CHALMERS
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Integrating Rapid Learning Cycles into Hardware Development

A practical improvement project within chassis development at Scania CV AB

Master's thesis in Product Development

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MASTER THESIS

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Abstract

Within rear truck chassis component development at Scania CV AB, Södertälje, Sweden, a need of improving the quality of deliveries at a milestone in the development process has been identified. At this milestone, product functionality should be proven and the life of the product should be indicated. The milestone precedes a tacted sequence of milestones to coordinate several sub-projects towards a common start of production. Due to the identified issues major loop-backs in late phases of development are frequently needed, which might result in significant additional costs and delays of product launches.

This thesis addresses the identified issues utilizing principles from lean product development. Through reviews of research and literature, interviews, observations, and study visits, the areas of rapid learning cycles, visual planning, and A3 reports, are identified as key focus areas. There are practical and theoretical examples of utilizing rapid learning cycles to improve output within product development. However, few guiding practical examples of integrating a knowledge based development procedure into a hardware development context exist.

An approach to integrate rapid learning cycles to the ways of working within rear truck chassis component development at Scania is developed. Learning cycles support to cross functionally focus on gaining the right knowledge, and frequent decision making while cost of change is still acceptable. Also, an approach for utilizing A3 reports during learning cycles and how to conduct visual planning is developed. Further, the thesis highlights the importance of frequent review of knowledge gaps, risks and problems, in order to create an urgency to manage possible issues before they turn into costly problems. Implications from this thesis might improve the understanding and perception of knowledge based hardware development at Scania. The thesis also constitutes a practical example of how to approach rapid learning cycles within hardware development in the automotive industry.

Keywords: *Rapid Learning Cycles, Lean Product Development, Product Development, A3 Reports, Daily Management, Visual Planning, Digital Visual Planning, Scania CV AB*

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Thanks to the support from Ola Brantefors, we have been able to present and discuss our findings and receive feedback from the teams. We would also like to thank Nicklas Carlsson, whose positive and visionary attitude has supported infusing our thoughts and findings into the ways of working at RTLR. Finally, we would like to express gratitude to the people at Scania, Ericsson, and Chalmers, who have invested their precious time to contribute to this thesis.

Remember, the fika is always closer than you think.

Södertälje, June 10, 2016

David Johansson

Victor Persson

Abbreviations

BMM	Business Maintenance Manager
C1	Case 1
C2	Case 2
C3	Case 3
CAD	Computer Aided Design
CDM	Chassis Development Manager
CE	Calculation Engineer
DM	Daily Management
DVP	Digital Visual Planning
GA	Green Arrow
LAMDA	Look-Ask-Model-Discuss-Act
LPD	Lean Product Development
LPS	Lean Production System
OSMG	Open Scrum Master Gathering
PD	Product Development
PDCA	Plan-Do-Check-Act
PGM	Project General Milestones
PM	Project Manager
PO	Product Owner (Scrum)
RA	Red Arrow
R&D	Research and Development
RLC	Rapid Learning Cycles
SBCE	Set-Based Concurrent Engineering
SM	Scrum Master (Scrum)
TCC	Targeted Convergence Corporation
TE	Test Engineer
TL	Team Leader
TM	Team Member (Scrum)
VIP	Vehicle Integration Points
VP	Visual Planning
YA	Yellow Arrow

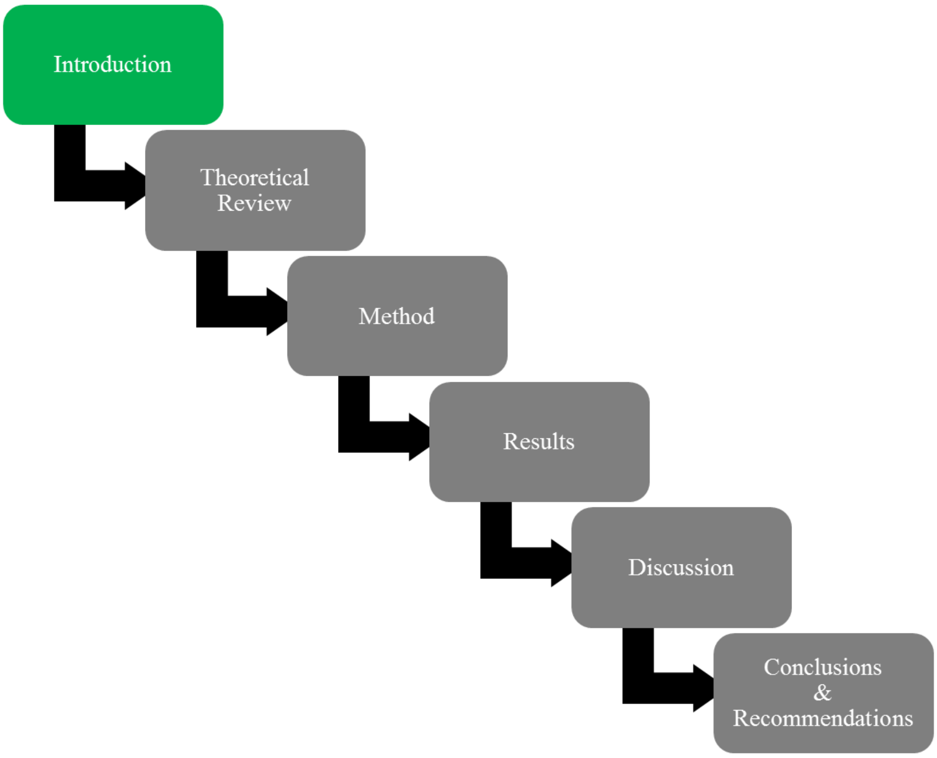
Contents

1 *Introduction*

Within hardware development, cost of change increases exponentially during late phases of projects. Tools and equipment for manufacturing, interfacing product sub-systems, and so forth limits development teams´ ability to change designs. Early and non-informed decisions might lead to drastic and costly changes in late project phases. (Lindlöf, 2014 a) Decisions should thus be made informed with as much relevant knowledge as possible in order for quality of decisions to be sufficient.

Within truck chassis development at Scania a need is identified to increase quality of deliveries to a certain milestone, PRY-3, in the current development process. This milestone precedes a series of common milestones where multiple sub-projects integrate in order to coordinate until a common start of production. Deliveries to this milestone are proof of product function and indications of product life. Thus, deliveries at this point are crucial in order to be able to deliver the required quality to subsequent milestones and to coordinate deliveries towards other sub-projects.

There are few practical examples or indications from research guiding how to approach the integration of a knowledge-based development into hardware development. In the case of chassis development at Scania, projects are carried out during several years, resulting in long development lead times. Thus also the employee turnover is evident within single projects. In some cases, decisions made in early phases of development eventually lead to major loop-backs in late phases of development projects, which drive significant costs. Hence, there is a need to increase the quality of decisions during development projects.



1.1 Purpose & Aim

As a delivery to RTLR, a department developing rear truck chassis components at Scania, this thesis addresses the identified needs of increasing quality at PRY-3. Hence, a research question was formulated, presented below.

How should quality of deliveries at milestones in the development process at Scania CV AB within chassis development be increased, utilizing principles from lean product development?

Throughout the thesis, research methods have been adapted to more specifically capture the needs of RTLR. Apart from review of relevant research and literature, also interviews with managers and co-workers at Scania, internal and external study visits, and workshops, have been conducted. This has supported development of recommendations which are inspired from research and literature, but can also be integrated to the ways of working at RTLR without major interruptions.

The thesis has been carried out as part of the M.Sc. program in product development at Chalmers University of Technology, Gothenburg, Sweden. Hence, the time frame of the thesis has been limited to 20 weeks of 40 working hours each, for a thesis project group consisting of two people. No specified budget limitation has been applied, since the thesis has not involved handling of expensive materials or trips with overnight stays.

This thesis develops recommendations for how to integrate methodologies from rapid learning cycles into the ways of working at RTLR. Also, recommendations for how to approach daily management and implementation of a digital visual planning tool are developed. These recommendations intend to support RTLR to increase the quality of deliveries for milestones in the development process through increasing the frequency of design reviews and decision points. This increases the quality of decisions during development projects, thus also the quality of deliveries at PRY-3.

The thesis report is initiated with an introduction to the development process utilized within chassis development at Scania, in order to frame the context of the thesis. Subsequently, the theoretical framework is presented, followed by the method of the thesis. Further, results are presented as the outcome from preceding chapters. A discussion follows, in order for the thesis group to discuss and reflect over findings and implications from the results. Finally, conclusions and recommendations based on the discussions are presented, as well as recommendations for future research efforts.

1.2 Scania in Brief

Founded in 1891, Scania currently employs approximately 42 000 people and has sales and service organizations in more than 100 countries. As one of the world´s leading manufacturers of heavy trucks and buses, Scania also operates in the industrial and marine engines business areas. During the last seven decades, Scania has reported a profit every year. The head office is located in Södertälje, Sweden, where R&D operations employ about 3 500 people.

1.2.1 The Scania house

The visualization of a "house" explains the core values and ways of thinking at Scania. Since its introduction the house has undergone a number of revisions. However, the principles behind the figure are firmly rooted in the organization. The Scania house is visualized in Figure 1.2-1.

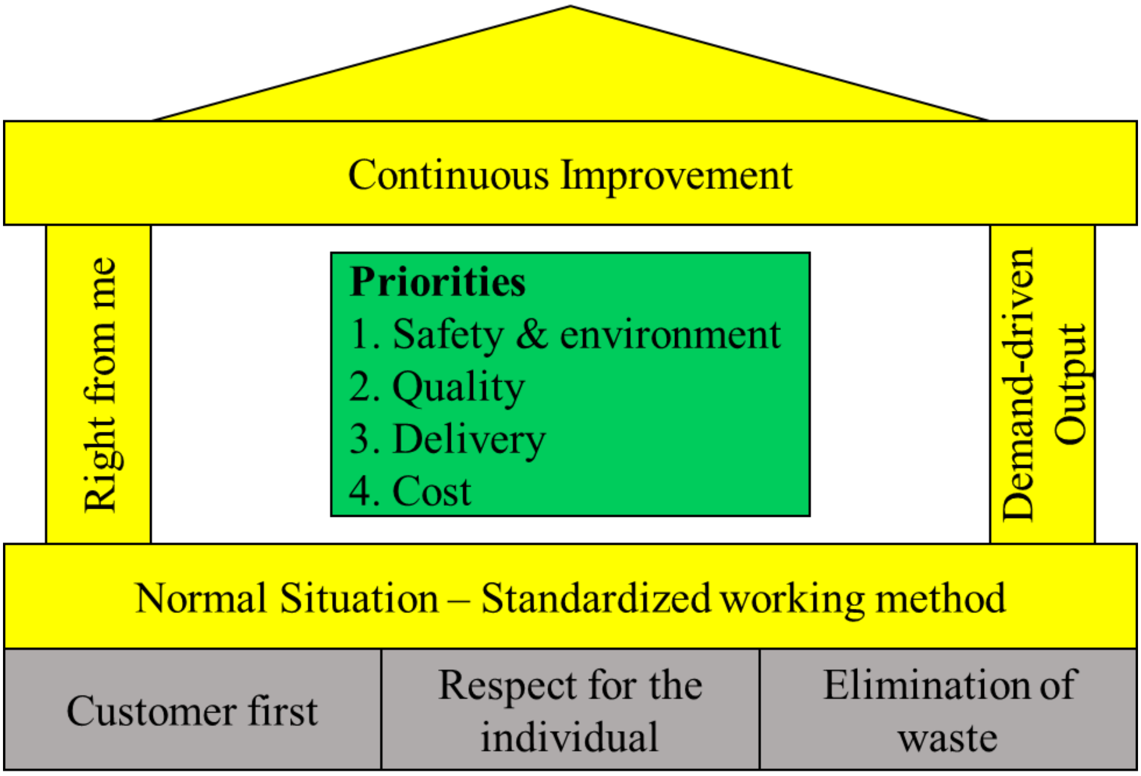


Figure 1.2-1 – The Scania house, adapted from internal material at Scania.

1.2.2 Core values

Scania´s objective is to provide the best profitability for its customers and thereby taking the lead in its industry. All operations are based upon three core values; *Customer First*, *Respect for the individual*, and *Elimination of waste*. Success factors are to focus on working methods and dedicated employees.

1.2.2.1 Customer first

In the center of the value chain are the customer´s operations. Throughout research and development, procurement, production, sales, financing, and delivery of service, Scania delivers solutions that contribute to customers´ profitability. This is achieved through deep knowledge about the customers´ operations and business conditions.

1.2.2.2 Respect for the individual

Working methods are improved and developed by recognizing and utilizing each co-worker´s skills, knowledge, experience, and ambitions. To ensure high quality, efficiency, and job satisfaction, day-to-day operations should foster new ideas and inspiration for development.

1.2.2.3 Elimination of waste

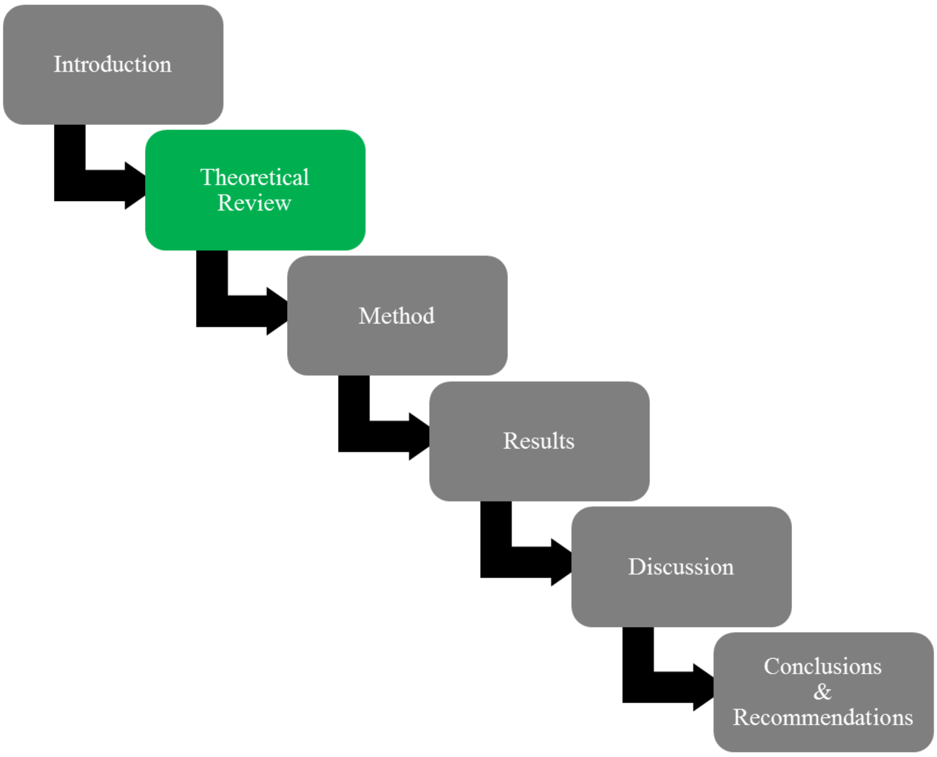
The profitability for customers relies on Scania delivering high-quality solutions. Scania improves the quality of its products and services continuously through knowledge about the customer needs, and ensures that deliveries meet expectations by eliminating all forms of waste. Deviations from standards and targets are utilized as a source for continuous improvements.

1.2.3 Continuous improvements

Increased efficiency is a prerequisite for Scania to maintain competitiveness and profitable growth. This is achieved through continuous improvements in production and streamlining of the production structure. The in-house developed Scania Production System (SPS) includes principles and methods leading to continuous improvement efforts. Ideas and innovations for improvements are encouraged and discussed, new solutions are continuously evaluated and introduced in a global production network. These principles are also integrated within the R&D organization at Scania.

2 *Theoretical Review*

This section provides a summary of existing literature and research within relevant areas for the thesis project. Most of the literature is based on theories within lean product development (LPD) and related areas relevant for answering the research questions.



2.1 *Lean Product Development*

In many industries lean is an established way of thinking, significantly within production systems, which has been adopted in a majority of all companies in the automotive industry (Morgan & Liker, 2006). The principles of lean production systems (LPS) are clear and straight-forward and can be summarized with increasing output utilizing less resources, by eliminating waste (Dennis, 2007). LPD is similar to LPS by its principles. The core of LPD is to reduce the time to market by reducing waste and maximizing customer value at each step in the development process. This supports companies to get the right products to market in the right time to the right price. (Radeka, 2013)

LPD origins from the development system used at Toyota[1]. It was first highlighted in 1990 when Toyota's way of developing cars was recognized as more effective compared to European and American automobile manufacturers. The time to market, manufacturing cost, and number of defects were considerably lower. (Morgan & Liker, 2006) Toyota is the largest and most profitable automobile manufacturer in the world. In addition Toyota also achieves the shortest product development and production lead times in the industry. (Holmdahl, 2010)

Even though lean often refers to LPS, there are indications that LPD was created before LPS by Sakichi Toyoda[2] and his son Kiichiro Toyoda[3], since they used the principles of creating knowledge through experiments. (Holmdahl, 2010)

2.1.1 Principles of LPD

Morgan and Liker (2006) have identified three key systems of LPD; *process*, *people*, and *tools & technology*. Related to these three systems they have listed and described 13 principles considered to be the foundation of LPD. They describe that these systems are closely linked together affecting each other and the outcome of the process. The three systems are illustrated as a triangle, see Figure 2.1-1. The three key systems are described in sections 2.1.1.1, 2.1.1.2, and 2.1.1.3.

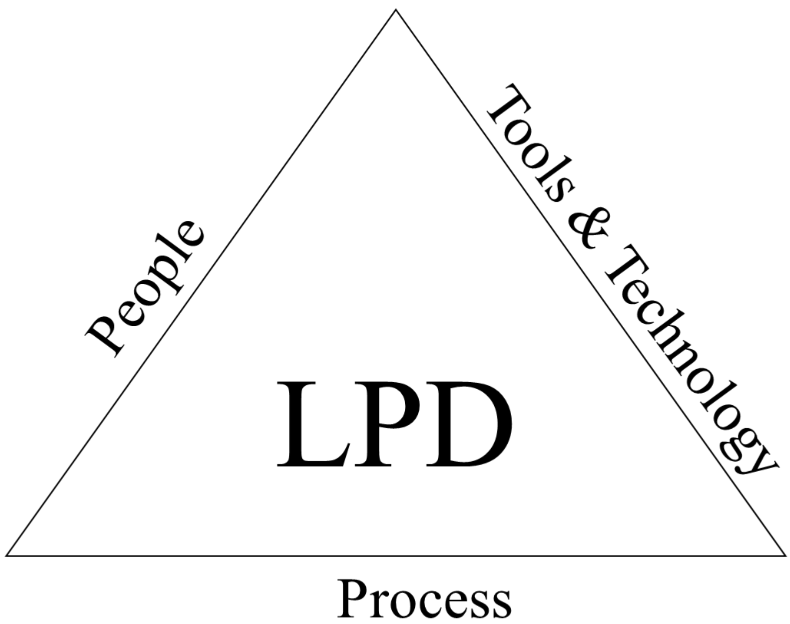


Figure 2.1-1 - The triangle describes LPD as a system built upon three major sub-systems. These systems are further described in the sections below. The figure as adapted from Morgan and Liker (2006).

[1] Toyota is a Japanese automobile manufacturer.
[2] Sakichi Toyoda was the founder of Toyoda Loom.
[3] Kiichiro Toyoda was the founder of Toyota Motors.

2.1.1.1 Process

The principles related to the system of processes are the ones related to organization and coordination of activities to successfully develop a product and minimize wasteful activities.

The first principle related to processes, regards customer value. In LPD the customer should always be the starting point and all activities that do not add any value to the customer are considered as waste and should be eliminated (Morgan & Liker, 2006). Holmdahl (2010) is discussing the importance of minimizing the distance between the user and the developer, preferably the developer should also be a user. At Toyota the voice of the customer to the development team is managed through a chief engineer, who is responsible for understanding value according to the customer and to ensure that these values are represented in the product (Morgan & Liker, 2006).

