDM team reported to management that PDM is a positive investment?
For more than two years ☐ For less than two years ☐ Not yet ☐ Check answer!

Score: 0

47-62: Stage 4 **9-24: Stage 2**
25-44: Stage 3 **0-8: Stage 1**