Another typical characteristic of a lean product development process is to take design decisions late to ensure that the optimal solution is found and hence late costly design changes are eliminated. A useful method for this mindset is set-based concurrent engineering (SBCE) (Holmdahl, 2010). SBCE is based on the principle studying a set of solutions and possible parameters in order to successively eliminate the worst alternatives. Compared with the more traditional approach, point-based design, where one concept at a time is investigated (Morgan & Liker, 2006). A further description and the principles of SBCE are given in section 2.2.

Standardized procedures are also a significant part of LPD. It means that once a better way of solving a problem is identified, this knowledge should be distributed and reused by others in the organization (Holmdahl, 2010; Morgan & Liker, 2006). Thus engineers avoid falling into the same pit-falls several time.

The core of LPD and LPS is to eliminate wasteful activities which do not add customer value. In LPS this is done by having a standardized process. To view product development as a process is according to Morgan and Liker (2006) one of the major factors of Toyota's successful development system. This has enabled Toyota to develop a standardized development process which has been continuously improved by repeated waste reduction each time carried out. Within LPS waste is relatively simple to identify, and has been divided into seven categories. Morgan and Liker (2006) stated that these categories can be translated into LPD as well, described below.

- *Overproduction* - When different activities are not synchronized and creates a gap between activities.
- *Waiting* - When engineers do not have what they need to continue with their tasks.
- *Conveyance* - The time when information is being transferred from one person to another and is therefore not in progress.
- *Processing* - This includes tasks which are unnecessary, such as fixing computer errors and mistakes by individuals. Many of these errors can be reduced by training and experience.
- *Inventory* - This is the result of overproduction and includes information waiting to be utilized in subsequent tasks. This often results in loss of information, thus rework may be necessary. Such reinvention is often caused by lack of guidelines for documentation, or documentation which is hard to access.
- *Motion* - This waste includes for example unnecessary meetings and writing reports that will not be read.
- *Correction* – Redoing tasks is a major part of an engineer's working day. Examples of correction is design loopbacks, where the development team needs to start over with a new concept.

Radeka (2013) has also summarized waste within product development. Similarities to Morgan and Liker's points can be found, however differences can also be found. Radeka´s additional points are presented in the list below.

- *Insufficient customer empathy* - To not deliver what the customer want is the most wasteful thing.
- *Excess requirements and specifications* - Establishing too harsh requirement specifications limits engineers' ability to utilize already gained knowledge. This in turn limits the ability to maximize value to the customer.
- *Excess project management overhead* - This is a waste necessary to the development process. It does not add any direct value to the customer but is crucial since the process is too complex to manage without someone keeping track of activities.
- *Overloaded resources* - A developer working with too many projects will slow down the progress of the development. Further, Wheelwright and Clark (1992) state that engineers should work with two projects at a time in order to optimize efficiency.

Standardizing the development process does not only lead to waste reductions, but also a more robust process with higher predictability. In addition to standardizing the process, LPD supports standardization in design and engineering skill-sets. Standardizing the design in this sense means reusing components which have proven to be reliable in similar applications. It also includes to strive for development of products upon existing product platforms. Standardizing engineering skill-sets implies training engineers to become specialized in certain areas. Toyota invests significant resources in new engineers, and from the first working day training is initiated to develop expert engineers. (Morgan & Liker, 2006)

2.1.1.2 People

LPD is based upon team work and to have skilled employees. The content of the principles related to people describes how to communicate and how to structure and lead organizations. LPD is also about creating a culture which fosters aiming for perfection and to never stop improving the processes. Continuous improvement is central and the most powerful characteristic of LPD. To work effectively with continuous improvements, it is required to identify root causes of problems as soon as they occur. (Morgan & Liker, 2006) Improving a process requires reflection and analysis of every task in a process before action is taken. This iterative process is commonly described using the *Plan-Do-Check-Act* cycle (PDCA). This cycle should be a never-ending iteration where knowledge is created during each cycle. (Oosterwal, 2010) A similar model to PDCA is the LAMDA-model; *Look, Ask, Model, Discuss, Act.* According to Holmdahl (2010), this model more effectively supports identifying root causes of problems compared to using the PDCA model. The LAMDA and PDCA models are further described in section 2.4.1.

Chief engineers should be ultimately responsible for design projects, establishing design guidelines to ensure delivering value to the customer (Morgan & Liker, 2006). To become a chief engineer it is required to have excellent engineering skills and that these skills have been proven in a line manager position. This can be compared to Swedish systems where a project manager is often promoted to a line manager position. The reasoning in the Swedish industry is that younger people, preferably without children, are available to work long days, meanwhile at Toyota more emphasis is put on experience and technical knowledge. (Holmdahl, 2010) Since chief engineers are responsible for delivering value to the customer and act as voices of the customer to the rest of the project teams, the chief engineer needs deep knowledge and understanding of the customer. When gaining this knowledge it is important that the customers are studied closely for a long time in order to identify their specific needs. (Morgan & Liker, 2006)

The engineering organization at Toyota can be described as a combination between a functional organization and a product organization. In a functional organization all co-workers within a function are co-located. In a product organization co-workers developing a product are co-located. This combination forms a matrix structure, where functions are co-located but combined through their functional general manager who has direct contact with the chief engineers for each product program. This structure enables exploiting benefits from both the deep technical knowledge gained from functional structures as well as the coordination benefits and product focus through cross functional integration from product organizations. (Morgan & Liker, 2006) Information exchange between different departments often takes place in a project room, called *obeya*[1]. Transparency is achieved through visualizing projects and highlighting problems. This enables a more accurate planning and it supports problem solving in early project phases. (Holmdahl, 2010)

The support for engineers to become experts within certain areas is part of LPD at Toyota. The culture is hence rewarding technical expertise rather than a broad knowledge base, which is often preferred by other automobile manufacturers. To become an expert at Toyota six to eight years of experience is required, where the first two years are invested in training to become a first level engineer.

The principles of LPD do not only include development of skilled engineers. Also, it is emphasized to develop the relation to the suppliers and to fully integrate them in the development process, in order to utilize their knowledge. (Holmdahl, 2010; Morgan & Liker, 2006) This can be done in several ways, either by assigning development tasks to suppliers or through exchange of engineers. Letting engineers work with suppliers or vice versa enables an information flow through discussions. It can also provide a general understanding and enhanced reliance between the parties. (Holmdahl, 2010)

2.1.1.3 Tools and technology

A common trend for companies today is to continuously identify and implement new advanced technical tools, in order to enhance development capability. At Toyota, and according to principles of LPD, it is emphasized to implement tools which are compatible with already existing organizations and processes, even if this might imply sacrifices in technical performance. Toyota has, according to Morgan and Liker (2006), identified five principles which should be considered before implementing new tools or technologies, presented below.

1. The technology should be integrated into existing systems without any flaws.
2. The new technology should only be implemented to improve existing technology and processes should not change to fit the technology.
3. The purpose of new tools and technologies should not be to reduce the number of employees, it should be to maximize the efficiency in the engineering work.
4. There is no tool that can solve all problems, thus it is important to have a clear specific purpose with each tool.
5. Simple tools should not be underestimated. It is better to have a simple tool which is easy to use, rather than having an advanced tool which is hard to use.

The reasoning for the principles at Toyota is that competitive advantage lies in skilled people and continuously improved processes. Advanced tools and technologies are available for all organizations, also for competitors. Thus the tools per se should not be considered as a competitive advantage. (Morgan & Liker, 2006)

What has been frequently used at Toyota and what has been a hallmark of lean is the use of simple and visual tools. The reason to use visual tools is to effectively and easily share information within projects and across functions. The communication method at Toyota is built upon the hypothesis that more information is not always better and that gathering too many engineers to present findings is often wasteful. (Morgan & Liker, 2006) It has also been proven that, by using visual tools, such as pictures and figures, information becomes easier to grasp. Hence these tools reduce the risk of misunderstandings. Research has also revealed that the creativity takes place before the situation is settled with words. (Holmdahl, 2010) The obeya, mentioned in section 2.1.1.2, is the project room where everything related to the project is visualized. The implementation of such rooms is one of the success factors in reducing development lead time since it enables cross functional information flow despite the functional organization (Morgan & Liker, 2006). Parts that should be visible in the obeya

[1] Obeya is the Japanese word for big room

are, for instance, goal and vision of the project, the responsible person of the project, and a time plan with defined deliveries. There are many tools which could be used for these purposes but what is common for all of them is clarity. If for instance the goal is not clear enough, engineers risk to get different perceptions which increases the probability of problems during the project. Once the project is up running it is common that also drawings and prototypes are visualized in the obeya. This makes it easier to find possible problems early in the process. (Holmdahl, 2010)

In order to not just learn as an individual, the need of continuous improvements implies that an effective sharing of knowledge within the organization is necessary. LPD strives for clear and available data, not overwhelming reports. Check lists is one of the tools that is recommended in LPD. These provide clear and precise information, for instance on different parameter ranges possible for manufacturing. Examples of check lists are drawings with handwritten notes describing for example necessary tolerances, possible ranges of release angles and so forth. (Holmdahl, 2010) Another example is a quality matrix, which describes potential quality issues for specific parts in each manufacturing process (Morgan & Liker, 2006). The checklists are regularly updated with new information. Every time the engineers exceed the predefined ranges with a successful result they are responsible for updating the ranges. (Holmdahl, 2010)

2.2 Set-Based Concurrent Engineering

As mentioned in section 2.1.1.1, SBCE is an effective way of finding the optimal solution by successively reducing the least promising alternatives. In contrast to traditional product development, where one concept is developed and evaluated at the time, SBCE is based on developing and analyzing "sets" of concepts. In this literature review, a set is defined as *".... a group of design alternatives fulfilling the same need or function."* (Raudberget, 2012, p. 10). The purpose with this way of working is to reduce the number of design loops and theoretically the development process can be conducted without any loop-backs (Liker, Sobek, & Ward, 1999). Reducing development time does not only reduce the number of engineering hours. In addition, it makes it possible to start the development closer to the market introduction, which reduces uncertainties regarding customer demands. Earlier market introduction is also an opportunity to gain larger market shares and the possibility to initially charge a higher price for a new product or service. (Wheelwright & Clark, 1992) Another benefit of SBCE is that an organization can allow taking risks within certain areas without jeopardizing entire development projects. This enables to either increase the rate of innovation to the same risk or keeping the same rate of innovation with a reduced risk (Holmdahl, 2010). However, despite the advantages with SBCE, there are indications that the actual use of it and the understanding of its principles are limited. Research has also shown that the benefits of SBCE can only be exploited if engineers and managers fully understand its principles. Otherwise it might have a negative effect on the development process. (Kerga, Rossi, Taisch, & Terzi, 2014)

2.2.1 Three principles of SBCE

Liker et al. (1999) have identified three main principles of how to use SBCE. These principles will be further described in sections 2.2.1.1, 2.2.1.2, and 2.2.1.3. These principles should not be considered as steps in a sequence, since they can be applied differently for different projects and organizations (Liker et al., 1999).

2.2.1.1 Map the design space

The first principle of SBCE is to generate a number of possible solutions for each component. This step is done for each sub-system concurrently and independently, in each relevant department. In the initial stage design constraints should only be based on each sub-system. Knowledge from similar projects in combinations with testing and analysis should be the base for a first elimination in which the worst alternatives can be eliminated. Design decisions should only be based on approximations and estimations if the sub-system does not provide a key function to the rest of the system or if the decision is obvious. Otherwise all decision should be based on comparable facts. To analyze how different parameters interact, it is common to visualize test data in trade-off and limit curves. This simplifies the communication of the data and makes it visual. (Holmdahl, 2010; Liker, Sobek, & Ward, 1999)

2.2.1.2 Integrate by intersection

When designs for all sub-systems are generated they should be combined. The first step is to look for intersections. This means reducing the total design space to only compatible solutions. Sub-system solutions which do not fit to other solutions and current specifications should be eliminated. Further the new set with compatible solutions should be narrowed even more by tightening parameter ranges. This is repeated until a final total solution is identified, see Figure 2.2-1. For this stage analytical tools such as trade-off curves, physical prototypes, and clay models are useful. However, it is important that all possible alternatives are specified at the same level of detail in order to eliminate alternatives based on facts, not gut feeling. To further develop concepts, they should be critically discussed and improvements should be proposed. This might also result in new, even more promising, concepts. When evaluating concepts, it is beneficial to reward concepts which are robust towards other sub-systems since this allows continuation of concurrent development without the need of additional information about surrounding sub-systems. (Holmdahl, 2010; Liker, Sobek, & Ward, 1999; Raudberget, 2012)

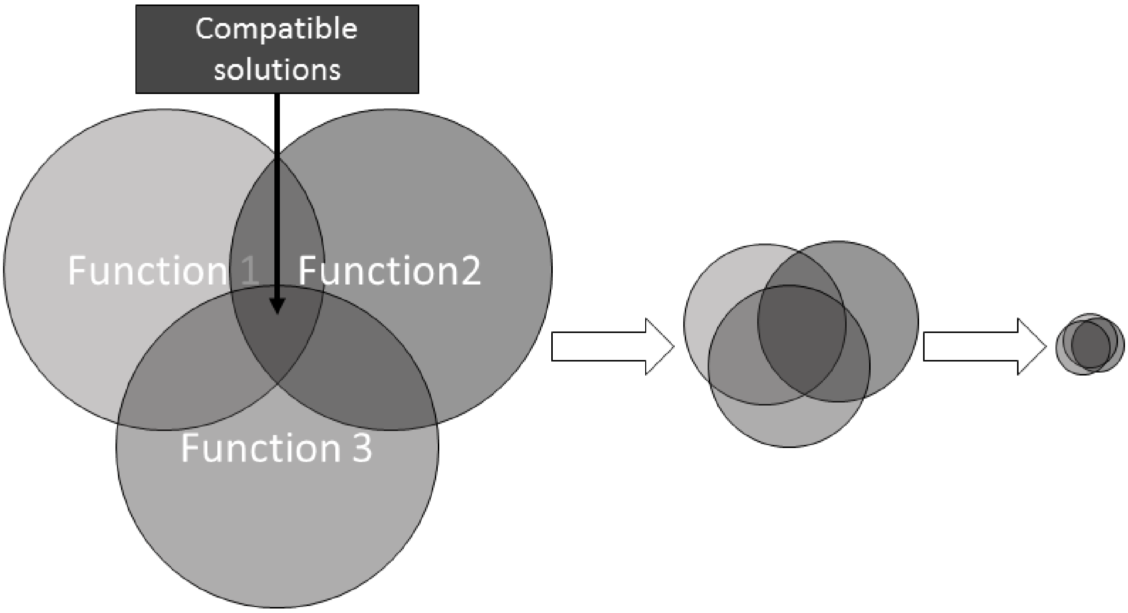


Figure 2.2-1 The set of possible solutions is successively reduced, until convergence is reached. (Raudberget, 2012)

2.2.1.3 Establish feasibility before commitment

By utilizing a set-based development process, this third principle should automatically be fulfilled. The third principle implies that before initiating detailed design, the design team should be sure that the design is viable. Liker et al. (1999) do not only state that SBCE results in a feasible solution, but also optimized performance on a system-level, reducing the risk of sub-optimized products. To succeed with this it is important to gradually increasing the detail level of the concepts. The first eliminations can be based on sketches but as the set of possible solutions is diminishing a higher level of detail is necessary to make fair judgements. Each function can narrow their sets simultaneously but in this stage frequent communication is recommended to ensure a smooth integration to the overall system. (Liker, Sobek, & Ward, 1999)

2.3 A3 Reports

The ability to communicate knowledge within an organization could be a key for waste reduction. In the industry, managers often spend approximately two and a half hours each day on unnecessary communication and information searching. A3 reports, focusing on the most important information, is an efficient way to improve ways of communication. In A3 reports, it is important to have a sound balance of pictures, text and figures. (Sobek & Ward, 2014) Radeka (2013, p. 47) defines A3 reports as *"…an especially effective communication tool for supporting the systematic problem solving and selectively standardized work that we encourage in a Lean environment.*"

The principle of using A3 reports is to condense what is usually written in large reports into one single sheet of paper of size A3[1]. There are many reasons to use this format. There is one quite obvious and practical reason, A3 is the largest format available from a standard office laser printer. A3s are also easy to handle and they are easy to carry in large amounts in a briefcase. Since it is only one paper there is also no risk that sheets get separated. (Holmdahl, 2010) Sheet sizes smaller than A3 will not be able to carry enough information and it is beneficial to keep all information on the same side of the paper in order to not hide any information at any time (Radeka, 2013).

When reducing the information of a report into an A3 there will be only the most essential information on the sheet. This enables readers to rapidly grasp the information of interest (Morgan & Liker, 2006; Sobek & Ward, 2014). This is an important factor since the report is written once but should be read several times and therefore it should only contain relevant information (Holmdahl, 2010).

There are several usage areas for A3 reports. It can be used for proposing ideas, inform about status, describing design guidelines and lessons learned, solving problems and so forth. (Holmdahl, 2010; Morgan & Liker, 2006). Sections 2.3.1, 2.3.2, and 2.3.3 describe some of the most common usage areas for A3 reports.

2.3.1 A3 for problem solving

Problem solving A3 reports are used when a problem is to be solved. It could be for instance targets which have not been reached or delays in time plans. The problem solving A3 should include necessary information to solve the problem and should preferably align with the PDCA cycle, described in section 2.4.1. Thus the content on the problem solving A3 should initially include an introduction with a short background to the problem, an analysis of the cause to the problem and an action plan for the implementation (Plan). A paragraph of how the action plan was implemented and its results should also be represented in the A3 (Do). The results should be compared with goals and whether the goals are achieved or not (Check), and finally how the results should be followed up (Act). If there are any deviations from the goals, a new iteration may be necessary. Hence this last paragraph should include what still needs to be accomplished and who needs to be informed and so forth. (Holmdahl, 2010)

2.3.2 A3 for proposals

Proposal A3 reports could be used when organizations need to take action to certain issues. It could be for instance to choose between a number of concepts, an investment within the organization or any organizational issues. (Holmdahl, 2010) The proposal A3 should initially have a paragraph with the necessary background and how it is connected to organizational goals. Furthermore the problem should be framed and explained, preferably with as much quantitative data as possible. (Holmdahl, 2010; Sobek & Ward, 2014) It is advised to make a root cause analysis to highlight issues causing the problem (Sobek & Ward, 2014). With the background and root cause in mind a number of alternative

[1] The A-format is part of ISO 216, A3 has the dimensions 297x420 mm.

solutions should be presented and compared with respect to relevant characteristics. Out of this analysis the author of the proposal A3 should give recommendations on the alternatives which were most promising and why they solve the root problem. Finally, a plan of how this proposal can be implemented should be presented and it is important to highlight the problems and uncertainties which still exist. (Holmdahl, 2010; Sobek & Ward, 2014) Often a proposal A3 is preceded with a problem solving A3, as an action to solve already identified root causes (Radeka, 2013).

Holmdahl (2010) also suggests that affected parties should be involved in the creation process of A3 reports in order to get feed-back during and before writing of the A3. This will increase the quality of the suggestions and unnecessary iterations may therefore be avoided.

2.3.3 A3 for status report

A status A3 report presents the current status of a certain project. It should communicate what has been done and what is still to be done. The report should include a short introduction with background and scope to contextualize the project. (Holmdahl, 2010) A status A3 report should be standardized, since the readers will probably read various reports from different authors. To have the same type of information at the same place thus saves time. (Radeka, 2013).

2.4 Rapid Learning Cycles

In order to focus at knowledge within product development at RTLR, the area of Rapid Learning Cycles (RLC) is investigated. There is a correlation between the ability of an organization to learn from both themselves and others, and their ability to solve customers' problems and to develop valuable new products (Mascitelli, 2011). There are challenges and powerful barriers related to the transformation into an organization focusing on building knowledge. An example is the strive towards maintaining status quo in an organization, which hinders innovation. However, RLC provide a structured process to support overriding the killing of innovative ideas, by supporting teams to fail fast to learn fast. (Radeka, 2014 b) Further, RLC support scheduling, resource utilization, and bring more decision points to projects to assess whether a project has enough probability of success or not. RLC also bring more frequent reflection and quick learning with previous work in mind, allocation of resources in manageable chunks, as well as making mistakes obvious in early phases of development. (Majerus, 2015).

The strive to focus on knowledge and learning is not exclusively useful within mechanical engineering. Another example of a useful area is the healthcare industry. As concluded by Etheredge (2014), investments within rapid learning provide opportunities for revolutionizing biomedical research, clinical care, and public health. This indicates a broad usefulness of organizational learning and knowledge buildup in order to facilitate resource efficient research and development.

2.4.1 LAMDA & PDCA

As mentioned in section 2.1.1.2, a method for rapid learning, and thereby knowledge creation and continuous improvements is the PDCA-cycle. PDCA (sometimes referred to as PDSA) is an acronym for *Plan – Do - Check (Study) - Act* and a way to work systematically with improvements and problem solving. (Bergman & Klefsjö, 2010) The cycle is divided into four phases described below.

1. *Plan* – As soon as a problem is detected the cause of the problem needs to be identified. Large problems need to be broken down into manageable sizes and countermeasures need to be developed. Further, an action plan for how to deal with the problems needs to be created.
2. *Do* – Carry out the action plan.
3. *Check* – Check whether results fulfill goals. If the goals are not fulfilled, the cycle needs to be repeated.
4. *Act* – If goals are fulfilled, new standards and routines should be established in accordance with the findings. (Bergman & Klefsjö, 2010; Holmdahl, 2010)

However, during the years PDCA has been used, several flaws have been detected for product development applications. For instance PDCA-cycles do not encourage defining problems in a proper way. Nor are the importance of identifying the root cause of problems emphasized enough. (Radeka, 2013) To deal with these flaws an improved method called LAMDA, see Figure 2.4-1, was introduced by Allen Ward in 2002 (Holmdahl, 2010).

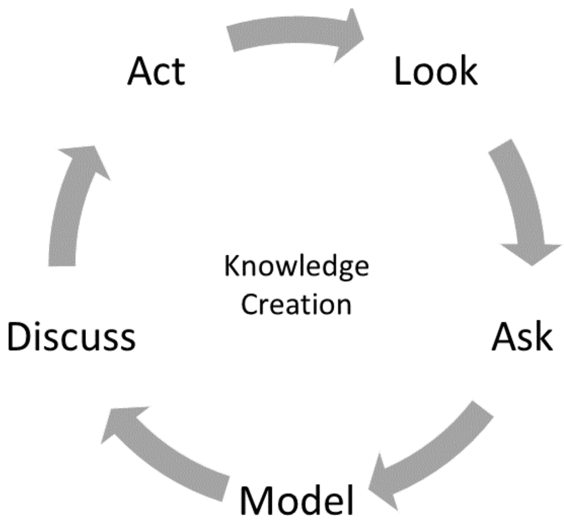


Figure 2.4-1 - Overview of the LAMDA cycle. Inspired by Radeka (2013).

LAMDA is an acronym for *Look – Ask – Model – Discuss - Act.* In comparison to PDCA this method focuses more on a proper definition and a more comprehensive problem investigation, and thereby the understanding of the problem and its underlying causes. (Holmdahl, 2010)

Kennedy et. al (2008) confirm that the LAMDA model prevent the engineers from directly solving a problem. Instead it reminds about first identifying the root cause of problems. Domb and Radeka (2009) also explain the relationship between PDCA and LAMDA, and states that each PDCA-cycle is represented by two LAMDA-cycles as visualized in Figure 2.4-2. Each of the five steps in LAMDA are described below, based on the description by Sobek and Ward (2014).

1. *Look* – The first step in knowledge creation and to understand a problem is to go and see the problem in order to collect first-hand information. Go and see is one out of four main principles at Toyota's internal Toyota Way and is often referred to as *genchi genbutsu*[1] (Morgan & Liker, 2006). It is important to remember that the observations should be carried out actively and to pay attention to details.
2. *Ask* – It is not sufficient to simply see the problem, it is also of high importance to understand why it occurs. Thus it is recommended to ask responsible people in order to find the root cause of the problem. To ask why five times is a commonly used method to investigate underlying reasons of a problem. The "ask" in LAMDA is according to Kennedy et. al (2008) probably the most important step in the cycle.
3. *Model* – Simple models should be created in order to increase the understanding of situations. The shape and detail levels of the models vary. It could be simple sketches and drawings as well as trade-off curves and physical prototypes. Models are used as mediating tools to create consensus among team members when decisions are taken regarding future action plans.
4. *Discuss* – Discussions are conducted to further create a common understanding of problems. Models and knowledge from the "model"-phase of the cycle should be used to develop ideas and understand characteristics of the problems. Similar to the PDCA, this stage may force the team to start over with observations, if sufficient knowledge has not been gathered.
5. *Act* - If sufficient knowledge has been gathered, the team should start implementing actions based on what has been learned. When all steps are carried out, the results should be reviewed in order to ensure that the root causes of the problems have been managed.

[1] Genchi genbutsu is a Japanese phrase literally meaning *the actual part, the actual place.*

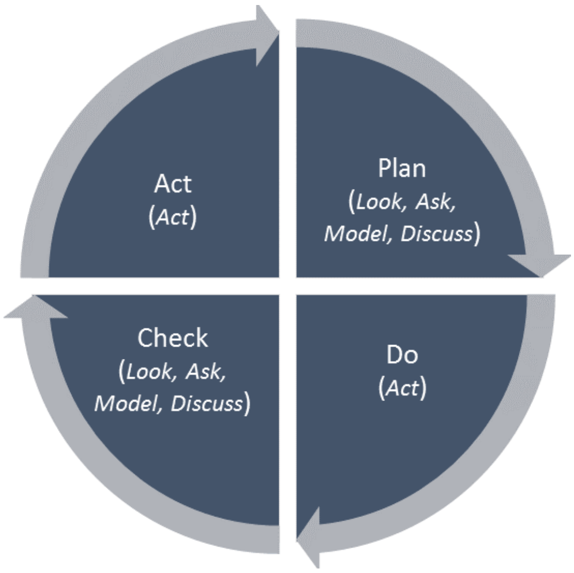


Figure 2.4-2 – The relation between PDCA and LAMDA cycles. Inspired by Domb and Radeka (2009).

2.4.2 Traditional product development - one long & slow learning cycle

Radeka (2015) discusses how traditional development processes in established organizations tend to be long and slow learning cycles. Further, Radeka discusses how the pressure to build products quickly slows the development down and how the pressure to make decisions wastes time.

Most product development (PD) is one and long slow learning cycle. Decisions are taken based on only previous knowledge and a vision for the new product. Hence decisions are often re-visited later in the process when additional useful knowledge has been gained. In worst cases, design teams do not learn until the new product is finalized and launched, when customers complain or refuse to buy the product until it has been changed. Figure 2.4-3 visualizes the implied statements by Radeka, where decisions are re-visited in late stages of the development process. (Radeka, 2015)

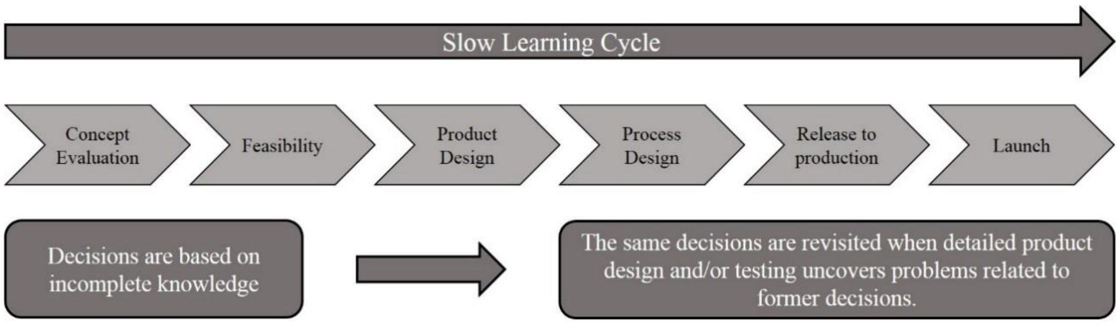


Figure 2.4-3 – Adapted from Radeka (2015). The figure visualizes a development process with concept evaluation as the initial activity and subsequent activities until launch of the new product. Further, the figure visualizes that this PD process is a slow learning cycle since decisions initially taken have to be re-visited later in the development process.

Oosterwal (2010) describes this type of PD as "point-based". Here, similar to Figure 2.4-3, a concept is chosen in initial phases of the process. When working according to a point-based development, process problems are normally identified during late phases of development, resulting in iterations of re-design, simulation, and testing. Point-based PD is therefore regarded as one of the primary reasons to why companies need to undertake major last-minute firefighting measures. It is difficult to know whether targets will be reached or not before a design is tested, and backup concepts are often not developed enough, due to lack of resource allocation. (Oosterwal, 2010)

When products are incrementally improved, little or no new knowledge is needed. When innovative, high risk and highly differentiated products are developed, the creation of new knowledge is essential.

Typically, design teams in the U.S. address development of new high-risk products by rapidly converging to one single conceptual design. Thus, design-to-test cycles are normally applied. This methodology results in learning in long time batches late in development phases. Significant resources are wasted into uncovering knowledge gaps which could have been discovered early. (Mascitelli, 2011)

In established companies, innovative and potentially great ideas are harshly reviewed due to a risk-averse development process. This forces development teams into decisions they are not yet ready to make, in order to formulate promising business cases for ideas to be funded. Once an idea is injected into the development portfolio, it might be difficult to kill even if it is early discovered that the idea will not fulfill requirements. However, the best way to learn about developing a product is to develop one. If sufficient knowledge already has been gained when initiating a development project, it would make sense to start designing and building immediately. In this case, decisions could be made early and people could be held ultimately accountable for the results. Many development processes are not formulated in a way which allows the design teams to take the simplest route to the goal. Building knowledge before taking decisions makes the development easier to conquer. (Radeka, 2015)

When decisions are taken early and learning comes late, obstacles to reach a winning finalized product arise. Teams often get stuck into multiple build-test-fix cycles, which are time consuming and lead to problems in late phases of development. Further, to learn whether an idea is promising enough is time consuming. Many organizations waste significant resources on ideas which should have been eliminated early. (Radeka, 2015)

These long and slow learning cycles might result in a disappointing product with low profitability, high scrap, difficulties to scale for large production volumes, warranty returns and so forth. The drive to make the product work leads to solutions eventually adding costs to the product, which will stay with the product during its lifecycle. This way of working leads to much learning about the final product and what decisions have been taken during development. However, this knowledge is not transferrable to new products and product families. Radeka concludes that the impact of long and slow learning cycles are increased time and resource consumption, as well as decreased quality and customer satisfaction. (Radeka, 2015)

2.4.3 Different views on rapid learning cycles

In this section, thoughts and findings from different researchers within the area of RLC are presented. In order to identify similarities and differences among authors and researchers in the area of RLC, several books, articles and A3 reports have been reviewed.

2.4.3.1 Breaking down projects and processes into shorter learning cycles

The long and slow learning cycles which constitute most traditional development processes can be broken down into shorter, smaller steps or learning cycles. By incorporating these cycles into PD projects several advantages are exploited. Among these are quicker learning, more frequent adjusting, and planning. RLC make scheduling and resource utilization easier, and opportunities to receive customer feedback on the product occurs more frequently. Further, RLC generate more decision points in PD projects with possibilities to stop a non-promising project or to launch the product earlier if possible. Reflection and quick learning occurs more often, and each learning cycle can be carried out with the previous cycle in mind. Risks can be managed better since resources can be allocated in manageable chunks, and mistakes can be caught more quickly without being passed on into later phases of development. (Majerus, 2015)

Figure 2.4-4 visualizes the effect upon product development projects carried out subsequently within an organization. The reusable knowledge created within one project may be utilized within the next project, which may be executed in shorter time. Since the reusable knowledge is already captured, new knowledge can be captured through RLC within previously unknown areas. (Radeka, 2011) The base of knowledge which can be utilized in the future, releasing resources for development in non-familiar areas, can hence be expanded.

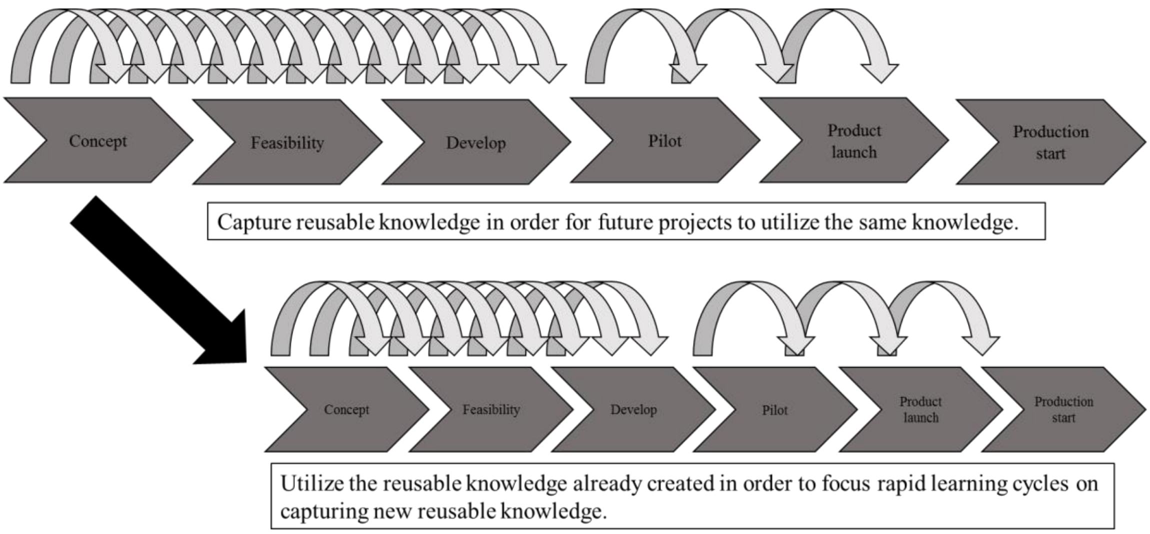


Figure 2.4-4 – Visualization of the leverages from implementation of RLC into product development projects, adapted from Radeka (2011). The leverages include the ability to carry out development projects in less time than before due to the knowledge which has already been created, which is re-used in future development projects.

2.4.3.2 The test-to-design approach

A methodology adopted by Toyota and other Japanese companies is the test-to-design approach, which supports learning and closing of critical knowledge gaps before detailed design is initiated. With this methodology risks are mitigated early in projects and the degree of confidence for a successful outcome is raised. The opposite of test-to-design is the design-to-test approach. Here, one single conceptual design is chosen early during a project. A fully functional prototype is fabricated and testing validates whether the concept fulfills requirements or not. If testing proves that the concept does not fulfill requirements another design iteration must be carried out. (Mascitelli, 2011)

When knowledge, which is already known, is made visible the critical knowledge gaps often turn out to be smaller and more focused than previously thought. Prototypes intended for testing are less complicated compared to full prototypes representing the final product. Since only issues related to the critical knowledge gaps need to be managed, the majority of the design can often be ignored. This implies possibilities to utilize simple prototypes representing only critical areas of the design. (Kennedy, Harmon, & Minnock, 2008)

Figure 2.4-5 visualizes how the test-to-design approach increases the probability of a successful outcome from development. The main yields from such an approach are “right the first time”, optimized designs and organizational learning (Mascitelli, 2011). Hence, yields from a test-to-design approach decreases the number of unwanted design iterations and increases the design quality as well as the degree of organizational learning within development.

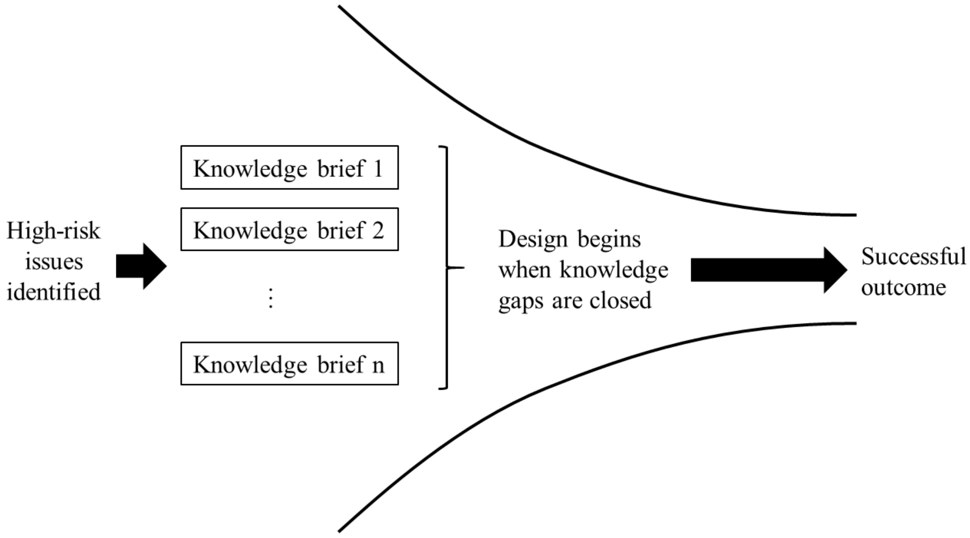


Figure 2.4-5 – Visualization of the test-to-design approach, adaption from (Mascitelli, 2011). High-risk issues are identified: knowledge gaps which should be closed. The new knowledge is summarized into knowledge briefs (A3 reports) which describe how the identified critical issues should be managed during design. Thus, the probability of a successful outcome is higher than if the critical knowledge gaps would not be mitigated before the design phase was initiated.

Figure 2.4-6 visualizes a traditional approach for developing high risk and innovative new products. The consequences of this approach are unpredictable schedules, risks for sub-optimized designs, and a minimized organizational learning (Mascitelli, 2011). The strength of the test-to-design approach is further stressed by Morgan and Liker (2006), who argue that the ability to learn and continuously improve might be the most competitive feature of a lean product development system. Sobek and Ward (2014) state that the focus on creating knowledge and hardware through RLC is one of the main principles of LPD. They explain that manufacturing is the primary customer for development and knowledge is its primary value. This creates a pull for the rest of the LPD system. Pull in the context of PD, when compared to customer orders within lean production, means that problems which are foreseen and known should be closed. (Sobek & Ward, 2014)

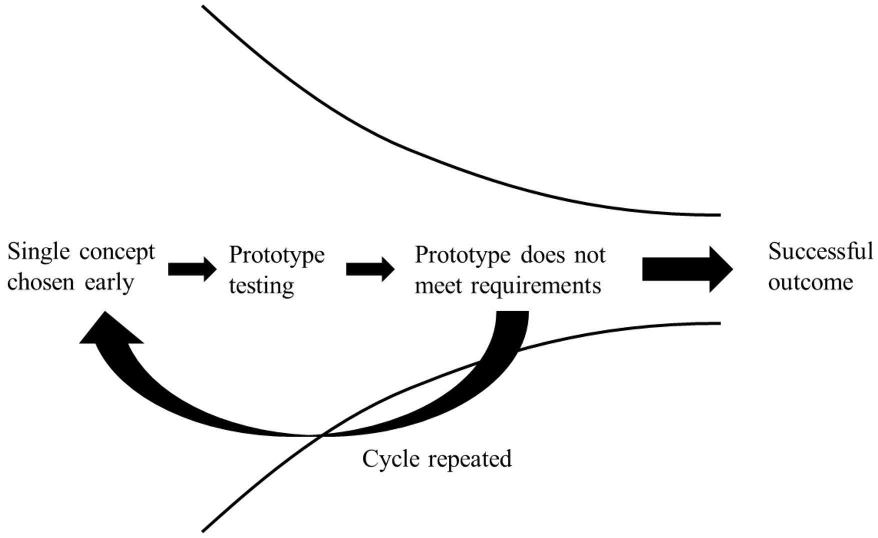


Figure 2.4-6 – Visualization of a design-to-test approach. One single concept is identified and chosen in early development phases, a prototype is fabricated and it is hence discovered late if the design does not fulfill requirements. In order to reach a successful outcome, the design cycle then has to be repeated, forcing the design team to start from early development phases again. This extends the learning cycle and might cause significant delays of product launch.

2.4.3.3 Rapid learning cycles and lean product development

Radeka (2014 a) presents three main ways in which RLC provide conditions for LPD and the transformation into LPD. Uncertainties about how to integrate RLC into PD programs limits the grade to which LPD efforts are pursued. Since RLC differ drastically from methods utilized during traditional PD programs, it opens space to build in practices of LPD into R&D organizations. The first way in which RLC facilitate the transformation into LPD is through providing a structure for LAMDA, in order to build reusable knowledge. Each RLC is a focused problem solving in order to close a knowledge gap.

Issues arising in design create knowledge gaps. An example mentioned by Radeka (2014 a) might be “fix the vibration issue”, which corresponds to the knowledge gap “how can the vibrations in certain components be reduced?” This knowledge gap drives learning and capturing of knowledge, rather than simply fixing the specific problem, in order to create useful knowledge also for future applications. Here, RLC provides the time and place for knowledge gap closing using LAMDA. (Radeka, 2014 a) This is also discussed by Oosterwal (2010), who connects set based PD to learning cycles in order to close knowledge gaps. Set based PD is not about generating several different concepts. It is about investigating which parameters affect the identified knowledge gaps. The knowledge gaps are considered as the relation between what is already known and what knowledge is needed, in order to realize a product. (Oosterwal, 2010)

RLC generate a pull to solve problems in development projects. The best use of LAMDA is to eliminate risks which lead to long design loop-backs or late design changes triggering large amounts of re-work. This is done through identifying and prioritizing knowledge gaps, which define problem statements for LAMDA. The prioritization of knowledge gaps is done through a learning cycle plan. Finally, RLC eliminate project management and process overload in early development. RLC instead create time for learning, eliminating heavyweight task-driven project management, by utilizing learning-centered agile program management methods. Design teams do not waste time in unproductive meetings, nor are decisions taken which the team is not yet ready to make. This waste reduction it one of the immediate benefits from adopting LPD principles since the teams are given time and structure to learn about what is needed to deliver superior products. Hence, less time is wasted and more time is used for experiments which support test-to-learn. (Radeka, 2014 a)

2.4.3.4 Rapid learning cycles and innovation

As mentioned in the preamble of this section, the need to protect the status quo is a barrier to innovation. Brand equity and customer expectations can also be considered as barriers for innovation, since the need to serve current customers might tend to eliminate rather than incubate immature technology. Some companies separate innovation teams from the rest of the organization or even start new companies who work with new innovations in order to protect the own reputation. In most cases new innovations are never realized due to all work required to ensure that the new innovation meets the company standards. (Radeka, 2014 b)

RLC help avoiding many of the problems which companies experience when they innovate, by supporting design teams to understand what they need to learn to mature a new technology to the point where it is ready to be utilized in a commercial product. Also, RLC provide structured time frames to prevent innovators from losing track of priorities and needs of the organization. When a process for innovation provides structure, agility, and the ability to identify and solve problems, disruptive innovations are more likely to be realized. In order to facilitate for innovation in organizations where survival is not at stake due to the success of an innovation, a framework to structure innovation is helpful. RLC provide the structure to facilitate innovation despite competing demands from different stakeholders. (Radeka, 2014 b)

It is not advisable to invest significant resources into products or concepts which will not work in targeted market segments. Nor is it advisable to eliminate ideas too quickly, especially in established organizations where many roadblocks to innovation typically exist. It is not constructive for the design team or the leadership team when leadership approaches new innovations with skepticism. Instead, the leadership team should work with oversight by setting up a set of increasingly difficult hurdles which the design team should overcome. This supports the design team to close the most relevant knowledge gaps. (Radeka, 2014 b)

2.4.4 Rapid learning cycles in practice

Mascitelli (2011) discusses how RLC can be practiced through scalable RLC events. In this context, scalable means that the time-consumption and content is adjusted according to the intended outcome of the event.

In order to mitigate risks related to a development project, Mascitelli (2011) proposes that RLC should be utilized. Risks are divided into two different categories; immediately actionable and knowledge gaps. Immediately actionable risks are those which are clearly understood, as well as the necessary actions being apparent. Figure 2.4-7 visualizes a situation where a knowledge gap is the obstacle between the current and the desired product knowledge. When the root cause of a risk is not immediately understood or actionable a knowledge gap is identified. In these cases, new knowledge must be created in order to mitigate the risks. (Mascitelli, 2011)

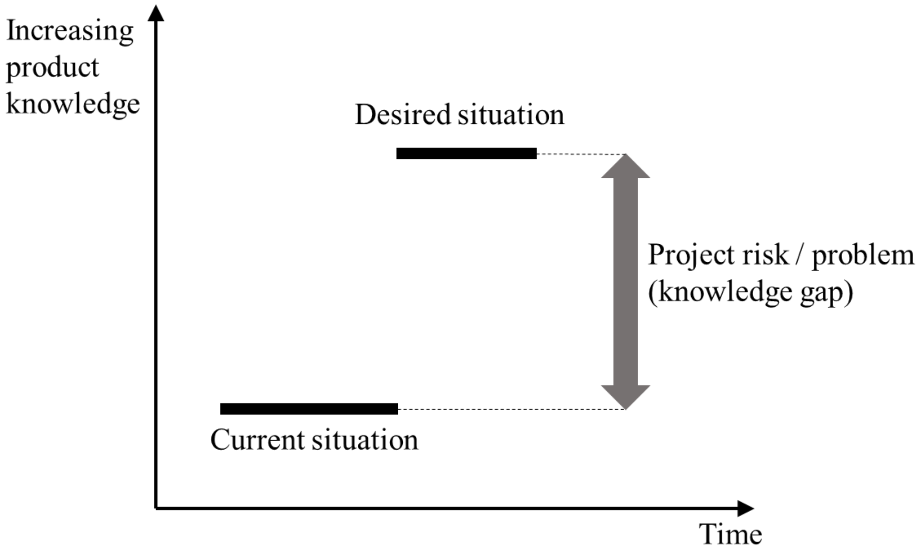


Figure 2.4-7 – Visualization of a knowledge gap, adapted from Mascitelli (2011). The figure explains the situation when there is a disparity between the current situation and the desired situation. In order to successfully achieve a product design, the disparity must be managed.

RLC events have to be properly adapted and scaled to the intended purpose. Vital inputs are a prioritized list of project risks, descriptions of the scope, and requirements of the project. The participants at the event might include only the development team, as well as representatives from other functions. Even external experts might be invited. The composition of participants should be tailored to the nature of the risks, which are or may be identified. The output from such an RLC event should be a mitigation plan for critical threats to the development project, rather than for all possible issues. Hence, prioritizing the risks is key to the usefulness of RLC events. (Mascitelli, 2011) A typical RLC event is described in Table 2.4-1. Here, Mascitelli proposes a full-day event, from 8:00 AM to 5:00 PM. The suitability depends on the organization and the nature of the development project which is carried out. As mentioned, Mascitelli (2011) proposes that RLC events are scalable, which means that the time and content of the event should be adapted to the context. Hence, in order to implement this way of practicing RLC at RTLR these events have to be adapted to the specific projects undertaken.

Table 2.4-1 - A typical agenda and content of an RLC event, adapted from Mascitelli (2011). Here, typical objectives, inputs, outputs, participants and agenda are presented.

A typical Learning Cycle event	
Objective	To gather and focus the knowledge available of the participants and their respective function on mitigation of critical project risks and elimination of related knowledge gaps before creating a new product design.
Input	Market and engineering requirements, a prioritized list of project risks.
Output	Mitigation action list for critical project risks, knowledge briefs/A3 reports documenting solutions to knowledge gaps, documented learnings of the team.
Participants	Team leader, team members, others such as supply chain, purchase, quality, market, and so forth.
Agenda	
8:00-9:00	review of prioritized list of risks, selection of critical issues.
9:00-10:00	Sorting risks into immediately actionable and knowledge gaps.
11:00-12:00	Plan for creation of knowledge briefs/A3 reports.
12:00-4:00	Discuss knowledge briefs/A3 reports and assign responsibilities and time for the next learning cycle.
4:00-4:30	Identify future actions.
4:30-5:00	Learning opportunity/outbriefing.

2.4.4.1 Implementation of rapid learning cycles

In order to implement a development process which supports front-loaded learning, Kennedy et al. (2008) recommend a three-step plan:

1. Robust visible knowledge development
   - Training within LAMDA / A3 reports.
   - For all problem-solving and decision-making, learn first.
2. Knowledge-based development
   - Test-to-design.
   - Appoint chief engineers / project owners.
   - Schedule and define integration events.
   - Establish a knowledge value stream, knowledge owners, and check-sheets.
   - Capture gained knowledge in set-based knowledge.
   - Lead creation of new knowledge and create a cadence of innovation.
3. SBCE
   - Sets of possible designs are defined utilizing trade-off curves from the knowledge value stream.
   - The project owner leads elimination of non-promising solutions until the optimal solution is identified.

In order to create a robust visible knowledge development, Kennedy et al. (2008) propose that employees should undergo training within utilization of the LAMDA framework, using for instance A3 reports. Further, learning should precede each problem-solving and decision-making.

When implementing a knowledge-based development system, Kennedy et al. (2008) propose a test-to-design approach, highlighted in section 2.4.3.2. The role of the chief engineer, described in section

2.1.1.1, as well as the project owner is stressed. The chief engineer is described by Liker and Morgan (2006, p. 12); “The chief engineer is the master architect with final authority and responsibility for the entire product development process. The chief engineer is the overarching source of product and process integration.” This description indicates a different responsibility compared to a “conventional” project manager, due to the vast responsibility of the entire product development process on an architectural level as well as the integration between product and process.

Further, Kennedy et al. (2008) propose that a knowledge value stream should be established, as well as knowledge owners and check-sheets. Figure 2.4-8 visualizes the product and the knowledge value streams. The product value stream differs between different projects, the knowledge value stream should be used across several projects. At Toyota both of these value streams are emphasized, and their integration is highlighted in early phases of development projects. (Kennedy, Harmon, & Minnock, 2008) A case study by Kennedy et al. (2008) highlighted the difficulties related to re-directing focus from the product value stream to both the product and the knowledge value streams.

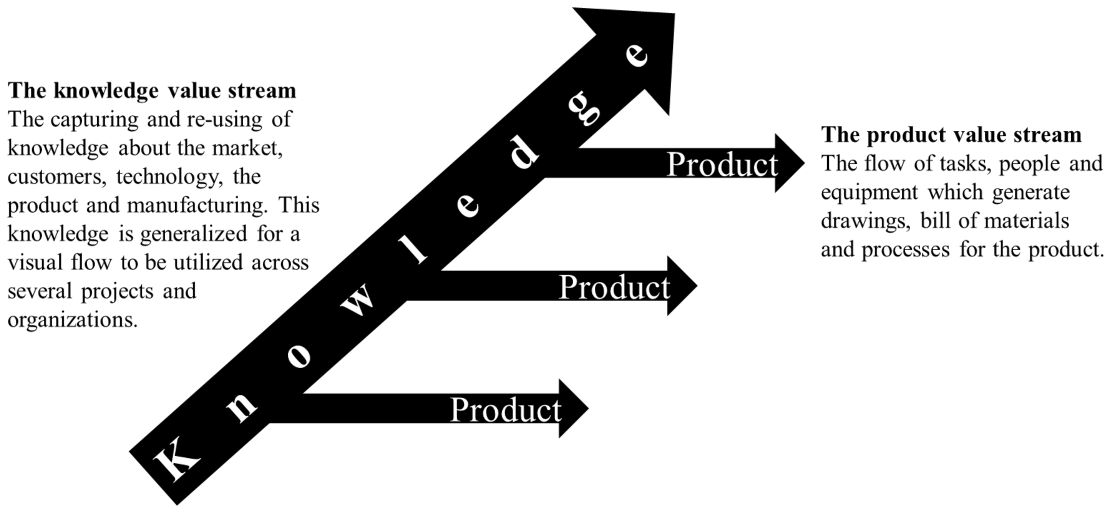


Figure 2.4-8 – Adapted from Kennedy et al. (2008). The figure visualizes the two value streams within product development. To the left is the product value stream, to the right is the knowledge value stream. Both these value streams are important to pursue.

The knowledge value stream is important to establish in order to implement a knowledge-based product development according to Kennedy et al. (2008). Further, they emphasize that learning should be captured in set-based knowledge. By this Kennedy et al. imply that in order to properly investigate different alternative solutions, the limits of each design proposal should ideally be found and documented. Design optimization is then performed across a set of possible solutions in order to avoid sub-optimizations.

The creation of new knowledge should be led and driven by a cadence (Kennedy, Harmon, & Minnock, 2008). Such a cadence is also described by Radeka (2011) who argues that events taking place in a predictable manner, for instance once a week, reduces scheduling work, overhead work and “pulls” work through the system. Hence RLC events should be recurring in all participants´ calendars, in order to avoid absence and unnecessary administration efforts in booking meetings with co-workers involved or paying stake in a project.

Finally, In order to accomplish SBCE there is a need for training in defining, seeing, and utilizing the trade-offs and the relationships which are explored during creation of the set-based knowledge. (Kennedy, Harmon, & Minnock, 2008)

2.4.4.2 The time frame and cadence of rapid learning cycle events

In order to implement RLC in an established organization with an existing PD process, relevant time frames are useful.

Radeka (2011) proposes that an RLC plan should have a specified cadence, which steers the “pulse” of the cycles. The notion of cadence is explained in section 2.4.4. Radeka proposes that sub-projects, such as industrial design, electrical systems, building interfaces and so forth, should integrate cross functionally at specified integration points, visualized in Figure 2.4-9.

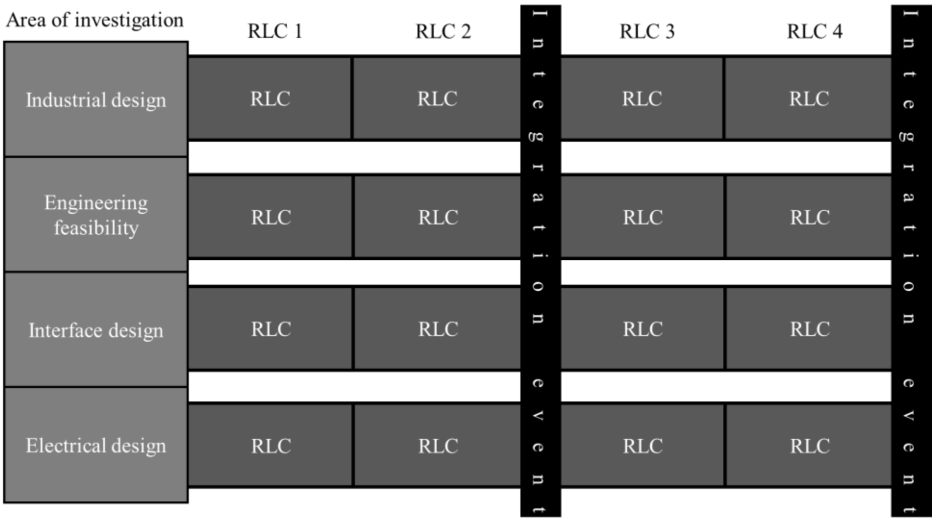


Figure 2.4-9 – Adapted from Radeka (2011). Visualization of how different sub-project teams run their RLC and integrate cross functionally at recurring integration events.

Radeka (2011) recommends that RLC should be approximately two to eight weeks long. Each cycle is initiated and finalized with a knowledge gap meeting. These meetings should include sharing of knowledge created during the previous cycle, a decision upon what to do during the next cycle and the plan should be updated. When initiating each RLC the knowledge gaps in progress should be identified and the knowledge created during the last cycle should be collected. The knowledge gaps to be investigated during the upcoming RLC should be identified, and the plan should be updated using a visual planning board. During integration events, recurring every fourth to twelfth week, knowledge should be shared, key decisions are taken and critical parameter questions should be answered. Also, the progress should be reviewed towards upper management and whether the project is well synchronized towards overall plans and directions should be assessed. (Radeka, 2011)

2.5 Daily Management and Visual Planning

Central parts of LPD are daily management (DM) and visual planning (VP) (Holmdahl, 2010; Majerus, 2015; Morgan & Liker, 2006). Creating a project plan is according to Mascitelli (2011) the most important activity for a project group in order to control the outcome of a project. DM is a combination of a visual time plan and the short and frequent meetings where the team gets briefed about team members´ activities. This is important since the planning board could never be a perfect representation of team members´ thoughts and thus the meeting is used as a complement (Catic, Stenholm, & Bergsjö, 2016). DM can be used on multiple levels within the organization, both by design teams and top management. However, it is important that it is used as an internal team communication method and not by individuals or across the organization. (Lindlöf, 2014 b)

Lindlöf (2014 b) states that the DM is a way of keeping the teem focused on the common goal and to reach these. Mascitelli (2011) suggest that the meetings should be used to answer the following questions;

1. What has been done since the previous meeting?
2. What needs to be made until next meeting?
3. What issues could possibly obstruct the team to complete the tasks?

2.5.1 The procedure for daily management

A key factor for an effective DM is to ensure that the meetings are short and should instead be conducted more frequently (Lindlöf & Söderberg, 2011). Mascitelli (2011) has defined the optimal length of the meeting to 15 minutes, which also aligns with theories from Lindlöf and Söderberg (2011). To keep the meetings focused, it is recommended by Mascitelli (2011) to conduct the meetings standing, and it is also advised to consider the use of a timer. Further, Lindlöf and Söderberg (2011) state that an optimal size of a team using DM should be six to twelve members.

There are several important aspects to consider about the mediating visualization board used during DM meetings. Lindlöf (2015) has identified five properties which characterize an effective visualization object, listed below.

1. It should enable an efficient two-way communication.
2. The communication around it should be synchronized, which means that there should be no delay between the participants.
3. The communication should be on a regular basis, however the optimal frequency is very depending on the group and have to be set individually by experimentation.
4. The visualization should be a representation of the actual process rather than the ideal process. It should represent the actual status in order to be able to make informed decisions.
5. The information always needs to be up-to-date. Hence the information needs to be updated before the meeting takes place. This is also a prerequisite for point 4.

In addition to these points Lindlöf (2015) states that the needs of the group should be the basis for the layout of the planning board. Thus the layout should, most likely, have different designs for different teams in order to suit the specific communication needs for each team.

Normally, team members write their activities on sticky notes and arrange them according to a time plan on a board. Each row on the board normally represents a team member and every column is a time unit. This planning should be done as a team activity and the discussion which occurs will contribute to a more accurate plan, a better understanding, and information sharing among team members. (Holmdahl, 2010) The tasks could be given different priorities depending on their criticality. This is normally done using different colors of the notes (Mascitelli, 2011). An example of a planning board, based on the description above, is visualized in Figure 2.5-1. Mascitelli (2011) also supports Holmdahl’s theory that planning should be a team activity, and gives a framework of how to perform DM meetings based on the three questions mentioned in section 2.5. The framework is summarized in the list below.

1. The first team member stands in front of the planning board.
2. The team member briefly describes what has been done since the last meeting and whether the planned tasks have been completed or not. If a task is completed, the task note should be removed from the board. If it is not completed, it should be assigned to a new deadline and be moved to the new date at the board. The team member also has the opportunity to assign tasks to other team members.
3. Once done with the resolved and unresolved tasks, the team member should give an update of the current status and the plan for the next days. If there is any new task, they should be written on sticky notes and be attached to the board on the finalization date. The other team members could give feed-back and guide the prioritization of tasks, but team members are responsible for their own planning.
4. The last step is to raise possible issues which could obstruct the time plan. These should be briefly discussed, and if it is necessary all team members who could be involved gather after the meeting to continue discussions.

This procedure should continue until all team members have presented their planning row. Hence, when the DM meeting is completed the column with the planning for past days should be empty.

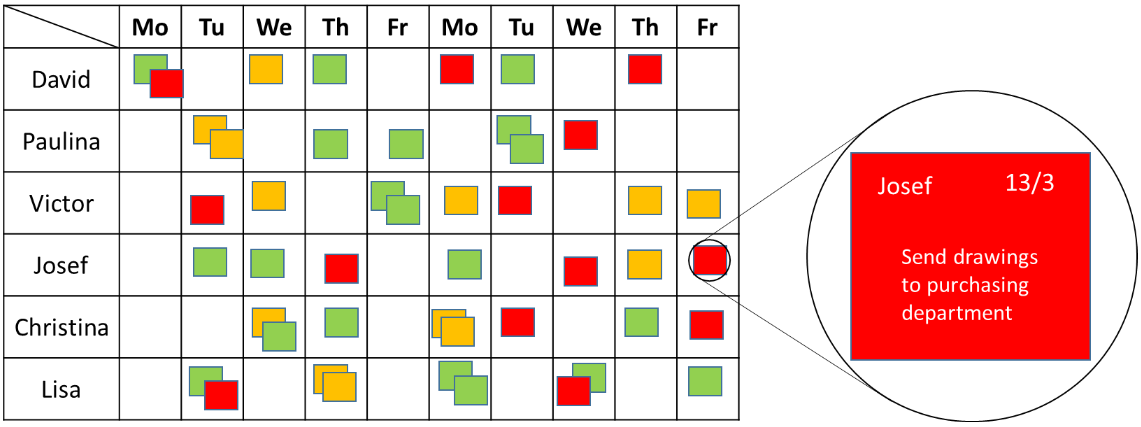


Figure 2.5-1- Example of visual planning with task of different prioritization. Adapted from Holmdahl (2010).

2.5.2 Reasons to use visual planning

Within lean there is an expression, "go to *gemba*[1]" which highlights the importance of going to the actual place and see. According to Lindlöf (2015) this could, in the context of product development, be the utilization of a visual planning board as a mediating tool which supports a consensus about the process and the planning.

A common attitude towards planning is to use a software to manage tasks and resources. However, when using a software the planning easily gets too complex and overwhelming. The reason to use simple, visual, analog tools is to make the planning transparent and up to date. This transparency and flexibility is impossible to achieve with normally used software, as for instance Microsoft Excel[2] and Microsoft Project[3]. (Alfredsson, 2011) Hence the reason to use VP boards is to gain a transparent view of ongoing projects that is always up to date. This will in turn support the management to level out the workload among the team members continuously during projects. (Lindlöf & Söderberg, 2011) Furthermore Holmdahl (2010) emphasizes the importance of planning being an activity carried out by teams. However, planning is often conducted by one person and even though time and budget have been in focus during the planning, projects often end up with delays and overrun budgets. (Holmdahl, 2010)

VP contributes to an effective communication within project groups in several ways. Lindlöf (2014 b) mentions that visualization contributes to more effective meetings, and therefore the frequency of the

[1] Gemba is a Japanese word, meaning "the real place".
[2] Excel is a spreadsheet application, developed by Microsoft.
[3] Project is a project management software, developed by Microsoft.

meetings could be increased at the same time as the total meeting time could be reduced. The increased frequency contributes to more accurate and up to date information (Lindlöf, 2014 b), which in turn reduces the risk of redundant work (Holmdahl, 2010). Visualization of tasks does also give the responsible manager the ability to clearly see the workload of every team member, and could thereby take actions to level the workload across the team early. (Lindlöf & Söderberg, 2011) Since VP is not only the planning board itself but also the meeting, the group is forced to share their knowledge during the planning sessions (Holmdahl, 2010).

2.5.3 Challenges using visual planning

Despite all benefits there are a few challenges connected to VP. In teams with specific competences it becomes problematic to spread the work load across the team, since there are specific tasks that could only be carried out by one or a few persons in the group. A common problem in the planning is that the team members have difficulties to specify when tasks should be finished. This adds to the difficulties of leveling the work load. (Lindlöf & Söderberg, 2011)

There is a reluctance to let other see the ongoing work, and some believe that the planning board is a tool for managers to keep control of the team members. A risk with VP is also that the team members who do not deliver in time will be portrayed as scapegoats. (Lindlöf & Söderberg, 2011)

Furthermore, there is a limitation in the amount of data that is possible to manage using analog VP. It is also a limitation that all team members need to be physically on site in order to update their own planning and to take part of new information. (Lindlöf & Söderberg, 2011)

2.5.4 Digital visual planning

There are several driving forces to make the VP digital. According to several authors and experts there are many pitfalls with digitalization. However, digitalization could also provide several opportunities for teams, and the number of suppliers of such solutions are increasing.

One of the most obvious driving forces to digitalize VP is to distribute the content to multiple geographical locations. Other benefits with digital visual planning (DVP) are the ability to connect activities to certain projects and the possibility to clearly mediate status of tasks. Further a DVP tool can support teams with relevant statistics and information such as visualizing the number of planned hours and to follow up delays and re-planned activities. However, when implementing DVP tools it is easy to forget to focus on the main objectives with the planning, by instead strive to achieve as many features as possible. This increases the amount of data, which might have a negative impact on the planning. The amount of data becomes overwhelming, which makes the planning difficult to manage. (Catic, Stenholm, & Bergsjö, 2016)

2.6 Agile Methods and Scrum

Agile methods is an alternative to the more traditional methods, such as the waterfall method. Instead of as in sequential waterfall methods, where each part of development is completed before handing over to the next team in the development chain, agile methods is an iterative process where small pieces are developed and tested concurrently. In this way organizations can deliver incremental changes and thereby add value to the customer continuously. (Sims & Johnson, 2011) One agile method that was developed for the software industry is the scrum methodology. However, even though it was developed for software applications, the method has potential to be utilized in any development project with complex and innovative targets. (Scrum Alliance, n.d.)

In scrum, small teams are working together with complex products. Teams work in short cycles called sprints in which new products are developed. As previously mentioned, this method was tailored for the software industry. Due to obvious limitations, such as delivery times from suppliers, utilizing scrum within hardware might imply modifications of the methodology. Such modifications could be, for instance, regarding CAD models as the product after a sprint. Thus, the method could also suit the hardware design. (Maximini, 2015)

2.6.1 Roles in scrum

Scrum teams consist of co-workers with three main roles, *product owners (PO), scrum masters (SM)* and *team members (TM).*

2.6.1.1 Product owners

In scrum teams PO are responsible to keep contact with the stakeholders of the project and thereby determine what needs to be done during the sprints in order to maximize the customer satisfaction. Hence PO are the ones who change prioritization and handle the coordination of activities in the sprints. (Sims & Johnson, 2011)

2.6.1.2 Scrum masters

SM in a scrum team have the main objective to achieve a self-organized team. SM must not be managers of a team since scrum teams have a non-hierarchical structure, in order to keep the reliance within the team. Furthermore SM should be the experts within scrum and should support the team to achieve as much as possible out of all activities. The SM role does not have to be a full time job, it is possible to have TM duties as well. However, when deadlines are narrow SM tend to focus on development duties to a larger extent, rather than duties related to the SM role. (Sims & Johnson, 2011)

2.6.1.3 Team members

TM in scrum teams are the ones that are carrying out development activities. PO are choosing what to do, but TM estimate how large tasks are and decide how the work should be done. Typical for scrum teams is the importance of team work and the culture of TM focusing on the team´s development activities, not each member´s tasks. (Sims & Johnson, 2011)

2.6.2 Sprints

As mentioned, scrum organizations are working in sprints. This is an iterative process with cycle lengths of maximum four weeks. However, the most common sprint length is two weeks. Each sprint normally starts with a planning meeting lead by PO. During the meeting TM discuss the items proposed by PO and decide if they can commit to them or not. When the items are selected they are decomposed into manageable tasks by TM. During this session PO should be available to answer questions and take action if the team has undertaken too many or too few tasks. (Sims & Johnson, 2011)

Along the sprints the team conducts short stand-up meetings, described in section 2.5, to highlight and coordinate tasks. In the end of each sprint there is typically a sprint review in which all stakeholders are invited. During this review the team presents what items were not completed during the sprint and also demonstrate the items which were completed. At this session the team can gather feedback from stakeholders, in order to sufficiently plan for which items to undertake during the next sprint. (Sims & Johnson, 2011)

2.7 Psycho-Social Work Environment

In order to identify characteristics of the working place and its impacts on employees within R&D at Scania, factors contributing to satisfied and motivated co-workers are briefly investigated.

2.7.1 Stimulating work gives better results

In order to make co-workers committed to their job and thereby receive a higher quality of the final products it is important to give them responsibilities and let them feel professional pride. Organizations should strive for the good circle rather than the vicious circle as shown in Figure 2.7-1. The vicious circle describes how top management lacks confidence in co-workers, which leads to increasing inspections and detail control which in turn make co-workers loose motivation. Consequences might be poor results and quality of deliveries. The good circle describes the relation between top management with confidence in co-workers leading to improved results and quality of deliveries, by delegating responsibility and authority which improves the motivation among co-workers. (Bergman & Klefsjö, 2010)

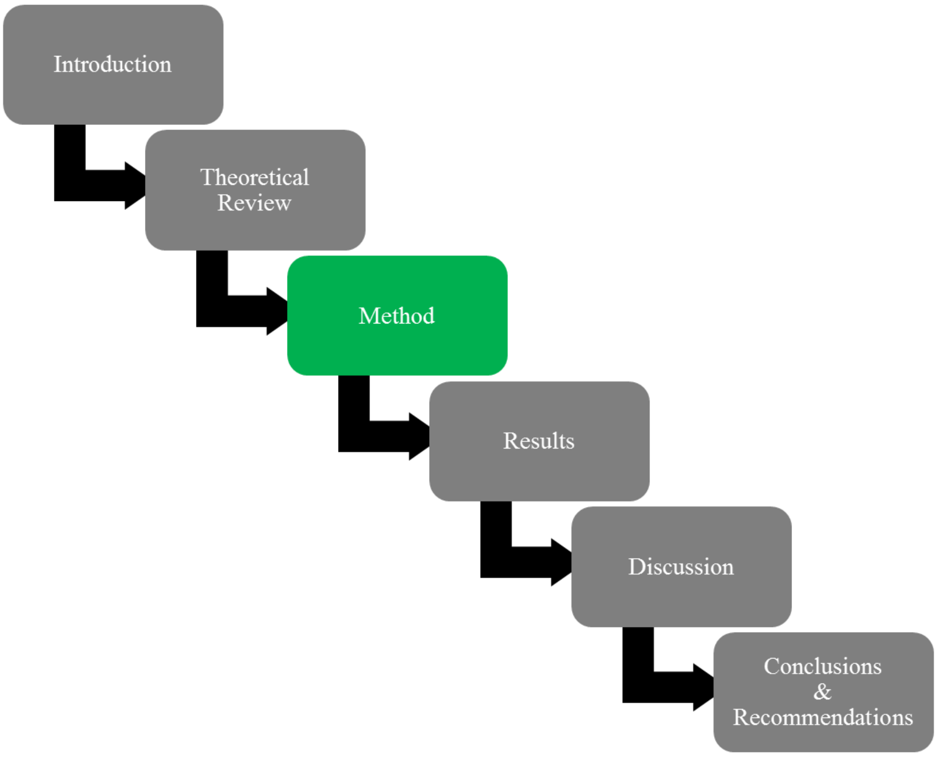
Figure 2.7-1-A - Vicious and good circles with different quality results. To the left is the vicious circle, which describes the relation between top management with lack of confidence in co-workers and poor quality of products. To the right is the good circle, which emphasizes how top management with confidence in co-workers generate improved results and quality of products.

To have a stimulating job with high level of responsibility is also emphasized by Rubenowitz (2004) in order to achieve a good psycho-social working environment. Rubenowitz (2004) lists five contributing factors of the psycho-social work environment.

1. The ability to control the ways of working to a certain amount.
2. A positive attitude between management and their subordinates.
3. To find stimulation from the working tasks.
4. Good contact with the colleagues.
5. To have an optimal work load.

3 *Method*

This chapter describes the methods used in the thesis project. The chapter addresses both methods for gathering data and how the data was interpreted, but it also describes administrative tasks such as planning and how interviews were summarized.



3.1 Planning

In initial phases of the thesis project, a preliminary time plan was settled. Expected activities were listed through brainstorming and subsequently broken down to a manageable detail level. Furthermore, the obvious milestones, such as final presentation and report hand-in, were listed together with a couple of additional milestones that were identified to be of importance for the project. The activities and milestones were arranged in a Gantt chart and the time for each activity was estimated. Gantt charts is, according to Vargas (2008), a commonly used and easily understood method to visualize time plans. This planning was done iteratively to get the activities in the right sequence and to make sure that the total time would be within the time range of the project. The Gantt chart in which the plan was visualized, see Appendix A, was created using Microsoft Excel.

In addition to the main plan, detail level plans covering two weeks were continuously developed throughout the project in order to work in a more structured way with a common view on the upcoming tasks. This short term planning charts also gave an indication on how well the general plan was on time. An example of a detail level planning chart could be found in Appendix A.

3.2 Theoretical Review

In order to create a theoretical framework for the thesis work, review of relevant literature has been carried from the initial phases of the work. Through discussions with examiner and supervisors relevant areas of research were decided to be LPD, SBCE, RLC, VP and literature describing the methods to be used during the project. When the relevant areas were identified, literature was found in the form of physical printed books, electronic books, articles, Ph.D. and M.Sc. theses. Electronic sources were identified through online databases and search engines, such as Google Scholar and the virtual library at Chalmers.

Initial literature was found within LPD and SBCE, in order to frame future focus areas. When proceeding into interviews with Scania employees, this literature framework was utilized to formulate relevant questions. When results from the interviews were summarized, the findings were presented and discussed together with supervisors, the examiner, the RTLR group manager and a TL at RTLR. From these discussions it was concluded that RLC, documentation of new knowledge and DM through VP should be the main focus areas.

In order to establish an understanding of the development process and the R&D organization at Scania, processes, methods, and tools utilized within development have been investigated. Internal material as well as an interview were used to gather information about the development process.

3.3 Brainstorming and Discussions

During the project there was a continuous need of decisions regarding interviews, agendas, recommendations and so forth. To come up with ideas for these purposes, brainstorming and discussions were frequently utilized. Brainstorming is an idea generation technique that is frequently used in product development contexts, but it could also be used for several other purposes (Wilson, 2013).

These brainstorming sessions often took place in a quiet room in order to not be disturbed by the surroundings. According to Wilson (2013), the idea with choosing another room than the original working place is also to stimulate the creativity since the number of interruptions, such as e-mails, colleagues and so forth will be reduced. During the brainstorming sessions a computer with a large screen and a whiteboard were utilized to visualize and document findings. Visualization is, according to Ulrich and Eppinger (2012), a useful tool for brainstorming. This is also aligning with the principles from LPD which emphasizes the use of visual tools since they are on a lower abstraction level compared to words. (Holmdahl, 2010).

Before starting to generate ideas the purpose of the meeting was specified and the expected outcome was defined. Since the room was bookable, a time limit was automatically decided. Most of the brainstorming sessions were used to plan and prepare for the interviews during the thesis project. Thus these activities were used to come up with the right questions and discuss how the questions should be formulated in order to maximize the quality of the output. Also the arrangement of the interviews, whether they should be structured or semi-structured, was discussed during the brainstorming.

Other purposes for the brainstorming during the project were for instance to identify and specify recommendations for RTLR. From these recommendations possible effects were identified and discussed. On these occasions the whiteboard had a very central role to visualize and document all discussion points. All findings from the brainstorming were electronically documented either during or directly after the sessions.

3.4 Case Study

A case study is a research method in which the aim for the researchers is to answer a specific and abstract research question that needs to be investigated in a context. Another characteristic of case studies is that the researchers should not, in contrast to many other research methods, have any initial thought or idea about the answer to the research questions. Before building theories and setting up hypotheses it is necessary to understand the context and start analyzing the data in order to know in what direction to go. (Gillham, 2010) According to both Gillham (2010) and Eisenhardt (1989), the first step, when setting up a case study, is to formulate a research question and formulate the aim with the study. It is recommended to initially formulate a quite vague aim since the outcome of case studies are often unknown and the characteristics of a case are very specific (Gillham, 2010).

During the thesis project, a case study was utilized in order to identify ways of working at RTLR and their relation to the R&D process. Flaws and deviations, as well as strengths of the process and ways of working were identified. The findings, which were used to formulate recommendations for improvement areas for RTLR, could not be identified through literature studies alone.

3.4.1 Choice of case

Through discussions with the supervisor at Scania, three suitable cases for the study were identified, with different characteristics. For instance, the results as well as the available documentation from the cases were varying. Semi structured interviews with responsible engineers or TLs for each project were therefore conducted, to find more information and to get a more holistic view of the cases.

Findings from the interviews were compiled and presented to the supervisors and the group manager at RTLR. Through discussions, one of the cases was chosen. The reason was mainly due to the amount of documentation in the project, but also since it was considered to give a good view of the working procedures at RTLR.

3.4.2 Searching for information

As soon as the choice of case was made an additional interview with the responsible TL was conducted, in order to gather knowledge on where to find information about the project. A number of paths in file structures related to the case were provided together with instructions of where to find relevant information. Protocols from RTLR’s weekly technology meetings were studied to give the initial view of the progress of the case. Further, reports with test results, both physically and FE-calculations were printed and studied. To clarify the results and to understand the decisions, relevant people such as a responsible calculation engineer, a test engineer and a project manager were interviewed. These interviews were semi-structured as described in section 3.5.2 and the results are presented in sections 4.2.3, 4.2.4, 4.2.5 and 4.2.6. Initial Interviews with people from RTLR, involved in the case, were set up. These interviews were short and structured, as described in section 3.5.3, with the aim to get indications of what the main problems in the working procedure were. The result from these interviews is presented in section 4.2.7

All interviews were recorded and summarized to get an overview of the content. Results from the interviews were discussed with supervisors, the examiner, the TL of the chosen case and the group manager at RTLR.

3.5 Collection of Data

During the thesis project data was collected through interviews, observations and study visits. The choice of data collection methods was adapted to the time-frame of the thesis project, as well as the availability of the co-workers at RTLR.

3.5.1 Observations

During the thesis project data and knowledge was gathered through observations. Observational methods are effective when the purpose is to understand behaviors (Walshe, Ewing, & Griffiths, 2012). Most of the knowledge regarding the DM was collected through observations. Several DM meetings were observed to find out what topics were brought up during the meetings and how the group dealt with the issues that came up. The meetings were documented through handwritten notes during the meeting which were later used as a support when summarizing the findings. If any questions came up during the meetings these were asked to the TL after the meeting and discussions about possible improvement areas were conducted between the meetings.

3.5.2 Semi-structured interviews

As part of the case study, interviews were conducted with a calculation engineer (CE), a test engineer (TE), a project manager (PM), and a chassis development manager (CDM). These were carried out in a semi-structured manner, which differs from structured and non-structured interviews.

In order to properly plan the interviews, guidance from Wallgren (2014) was utilized. Through a discussion the thesis project group formulated questions which covered the relevant areas of interest related to the case study. The exact formulation of the questions, their order of sequence, as well as the content of specific questions differed depending on which interview to be conducted. These questions were summarized into guiding documents (see Appendix B). The structure of the interviews were established according to suggestions from Wallgren (2014), who argues that the interview should initially contain neutral and general topics before proceeding to content which might require deeper reflections upon more sensitive areas.

The interviews were conducted in quiet rooms with good ventilation and natural light in order to minimize disturbances and fatigue. The interviews lasted for approximately one hour and follow-up and confirming questions were asked in order to avoid misunderstandings. This interview technique is also argued by Wallgren (2014) to be effective during semi-structured interviews.

Findings from the interviews were summarized from recordings and handwritten notes. These summaries, found in sections 4.2.3, 4.2.4, 4.2.5 and 4.2.6, were used for further discussions and to formulate conclusions and recommendations for RTLR.

3.5.3 Structured interviews

In order to frame opinions of co-workers at RTLR regarding the two projects of interest, project team members were asked to participate in initial short and structured interviews. These interviews were conducted to point out an initial direction for further work and finally recommendations for RTLR.

Lucas (2005) point out that a powerful tool to rapidly grasp content and opinions is a well conducted interview. Through discussion with the supervisor at Scania and suggestions from the six-step process proposed by Lucas (2005) interview questions were formulated.

1. *Establish a purpose for the interview*

   When starting the interviews, the purpose of the thesis project as well as the interview was presented. This allows both the interviewers and the interviewee to establish an understanding of the context and the mission of the interview.

2. *Identify what is already known*

   By searching for information about the topic to be investigated before the interviews and grasping the context as far as possible a knowledge ground is founded. This is useful in order to identify significant issues and areas where further probing might be useful during the interview.

3. *Prepare a list of questions*

   Plan which questions and an approximate order of them, driven by the goals of the interview. The depth of the interview is determined by the level of the questions. It is proposed to use questions categorized into three different levels, where starting and follow-up questions are used. When the starting questions have framed issues or areas of interest, more in depth follow-up questions are used to deeper investigate certain areas of interest.

4. *Plan the interview*

   The interviews are planned by answering who is the best person to interview, how much time will be needed, if appointments can be set with the interviewees, and if booking of an appointment will need approval and introduction. The purpose, goals and already known information should be available to present when planning the interviews.

5. *Conduct the interview*

   The interviews should start by the interviewers presenting themselves and the context and explain why the interviewees are asked to participate. During the interview, open questions allowing for discussion should be used in order to avoid answers such as “yes” and “no”. Further, it is important to recognize when a subject should be left to move to the next question. At the end of the interview the interviewees should be informed about how the work will proceed and how their answers will be useful.

6. *Follow up as needed*

   It is proposed to call or email the interviewees for follow up questions if needed. Regardless of the need for follow up, the interviewees should be contacted and informed about their contribution and the results made possible by them participating in interviews.

These guidelines were used in order to formulate suitable questions for the initial structured interviews. The interviews were conducted with as many team members as possible within the project teams during approximately five work days, and consumed approximately 20 minutes each. The structured layout of the interviews provided possibilities to compare answers between different interviewees. After completion of the interviews, the interviewees were asked to fill in a questionnaire regarding the subjects of interest from the interview. This was done in order to make a quantitative analysis of the answers possible and to investigate whether any common trends among the respondents could be found. The questions used during the structured interviews are attached in Appendix C.

The interviews consisted of eight questions. The first point was to present the thesis, the main purpose of the thesis and why the interviewees were asked to participate. Initially two questions were asked regarding the interviewee´s knowledge about the design process, and in what ways it is a support in the daily work. The third question regarded the re-use of precious knowledge in the project the interviewee was part of at the time, and how new knowledge is documented. The subsequent question regarded the daily management meeting conducted each day and which positive and negative aspects the interviewee had identified with those meetings. The sixth question regarded development and elimination of concepts in development work, as the seventh question regarded how decisions whether or not to continue and raise the status of concepts were managed. The last question related to the previous question, but was asked more specifically about passing of the PRY-3 milestone and whether the interviewee believes that the milestone is passed with certainty about future results or not.

In order to be able to more freely discuss results and implications from interviews, interviewees were given alias names, such as A, B, C, and so forth. This allowed the thesis group to present results without the risk of naming individual co-workers at Scania.

The interviews were recorded, and files were transferred to computers at Scania where the interviews were listened through and answers were written down. These notes were analyzed and summarized into brief statements about opinions from different co-workers within the different questions. This summary was formulated in A3 format which made the information easy to grasp in order to facilitate discussions on how to proceed with the thesis work.

3.5.4 Presentation with discussion

Before establishing the final recommendations to RTLR it was decided to let the group give their feedback on the preliminary recommendations. This was to ensure that the recommendations would be suitable but also to tune in the details of the recommendations to fit the group as good as possible. In order to gain maximum response from the group it was decided to utilize an interactive session with group discussions instead of a more traditional informative presentation. For this reason the presentation was divided into three parts based on the three main areas of recommendations. For each part a short introduction to the improvement recommendation was presented before the group was divided into sub-groups of approximately three people in each with the directions to discuss a couple of questions and brainstorm about possible consequences for the recommendations. Answers and thoughts were documented on a sheet of paper by each sub-group. After approximately three to five minutes of discussion, the sub-groups were given the opportunity to answer the questions and present their thoughts and ideas in front of the rest of the group before handing in their papers. When the questions were discussed in the group the next topic was presented.

During the entire thesis project, meetings with both TLs and team members have been conducted to continuously get their feedback. This could be compared to the learning cycles recommended to the group. Since feedback had been given throughout the entire project the presentation with group discussions was more of a final confirmation and fine tuning than a big stage gate.

3.5.5 Internal and external study visits

In order to collect input from external and internal practitioners of RLC and DVP, study visits were carried out. Internally a group within chassis development has been visited, where DVP is used. External study visits have been conducted at Ericsson 3G in Kista, Sweden.

The thesis group discussed the current use of DVP tools during DM meetings at Scania, and was informed about several examples where such tools were already used. One example was a group within chassis development, working with fuel and selective catalytic reduction systems installations. Here a digital tool, developed at Scania, for DM meetings was utilized. The thesis group carried out three visits during DM meetings and observed how these meetings proceeded. Notes were taken from observations and the experiences from DVP during DM were discussed with an engineer and the manager at the visited group.

Through contacts provided by one of the supervisors two study visits were planned during two learning events at Ericsson 3G. The thesis group visited Ericsson´s site to make observations of the ways of working during these learning events, speaking to participants and responsible people. The findings were documented through written notes and photos during the visits. Findings from the visits are part of the foundation for further discussion about how RTLR should proceed with RLC in order to promote a learning-first culture.

3.5.6 Q&A with Michael N. Kennedy

Michael N. Kennedy is the founder and CEO of Targeted Convergence Corporation (TCC), Carrollton, US. TCC provides consultancy services within mapping of learning, decision-making practices, products, and culture. Kennedy is also the author of the book Product Development for the Lean Enterprise (Oaklea Press, 2003), as well as several other books and publications.

The thesis project group contacted Kennedy via email, asking five questions related to LPD, RLC, DVP, and documentation of knowledge and decisions. The exact questions from the thesis group and answers from Kennedy are found in Appendix E. The answers from Kennedy were analyzed and summarized (see section 4.4) in order to extract the information which was useful for the thesis project.

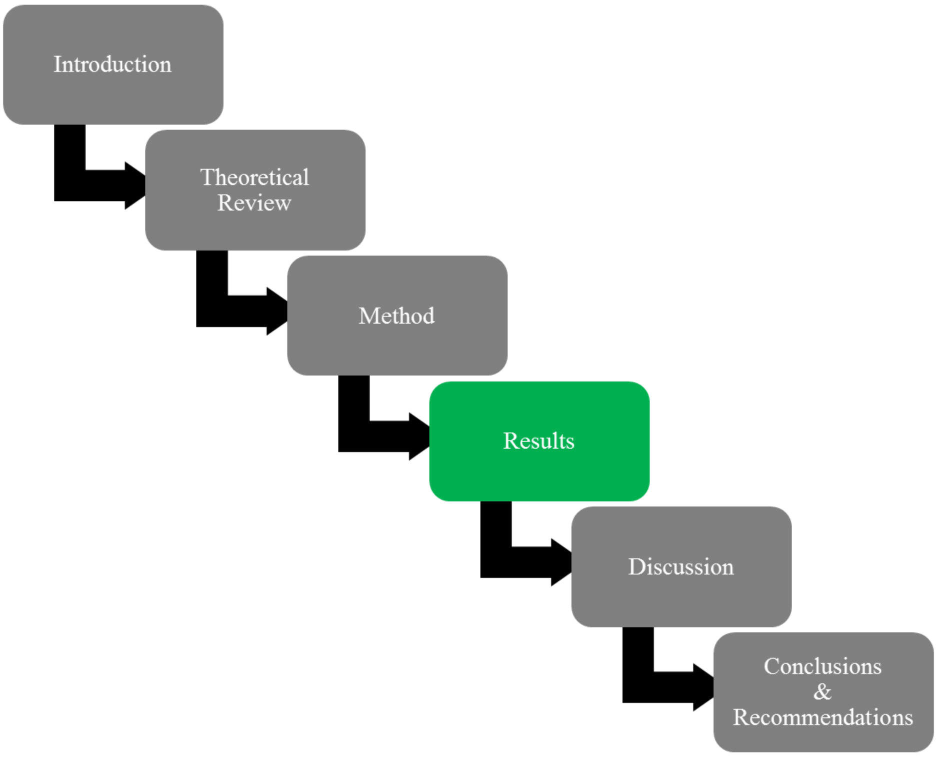
3.6 Summarizing Collected Data

In order to get an understanding of results from the data collection, all data was summarized. Recordings from the interviews were summarized into text documents. These documents with the content from all interviews were considered to be too overwhelming and hard to digest, hence the summaries were further sifted. The shorter interviews were structured and could therefore be summarized in an effective way by writing down the essence of each answer. The longer semi-structured interviews with the PM, the CE and the TE were summarized on one single A3 page containing only the most important results from the interviews. This way of summarizing results on an A3 is a popular and effective way to condense information in order to only visualize the most important (Ward & Sobek, 2014; Holmdahl, 2010).

When all information was gathered and summarized it was brought up for discussion with supervisors, a TL for the chosen case and the group manager at RTLR. This was done both to inform about the findings and to get feedback whether the findings were representative for RTLR or if they were specific for the studied case. Through these discussions the thesis group´s understanding of the most critical areas of improvement was clarified.

4 *Results*

This section describes the results from the case study, interviews, internal and external study visits, observations at RTLR, and studies of the R&D process at Scania. Discussions of, as well as conclusions and recommendations based on the results are found in sections 5 and 6.



4.1 The Development Process at Scania

This section briefly describes parts of the development process within R&D at Scania, in order to provide the practical context of this thesis project. Parts of the process described are chosen due to their relevance for the thesis project, hence parts considered out of scope are not included. Information about the process is retrieved from internal sources at Scania. The content of these sections has been reviewed and confirmed by Peter Palmér, senior manager at Scania. Internal figures about the development process at Scania has not been used.

In 2011 the development process at Scania was revised, with an ambition to increase the output from development utilizing less time, and improving delivery precision and quality. A new development process and a related toolbox were introduced. The processes are used to support planning efforts and the creation of time plans. The common language within development projects and visualizations of the processes support cross functional communication and the understanding about the process among those involved in development projects.

The development process describes how products should be developed and which areas of responsibility are involved in development projects. General milestones are the common delivery points, which concern all functions involved in development projects. Another improvement of the development process is the use of coordinated vehicle integration points (VIP), which is a way of coordinating several functions at common milestones when approaching ramp-up and closing stages of projects. This enables working in a tacted flow where milestones are reached commonly by several different functions in order to secure deliveries at the VIP. The VIP are visualized by Figure 4.1-2 in section 4.1.2.

Activities and deliverables on an overall level are visualized in the development process. Hence the development process should be followed by all involved teams within different departments. However, the process should be interpreted and adapted by each team in order for the process to fit specific needs.

4.1.1 Yellow, green & red arrow

Within R&D at Scania activities are categorized into concept development, product development, and product follow up, as visualized in Figure 4.1-1. These stages are visualized using different colors; yellow, green, and red arrow, respectively. The development process also includes advanced engineering and research. However, these stages of development are not investigated in this thesis project. The scope of the thesis project is only including the development process within green arrow (GA).

The input from concept development (YA) to GA can be, for instance, technical specifications, drawings or more well-defined and developed concepts. The input is balanced with respect to the extent of technical challenges in assignments for GA. Further, directives on assignments handed to GA should state degrees of freedom, and what is constrained in design and features. In many cases the extent of design scopes grows when assignments are handed from YA to GA.

RA, product follow-up activities, are those which concern eliminating faults and improving products already introduced in serial production. For instance, RA matters can be issues affecting ability to assemble components in production and cost reductions.

Research and advanced engineering are those activities within R&D which develop, investigate and evaluate future technologies which are of interest for future product development projects. Upon deliveries from research and advanced engineering concepts can be developed by YA. When risks related to new technology are assessed and handled, the technology can proceed from conceptual development to product development and eventually be implemented into new products.

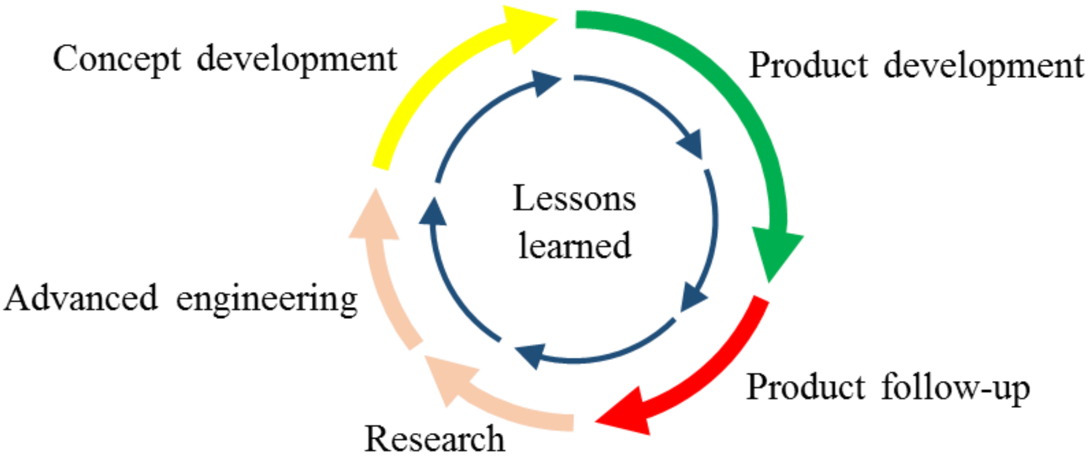


Figure 4.1-1- Visualization of the green, red, and yellow arrow processes within R&D. Research, advanced engineering and lessons learned are also included in the figure.

4.1.2 The green arrow development process at Scania

The product development process within GA is the area of research in this thesis project. As from now, the GA process is referred to as the development process. As visualized in Figure 4.1-2, the development process is divided with respect to level of detail. The general development process milestones (PGM) are common for all functions involved in a development project. Using defined criteria at these milestones internal stakeholders and customers review and assess project outcomes and status, to plan for future actions and decisions. Results at this point should fulfil requirements and specifications stated in the description of the PGM. The PRY-3 milestone is one of the PGM, and is described in section 4.1.3.

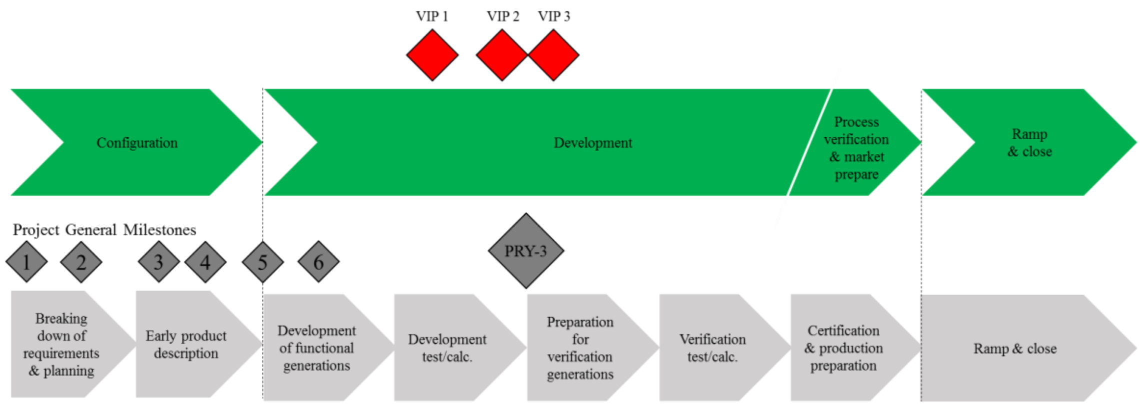


Figure 4.1-2 - The development process, adapted from the internal process chart used at Scania.

Activities are divided into configuration, development, and subsequently process verification and market preparation, and ramp and close. These activities are defined in more detail at the development process level; break down requirements and planning, early product description, development of functional generations, and development test/calculation. At this stage the deliveries for the PRY-3 milestone should be finalized and ensured. Subsequent activities are part of a tacted set of common milestones until market introduction of the new product.

Each sub-project involved in development projects work according to adapted versions of the development process. RTLR develops hardware components, hence it works according to a specific hardware development process.

In section 4.1.3 the PRY-3 milestone is described. Preceding and subsequent milestones are not included in the scope of this thesis project, and are thus not described.

4.1.3 The PRY-3 milestone

The PGM are milestones which all sub-projects deliver to. PRY-3 is one of the PGM, as visualized in Figure 4.1-2. It is the milestone in the development process to which this thesis project aims to improve the quality of deliveries from RTLR. At this milestone, the product should have reached a certain maturity. A maturity check involves a complete go through of product properties, proving that development testing is complete, and indications of the product life. The description of the PRY-3 is provided in the list below.

1. *Review of the product properties*
   - The property review should show that target properties have been or will be fulfilled during subsequent activities in the project.
2. *Development testing*
   - Hardware design should be finalized. Development testing conducted with results indicating that functional requirements are fulfilled and that the product life is indicated.
3. *Indication of product life*
   - Enough virtual or physical functional prototypes have been simulated or tested. Prototypes for verification can be ordered for final verification with high probability of success.

Figure 4.1-3 visualizes the function of the PRY-3 milestone. Preceding activities are to a large extent managed by each sub-project from, for instance, hardware design, embedded systems, simulation, and so forth. At the time of reaching PRY-3 a certain product maturity should be achieved, in order for sub-projects to deliver to common milestones in a tacted flow of activities until the ramp and close phases of the project.

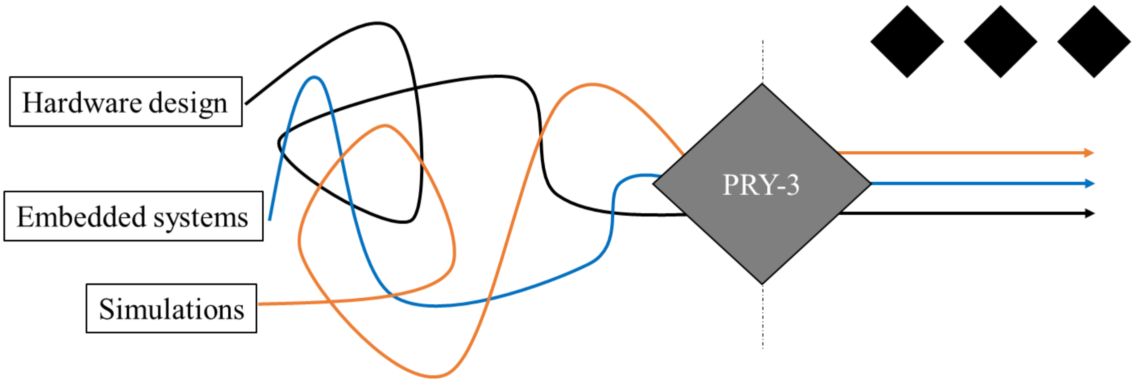


Figure 4.1-3 – A visualization of the function of the PRY-3 milestone. Sub-projects (1, 2, and 3) are coordinated through PRY-3 and follows a tacted flow of common milestones (the black diamonds) until the ramp and close phases of the project.

4.1.4 Interview with a business maintenance manager

Through an interview with a business maintenance manager (BMM) at Scania, the underlying reasoning behind the R&D process and how it is supposed to be utilized was investigated.

The development process used at Scania is supposed to view the actual working procedure from successful projects at Scania rather than showing the theoretical ideal working procedure. It is built as a road map to the engineers in order to guide through the different standards and activities that are supposed to be considered during the development process. Since it is a general process, valid for many design disciplines, all activities are not suited for all projects and some of them could therefore be ignored. Hence the process should be considered as a support for engineers. Previously the development process consisted of a list of tools and activities. In the current development process these are arranged in a chronological order.

Since the process is based on best practice from Scania and not on theory the process is not directly based on the LPD principles. However these principles can be aligned with principles from the Scania house (described in section 1.2.1). SBCE is not a main area of focus in the development process, however most of the concept work is done in the concept development (yellow arrow) prior to product development (green arrow).

Even though the new process is more intuitive and clearer than the previous list of activities the BMM highlighted a number of flaws with the development process. The main problem with the process is that a large fraction of the users are using it incorrectly due to lack of knowledge. There is also a large number of engineers who are not aware of the process. The BMM also highlighted that it is cumbersome to navigate in the process map, and that an interactive representation of the process would be desirable. There is also a problem that there is no standardization in how the tools, which are linked to the activities, should be designed. Thus the tools vary a lot and some tools are very comprehensive and consist of several large standards which are expected to be studied.

4.2 Case study

During the case study three cases were initially investigated, described in section 4.2.1. When a case was chosen for further studies interviews with people involved in the case were conducted.

4.2.1 Three cases

Three case projects were initially investigated for the case study; case 1, 2, and 3. These are briefly described in sections 4.2.1.1, 4.2.1.2, and 4.2.1.3, respectively. Case 1 proved to be the most relevant project and was therefore chosen to be studied.

4.2.1.1 Case 1

Case 1 (C1) has been a problematic project carried out at RTLR. It started with the intention to generate minor modifications of a sub-system of the chassis. When the project had started, it turned out to be significantly more comprehensive than expected, since the load cases were discovered to be complex. Both the considered sub-system and its interfacing parts failed during physical testing. This structural failure lead to a growth in the scope of the project and inclusion of more parts than initially planned. Due to the expanded scope of the project, it involved development of various parts with several different materials and with complex geometries. Thus a decision was taken to re-initiate the project in order to develop a new version of the sub-system. This second part of C1 is from here referred to as C1 part 2. For C1 part 2 several actions in the working procedure was made in order to develop a better product in a more efficient way.

4.2.1.2 Case 2

Case 2 (C2) was similar to case 1 since the scope of the project expanded during the project. The reason for this was mainly due to surrounding structures and parts interfacing the sub-system which was developed during C2. Initially the sub-system failed during physical testing due to a complex mechanical behavior. Hence major design loops needed to be carried out during the projects. The complexity of the sub-system derived from utilization of various materials and complex geometries. The case seemed to be a promising one to study. However, there was a lack of available documentation.

4.2.1.3 Case 3

Case 3 (C3) was different from the other two projects. This project was well documented and was performed in a structured way. The responsible engineer had created a system with several revisions of a PDF file representing the R&D process where all performed activities were ticked off. An interesting characteristic of this project was that it turned out successfully without any major loop-backs in the process.

4.2.2 Results from studies of case 1

The case study of C1 part 2 showed that the ways of working were more aligned with methodology from LPD. C1 part 2 was initiated with a cross functional meeting where involved parties got the opportunity to raise concerns about issues which could be predicted in advance. During C1 part 2, design reviews have been conducted every ninth week, which is significantly short compared to most development projects within chassis development at Scania. Further, involving CEs and TEs earlier and more frequent has had a positive impact on the motivation and sense of ownership towards the project.

During the case study, interviews were conducted in order to identify impressions from C1. Further, in the area of RLC, documentation in A3 format was also discussed. In sections 4.2.3, 4.2.4, 4.2.5, 4.2.6, and 4.2.7, findings from the data collection are described.

From the case study it became evident that many of the problems that occurred in C1 were known already in early phases of the development. Sub-systems and components were to be carried over from the previous version of the system developed in C1. However, when investigating documentation from previous projects and C1 part 1 it became obvious that these carry-over articles needed to be re-designed in order to withstand new requirements in C1.

4.2.3 Interview with project manager

The PM works with a project which all cases described in section 4.2.1 are part of. The PM has been working on several other positions at Scania, such as design, crash calculation and group manager. In total the PM has 14 years of experience of working at Scania. The reason for this interview was to see the project from another perspective and to understand how decisions were taken in C1. The findings from the interview are presented in the following paragraphs.

The studied case has been comprehensive and complicated, mainly due to changed requirements during the project. The information about the changes did not reach all groups which resulted in a need of several quick fixes in final phases of the project, when it was realized that the products would not meet the requirements. These quick fixes initially lead to heavy designs which were also difficult to assemble. When problems have been solved, using quick fixes, other problems with the product have occurred.

These problems occurred due to the complexity of the product. Thus several aspects must be considered during design, such as manufacturability and different configurations. Many of the designers involved in C1 have limited experience and some design activities are outsourced to consultants at other locations, which adds to the complexity of developing the product.

All design decisions were made by each department in the organization and the ways of taking decisions varied. RTLR has frequent communication with project management in order to get support for major decisions. According to the PM, the new working procedures of C1 part 2 have become clearer and RTLR has improved the ways of working together with production and the testing department. The PM also stated that the group constellation has been assembled in a very sound and efficient way.

A downside of C1 has been the lack of documentation and writing of lessons learned. This will probably be done after the project but then large parts of the useful information will be lost. The PM would like to improve the documentation but highlighted the importance of the information being digestible and written on a basic level, in order for others to understand it.

4.2.4 Interview with a calculation engineer

In order to identify opinions and thoughts from the strength simulation department, RTLC, a semi-structured interview with a CE was conducted. The CE was part of C1 in initial stages, working towards one co-worker at RTLR. According to the CE, C1 was initially not much of a project, as the resources dedicated were too small and the restrictions in design were too many. As results from physical testing indicated durability problems due to unpredicted dynamic behaviors of the component system, additional resources were dedicated to C1.

Initially, C1 was experienced as tough and frustrating due to time restrictions as well as design limitations due to carry-over of components from previous component systems. According to the CE, much of the efforts dedicated to design of the component system in the initial phase of C1 regarded adaptions of new designs to carry-over articles. Previous projects, simulations and tests indicated that these parts, subject to carry-over, were already loaded to their limit for durability toughness. Hence, much of the component design in C1 was done in order to unload the carry-over parts from previous designs. According to the CE these restrictions hurdled changes which were necessary to be able to fulfill the technical requirements specified for the system designed in C1.

As more resources were dedicated to C1, a more structured way of working was applied. Related to these changes, the flexibility in design increased despite a time schedule with narrow deadlines. According to the CE this also increased the collaboration between RTLC and RTLR, involving calculation engineers earlier in the development of components. The CE and others at RTLC got deeper involved into creative phases of design, evaluating different conceptual solutions. Even though the time schedule was tight, C1 was a functional project in which useful learnings were exploited and applied to improve the product, according to the CE. The learning was also accelerated by the increased maturity of the concepts during C1.

When C1 part 2 was initiated the constellation was changed as the project team grew. Here, RTLC became involved early in the conceptual development at RTLR. The CE described that the conceptual evaluation was moved from RTLR to RTLC. Previously RTLR has been developing concepts requesting RTLC to evaluate them using analysis software. When moving C1 into part 2, new conceptual designs were developed and evaluated. Development and evaluation of concepts involved co-workers at RTLC to a large extent and RTLR evaluated the functionality, manufacturability, serviceability and so forth. According to the CE, this work procedure increased the sense of ownership of the concepts and the motivation among the involved co-workers despite the tight time schedule. Further, the frequency of face-to-face contact between RTLC and RTLR increased, thus the information flow also increased. According to the CE, this resulted in that co-workers from RTLC gained understanding in the daily activities at RTLR which differed from RTLC. Examples mentioned by the CE were contact with suppliers, purchasing, service and so forth.

The CE mentioned that senior co-workers at RTLC have been stating that if they would be involved already in the concept development, many problems which occur due to strength and durability would be avoided. If these problems were addressed early they would not surface late in development projects and hence reduce cost. It has been acknowledged that RTLC and other simulation groups should be involved early in development projects. C1 part 2 demonstrates the advantages of involving simulation engineers early in the process, where they are not simply performing ordered tasks but are involved already in development and evaluation of concepts. The CE states that working according to the procedures of C1 part 2 is more enjoyable and inspirational compared to when engineers at RTLC simply receive models from design departments, simulate the models, and present the results. Further, the CE mentions that when calculations of concepts are presented and discussed between design engineers and calculation engineers during C1 part 2, the root causes of stress concentrations and other results are critically discussed by both parties.

The CE mentioned positive aspects of simple simulations which design engineers can carry out themselves using simple simulation tools built into the CAD software. Analyzing simple models with a low level of detail generates much knowledge in relation to the invested effort and time. Detailed simulations of complete component and component system concepts should still be carried out by simulation engineers utilizing software specialized for simulations, in order to secure accuracy of the results. The CE mentions the advantage of experimenting with simple and exaggerated models when component and component systems are investigated. An example can be to increase the stiffness of a certain component in a system a thousand times. By this, behaviors of the system and how it is affected when component properties are drastically changed can be understood. Thus, design engineers can extract much knowledge about new concepts through simple simulations in CATIA[1]. The main issue with these kind of simulations is that they are generally not documented in a way that makes the results available and visible to other co-workers. The communication on these simulations between simulation engineers and design engineers is difficult due to the lack of documentation. However, simple documentation visualizing the model and what load case was applied would support the communication.

Documentation is time consuming but worth doing. At RTLC, much documentation is done through writing detailed reports from simulations. The problem with this type of documentation is that it is often carried out post-projects. One of the main purposes of this documentation is to make the information of who has done what available. This information is valuable if someone at RTLC has previous experience of simulating a certain type of component or system. During projects, calculation reviews are carried out where simulation engineers present simulations and possible areas of components or systems causing strength or durability problems. For this purpose, PowerPoint[2] presentations are easier to use than reports. The content becomes more concise and figures are used rather than text and equations.

An obstacle with using reports is the fact that to read a printed report, pages have to be turned. The concept of A3 was brought up during the interview with the CE, who had limited experience of

[1] CAD software developed by Dassault Systèmes.

[2] Slide show presentation program developed by Microsoft

writing reports in A3 format. However, the CE had recently written such a report, and agreed that it is an effective way of documenting a component and component system development, and that it is a manageable way of summarizing information. The most important feature of documenting work is that it is done each time it needs to be done, according to the CE. Another key feature of documentation is that it should be easy to access. The information being visual is important, but should not be prioritized higher than the accessibility.

4.2.5 Interview with a test engineer

The TE has been working at Scania since 2002 and has been involved in C1 from its initial phases. The TE's role in the project has been to be the contact between the groups and to give recommendations in accordance to the test results from the physical testing. At the test department, mainly two kinds of testing are carried out. One is conducted late in the process to test a complete product and determine how well it performs compared to the set requirements. The other kind is simpler where single components can be tested to see how well they comply with the simulation models, or to provide simulation departments with necessary boundary conditions.

The component system considered in C1 is a mechanically complex product since it is not only exposed to static forces. In addition, it should fit into the modular system at Scania where several variants might result in different mechanical behaviors. It should also fulfill requirements from manufacturing and assembly. These characteristics have made it difficult to predict the behavior of the product.

In early phases of C1 it was discovered that the concept developed was not suitable for all market segments. Thus a decision was made to launch it for certain market segments. At the same time a new project (C1 part 2) was initiated to create a new concept for the rest of the market segments. This second part differed in many ways from the original way of working. It started with a focus group where all involved parties gathered for a couple of meetings to generate new concepts. This activity is relatively unique for this kind of projects at Scania but the meetings worked well and the TE appreciated this way of working. However, the TE believed that it is difficult to decide who should attend to such idea generation sessions. If there is a complex problem the number of involved people are rapidly increasing and thus the meeting becomes difficult to manage.

There was also a difference in the way of communicating between C1 part 1 and C1 part 2. During C1 part 2 it was clearer that problems were related to strength and durability, thus a frequent communication between RTLR and testing and simulation departments became more important. This was encouraged by the TE but it became stressful for the testing department when the pace increased and the concepts were rapidly modified. Since the testing department is responsible for all physical hardware testing at Scania, these changes in the ways of working had a high impact of the department's work load. Another difference in the way of working was that the testing group was involved early to give recommendations of which tests that might be necessary and when they should be carried out. The TE supported this way of working, but highlighted that the problematic history of C1 made the testing department aware of possible problem areas and could therefore give better predictions of which tests to do.

A difference in communication between the test group and RTLR compared to other groups within Scania was noted during the interview. RTLR, and more specifically the C1 team, are large groups. Normally, testing only considers single components and hence it is only necessary to be in contact with two or three people. In C1, where several components and sub-systems were developed, the communication became complex since the team was divided into sub-teams and sometimes new information did not reach the entire team.

The TE stated that a more effective working procedure would be to let each competence area, such as testing, simulation and manufacturing, have larger responsibility for their respective property in the product. At the moment the design departments have been responsible for all properties and have been using support from different competence areas as a base for decisions. The TE believed that with a higher property responsibility, the dialogue between departments would result in higher decision quality. The TE also stated that it would be preferable to utilize competence and knowledge within the testing department to inform on design decisions. For some concepts testing is not possible until the late phases of a project. In such cases these concepts should be eliminated from further development as early as possible. For promising concepts the testing department needs to study how to perform certain testing, which is also a reason to have a cross functional dialogue in the early phases of development.

Testing results are mainly delivered through reports but usually the TE also calls on responsible people to inform about the results. However, even if the tests are well documented through the reports, the TE claimed that they were rarely read by others. The TE believed that few people are aware of these reports and thus rather calls the testing department than search in the archive.

4.2.6 Interview with chassis development manager

The CDM works as a section manager for RTL, which is the section that RTLR belongs to. The CDM's role includes to ensure that all groups have enough resources and to act as a support in decisions and communication between different projects. The reason for this interview was to get the CDM's input on the new working procedures in C1 part 2 and to find out if this was supported by the management. This interview was also a way to confirm that findings from the case study and possible improvement areas was supported by top management. Findings from the interview are presented in the following paragraphs.

The CDM stated that the working procedure of C1 part 2 was in line with how development projects should be carried out at RTL and highlighted that more projects should be carried out similarly. The characteristics of C1 part 2 highlighted as superior by the CDM were, for instance, the frequent communication with cross functions and that the design loops were very clear. The CDM also supported that the C1 team challenged conventional ways of working.

Building knowledge through short design loops in the beginning of development projects and involving relevant cross functions is one of the keys to success. It is important to include testing and simulation early in order to calibrate the virtual models with physical testing. This will give more accurate results from simulations and could therefore be used to understand the behaviors of components and systems in early phases of development projects. It is also important to experiment with input parameters in simulations, and even use unrealistic parameters, in order to see how systems are affected and thus gain a better understanding and predictability of components and systems.

Before initiating detailed design it is also of great use to investigate design guidelines. Hence, design guidelines should be documented in a format which is easy to grasp. In order to motivate co-workers to document properly, the format should also make the documentation simple to create. The CDM mentioned that several versions of one part often becomes confusing, thus it would be useful to have a short explanation of what has been changed from one version to another. The CDM was familiar with the A3 format (see section 2.3) and believed that it could be a suitable format for the documentation, both for short design guidelines but also to summarize extensive reports. It could also be a good idea to use the A3 format for documenting concept screenings, such as decisions of why or why not concepts were selected for further development.

4.2.7 Structured interviews with C1 project team members

In order to identify views upon the design process, the DM meetings, and the ways learning and documentation is done at RTLR, structured interviews (see section 3.5.3) were conducted with seven design engineers working with C1 part 2. This section summarizes findings from these interviews. More detailed summaries of each participant´s answers are found in Appendix D. The guiding questionnaire is found in Appendix C.

During the structured interviews common thoughts and opinions were identified, which contributed to further discussions and recommendations for RTLR. These thoughts and opinions are summarized in the list below.

- The introduction to the R&D process has varied between different co-workers. Most co-workers have not received any dedicated introduction.
- Many experience the R&D process as a support in the daily work, but lack a holistic view of it.
- The documentation of new knowledge is limited, as well as the utilization of previous knowledge.
- Documentation is not carried out in a standardized manner.
- The opinions about DM varies, some consider it to be helpful while some consider it to be too time consuming.
- There are indications that the DM lacks the connection between the short-term and the long-term planning.
- All of the participants consider the opportunity to highlight issues and to get response from the group manager, TLs, and object leaders during DM as positive.
- The decision to pursue development of only one concept is taken in early phases of projects.
- Decisions whether or not to proceed with concepts and designs are based on a mixture of facts, gut feeling and time-plan.
- There is no clear routine for managing deviations from the time plan.
- The PRY-3 milestone is in general passed with uncertainties.
- The availability of time for physical testing is limited.

4.3 Study Visits

In order to collect first-hand input from real-life practices of DM and RLC, study visits were conducted. The DM meetings were observed at RTLR as well as another group within chassis development, RTLS. Further, two study visits were carried out at Ericsson in Kista, Sweden.

4.3.1 Daily management at RTLR

DM meetings took place in a room next to the workplaces of RTLR. This room was a regular conference room available for anyone in the organization to book and occupy. The walls in the room were covered with whiteboards with a short-term planning very similar to the planning boards visualized in Figure 2.5-1. The furniture in the room consisted of two high tables and approximately ten high chairs.

Every day the C1 team gathered in the room at a specified time. Parts of the team were sitting around the tables and others were standing along the walls. The C1 team was large, consisting of approximately 16 engineers who worked with the same sub-system. For a comparison, Lindlöf (2011) identified the optimal team size to consist of six to twelve persons. The DM started with the team leader (TL) briefly presenting general information and status of projects related to C1, followed by team members briefly presenting their own planning and status. The team leader moderated this status update and passed the word to each co-worker in the room. Each co-worker briefly described the own general feeling about the own planning, and whether any problems or difficulties with activities and planning had occurred.

If a deep discussion was initiated, a separate meeting after the DM was planned with involved people. In order to update the planning status, each co-worker marked the own planning “row” on the board with magnets of different colors. The colors represented how the current workload was perceived and if upcoming days and weeks were already planned or not. The content of the sticky notes at the planning board was rarely brought up during the DM meetings, since the planning status was prioritized. The first DM meeting which was observed by the thesis project group lasted for approximately 30 minutes, which was common for these meetings according to the TL.

Between the meetings the thesis project group discussed potential improvements of the DM meetings with the TL. In order to avoid deep technical discussions during DM additional weekly meetings, where technical issues should be discussed, were proposed. This lead to that deep discussions were moved to these occasions, thus the DM became more focused on the planning. The DM meetings could therefore be reduced to approximately 15 minutes. According to the TL this arrangement worked well and the meetings became more efficient. However, the content of the sticky notes on the planning board was still not brought up during the meetings.

4.3.2 Daily management at RTLS

A group, RTLS, working with fuel and emission control systems, has recently implemented a new way of managing DM using a DVP tool. Similar to RTLR, RTLS consists of a number of sub-teams, referred to as teams below. Study visits were conducted in order to investigate the experiences of DVP at RTLS.

The system which has been implemented at RTLS is developed by co-workers at Scania using the software *Microsoft Access*[1], which was connected to general project forecast files and each group member’s calendar. When new activities were registered in the general forecast they were automatically assigned to responsible co-workers at RTLS. The person receiving the task had to specify estimated time to complete the task and when it would be carried out. All group members could also create new tasks in the system and specify time consumption and expected starting date. In addition, meetings which were planned in each group member’s calendar could be exported into the system. The arrangement of the tasks was visualized in a list together with a weekly calendar showing which week and weekdays the tasks would be carried out, as well as the total estimated time for the tasks. In Figure 4.3-1 a screen shot from the tool is visualized.

[1] A database management system developed by Microsoft.

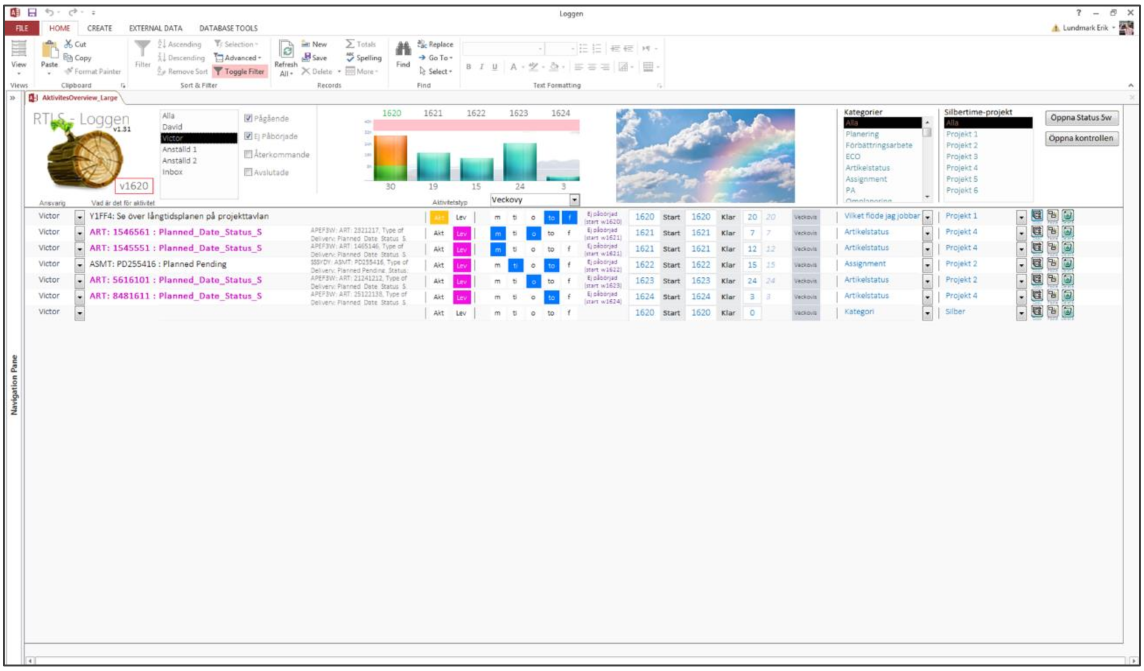


Figure 4.3-1 - This figure shows a screen-shot from how the digital planning tool look like. This view represents the tasks for one co-worker for one week. The bar chart represents how many planned hours this specific co-worker have for the upcoming weeks.

The DM meeting took place in a corner of the office where planning boards were located. Even though the group had implemented a digital planning tool, an analog planning board with sticky notes was used to visualize the long term planning. The short term planning tool was visualized on an LED screen, which was moderated by one of the team members. The moderator passed the word round the team and switched between the team members' individual planning boards at the screen. The total estimated time for each week was clearly visualized for each team member. If any team member had planned close to or more than 40 hours during a week, tasks were re-arranged and re-distributed to other team members.

At each Monday and Friday the meetings, which were supposed to be longer than the regular meetings, the week is opened and closed, respectively. These meetings lasted for approximately half an hour, compared to the regular DM meetings which lasted for approximately ten minutes for each team. During the Monday meeting all activities already planned for the week were presented and tasks from RTLS' common task-inbox were assigned to the team members. During the Friday meeting activities from the week were reviewed in order to secure that additional time was dedicated to certain tasks if needed. The team members also got the possibility to inform about delays and to update the plan for completion of tasks. Further, during the Friday meeting the team also ensured that the planning for the upcoming weeks was synchronized with the long-term planning.

Before implementing the DVP tool all co-workers at RTLS wrote identical sticky notes twice, one to put on the planning board and one to bring to the own desktop. During an evaluation meeting at RTLS, the yields from the DVP tool were discussed. According to several co-workers at RTLS, it has become easier to visualize and to get reminded about critical tasks using the DVP tool instead of the physical planning board alone. The DVP has also simplified the updating of the individual time plan. Another benefit mentioned by several co-workers was the ability to visualize the occupancy rate for each co-worker, which in turn simplified levelling the workload within the teams.

During the evaluation meeting the group also had an opportunity to raise problems and lack of functions. Since the DVP tool was developed at Scania and administrated by a co-worker at RTLS, customization of the tool in order to fulfill requirements could easily be carried out. The most critical limitations and desired functions, mentioned during are listed below.

- A need to visualize the planning for the upcoming weeks more clearly was identified, as the possibilities for this were limited.
- It was not possible to see how many hours that were planned for each day.
- A desired functionality was to be able to visualize how large fraction of the planned activities during the week that remained to be carried out.
- The ability to choose different colors in order to visually separate activities and deliveries was missing.

4.3.3 Daily management using Yolean

Daniel Stenholm is a Ph.D. student at the Department of Product and Production Development at Chalmers. Stenholm conducts research within methodologies and IT-support for LPD and takes part in a project where a DVP tool, *Yolean*, is developed. The interview was conducted in order to gather insights, thoughts, and aspects which could be useful for a possible implementation of DVP at RTLR.

Stenholm clarified that the reason for implementing DVP should not be to achieve as much functionality as possible. It should instead primarily be to replace the existing solution and fulfill the same requirements. However, as soon as the implementation is carried and the team is comfortable with the solution, the team might consider to experiment with additional functions of the tool. The main purpose, which is to coordinate and synchronize tasks, should always be in focus. Also, the DVP tool should not distract team members from the physical meeting around it which, according to Stenholm, is the most important part of VP.

The meeting around the board is a way for the team members to highlight and share lessons learned. However, the main area of usage of the meeting is to visualize and discuss short-term planning. If a co-worker has a too high workload it should be possible to distribute tasks within the team. Hence the DVP tool should visualize the occupancy rate for each team member.

To be able to distribute tasks in the team, the maximum length of the tasks should be reasonable. If tasks are too long and unspecified it might be difficult to delegate them to other team members. The optimal length of tasks depends on the context. However, Stenholm recommends to divide tasks into work packages of about three to four hours. This task size is utilized by both the *Yolean* project team, and at for instance Autoliv[1] where the software is utilized. Also, the content brought up during meetings depends on the composition of the team. For a homogenous group, such as RTLR, where most of the co-workers have similar duties it is advisable to also bring up the content of the planned tasks and activities. If a group is more diverse with respect to the co-workers duties and professional and academic background, such an approach would not be useful.

Initially the DVP in *Yolean* was a virtual version of a physical planning board. It was used to examine whether it was possible to use a digital planning board without disturbances. Result from the study indicated that a digital solution could replace a physical planning board. Upon these results the software was further developed and features, differentiating a DVP tool from a physical planning board, were added.

The software is built upon a database which stores all planning changes and actions. The group has the possibility to access statistics from stored data, such as number of delayed tasks, re-planning, and so forth. These features are, according to Stenholm, missing in other similar software, for instance iObeya.

Further, Stenholm recommended to use a large touchscreen when conducting meetings using DVP. This would serve as a mediating tool to gather around which supports a common understanding among team members. Touchscreens, compared to regular screens, are more interactive and are therefore easier to use as a mediating tool. However, Stenholm also mentioned limitations regarding the user friendliness of touchscreens when, for instance, writing virtual sticky-notes. Therefore Stenholm recommended to plan and register new activities using standard computer hardware.

[1] Autoliv is a Swedish company developing automotive safety systems.

Yolean is a relatively new software, used by several large companies such as Autoliv, Volvo Cars[1], Toyota Material Handling[2], and Kongsberg Automotive[3]. When the software was implemented at Autoliv it was first used by a single team and was then spread throughout the organization. The reason was to be able to customize the virtual planning board for each team rather than forcing all teams to use an identical solution.

As final recommendation to RTLR for a successful implementation of digital aids Stenholm highlighted three points, which are listed below.

1. State the main purpose of the planning meetings, and design the DVP tools accordingly. Hence it is a prerequisite to fully understand and to have a clear and common purpose of the planning meetings.
2. The DVP tool should satisfy the same need as the previous solution. When these needs are fulfilled, improvements and further customizations can be implemented.
3. It is possible to initially use both a physical planning board and a DVP tool, and gradually move towards a fully digitalized solution.

4.3.4 Learning day at Ericsson

As part of the data collection the thesis group participated in a Learning Day at Ericsson in Kista, Sweden. Ericsson develops both software and hardware, and has since 2010 transformed from working according to an R&D process with long development cycles into working according to three-week prints. These sprints can be considered as short learning cycles where improvements are integrated to the end products. Further, top management supports co-workers to dedicate 30% of their work time into learning and innovation. As part of this dedication full day activities, called Learning Days, recur on the second week of each sprint. The department visited was Ericsson 3G, which globally consists of approximately 1 800 co-workers, divided into 100 teams at ten sites.

4.3.4.1 The leaps in ways of working at Ericsson 3G

Schön (2016) presented the ways of working within development at Ericsson 3G, as well as the transformation from the previous to the current development process and the yields from this transformation.

In recent years the utilization of the 3G network has increased drastically due to the transfer of information through mobile devices. For more than 30 years, Ericsson improved their "waterfall" model within development, see Figure 4.3-2.

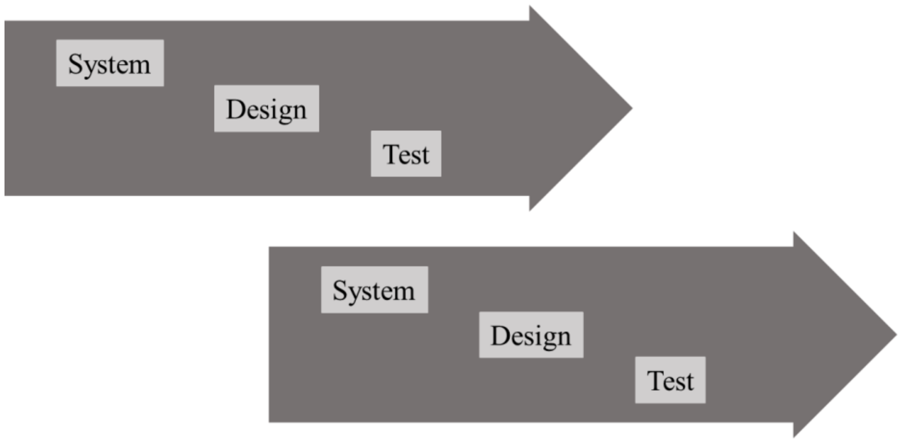


Figure 4.3-2 – Visualization of Ericsson´s waterfall model, adapted from Schön (2016).

When working according to the waterfall model, Ericsson undertook projects of between two and three years, involving between 100 000 and 200 000 work hours. Integration of new features into the

[1] Volvo Cars is a Swedish automobile manufacturer.
[2] Toyota Material Handling is a forklift manufacturer, part of Toyota Industries.
[3] Kongsberg Automotive is a Norwegian automotive parts manufacturer.

products were made approximately twice a year. In 2010 management argued that the potential for improving this model was low. Hence fundamental changes in ways of working were initiated. Clear needs were identified, which described where development at Ericsson 3G aimed to strive.

- Increase efficiency to enable more output.
- Reduce lead-time to be more responsive.
- Build quality into the ways of working.
- Empower people.

A new way of working was identified through dialogues with colleagues from the same industry, which worked according to scrum, see section 2.6. A leap in focus and thinking was to be made. Figure 4.3-3 visualizes this change in ways of thinking.

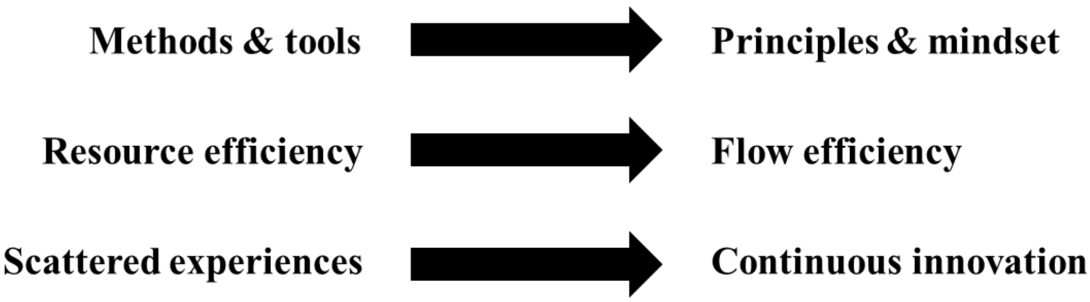


Figure 4.3-3 – The leap from focusing on methods & tools, resource efficiency and scattered experiences to principles & mindset, flow efficiency and continuous innovation. Figure adapted from Schön (2016).

When transforming from focusing on methods and tools to principles and mindset a new culture had to be established. This transformation is visualized in Figure 4.3-4. Here, methods and tools were utilized for the leap into new principles and mindsets. Scrum generates a flow through shorter cycles in development. Kanban, inspired from the use of visual signals to schedule demand within production at Toyota (Gross & Mclnnis, 2003), drives the principle of visualization. Issues, problems, targets and so forth should be made visual in order to generate a demand-driven development. Continuously integrating new features and functionality into the products contribute to a continuous learning related to each integration. The learning happens continuously, since feedback on integration is received more frequently.

Figure 4.3-4 – The transformation from methods & tools to principles and mindset. Adapted from Schön (2016).

The leap from scattered experiences to achieve a continuous learning was made through securing time for innovation and learning. The decision from top management to dedicate 30% of co-workers´ time into learning supports planning for innovation. As visualized in Figure 4.3-5, the initial capability will not reach its maximum potential when investing 30% of the time in learning. However the capability will increase due to learning and innovation. Hence, planning with less than full utilization will create an environment supporting innovation which increases the capability. If no time for innovation is planned, the initial capability might be higher, however there will be no potential for improvements in capability.

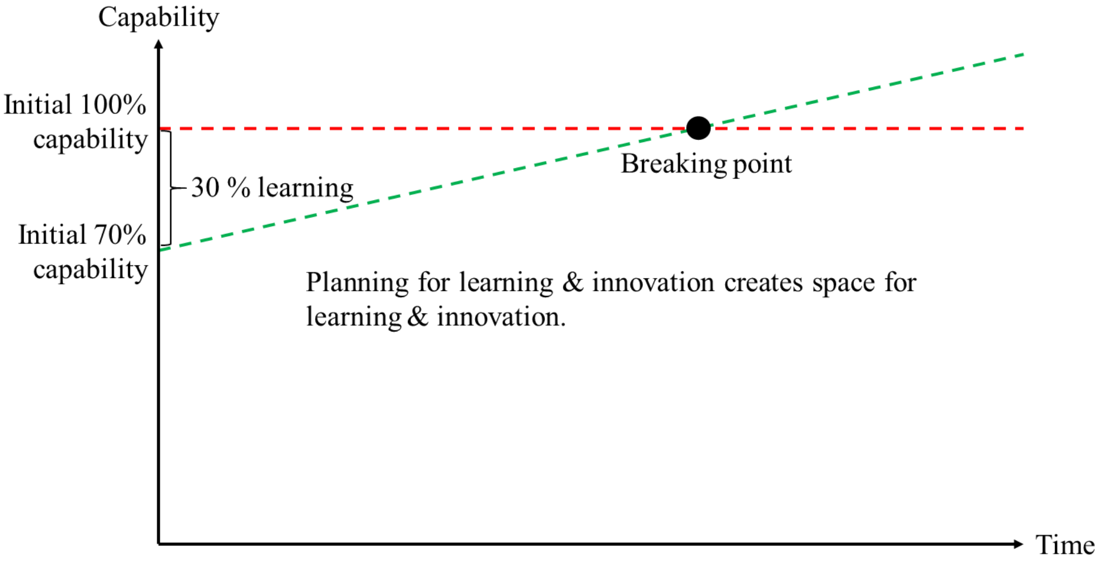


Figure 4.3-5 – Visualization of how the planned time for learning and innovation generates an increasing capability. Thus, the initial capability loss will pay off in terms of improved future capability. Adapted from Schön (2016).

4.3.4.2 The development sprints at Ericsson

The way of managing development projects at Ericsson 3G was transformed from utilizing the waterfall model into working according to scrum to create a responsiveness and agility within development. At Ericsson 3G development efforts are carried out by the teams in three-week sprints, or cycles, where changes, improvements, and new features are integrated with the products by the end of each sprint. By this, Ericsson 3G achieves a continuous innovation through small “experiments”. These drive the leap towards upcoming challenges. Figure 4.3-6 visualizes how these sprints result in integration to the product and that the yields are improved capability, increased number of features over time, and decreased number of trouble reports. These yields are the result of development efforts packaged into smaller steps where the teams more frequently receive feedback and gather a greater understanding of the end product.

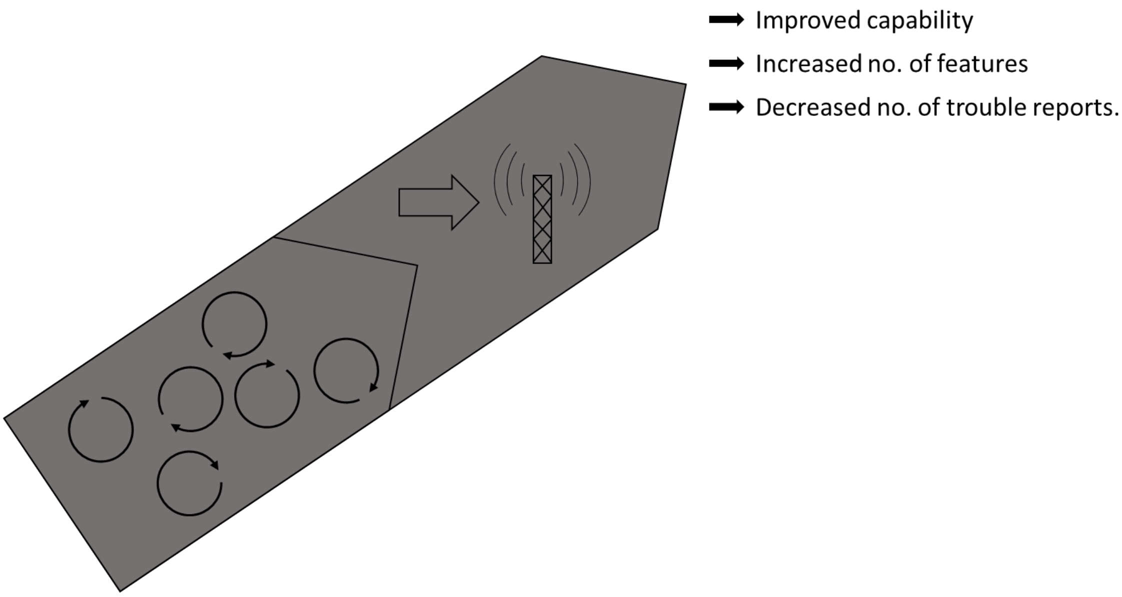


Figure 4.3-6 – Visualization of how the short sprints constitute small experiments which drive the leap towards upcoming challenges. Adapted from Schön (2016).

4.3.4.3 The learning days at Ericsson 3G

As part of the decision to dedicate 30% of the time into learning and innovation, one full day each development sprint is dedicated to learning. At Ericsson 3G, one day during the second week of the sprints is planned and scheduled for learning where internal and external presentations, workshops, movies, lunch presentations, and so forth are arranged. Co-workers choose activities considered as relevant, in order for the learning days to be driven by demand and to avoid co-workers participating without the possibility to learn or contribute. Also international sites are invited to participate through video and audio links. In addition, also other sites carry out local learning days.

The learning days being scheduled the same day every third week make them a recurring subject in the co-workers' calendars. This, together with the decision from top management of dedicating resources into learning, support co-workers and managers to avoid planning other meetings and activities during the learning days. The recurrence hence support the learning days to be conducted each time.

4.3.4.4 Quantifiable yields from the new ways of working

The transformation from the waterfall model into scrum and development sprints at Ericsson 3G has brought measurable yields with direct impact on the financial results of the organization. The output from development in terms of new features has increased approximately four fold. This is a result of a decreased lead-time of new features from an average of 100 weeks to 36 weeks. The number of monthly trouble reports has decreased from approximately 200 to 40, while the motivation and satisfaction of the co-workers has increased.

4.3.5 Open scrum master gathering

Open Scrum Master Gathering (OSMG) at Ericsson is a conference with both internal and external participants, mostly from software developing companies. During the OSMG representatives from Agile42[1] and Spotify[2] presented their view upon scrum. In addition the OSMG included interactive events in which all participants took part. In total more than 120 participants from ten different companies attended. The thesis project group attended the OSMG in order to gather insights from ways of working within the software industry.

Three interactive activities involving group discussions were carried out, where subjects were decided by the participants. Everyone got the opportunity to briefly present a subject and assign it to a time slot

[1] Agile42 is a coaching company in agile development.
[2] Spotify is a Swedish commercial music streaming, podcast and video service.

and place. In total 30 subjects were presented which were discussed at ten locations during three sessions. Hence participants decided individually which subject they wanted to discuss or learn about. The project group attended three discussions with the topics “how to motivate the team for scrum meetings”, “positive and negative aspects with digital and analog planning boards”, and “measurements for sprint cycles”.

The first topic about motivating people for scrum meetings, similar to what is referred to as DM meetings at Scania, generated several new thoughts. Most of the participants worked as scrum masters, who shared their experiences from scrum meetings. A common experience among the participants was that rotating the responsibility of the meeting among different co-workers, which seemed to generate a sense of ownership of the own planning and a motivation to carry out scrum meetings. The scrum master who is usually responsible for the meetings was suggested to facilitate rather than lead the meeting. During the discussion it was also highlighted to make clear who is talking and give this person space to talk without interruptions. Some scrum masters made this possible with a token, an item which is passed around the team. Passing the token around the team also generated a random order of who is speaking, which made the meetings more dynamic.

During the discussion about positive and negative aspects of digital and analog planning boards, no aspects previously unknown to the thesis group were brought up. However a consensus was reached about the importance of understanding the purpose with the board before implementing a DVP tool. Thus, it might be beneficial to implement an analog board first to learn about the meetings before implementing a digital solution.

The third subject was about which measurements should be used to evaluate a development sprint. It is complicated to generate measurable data from the sprints through performance indices since each sprint is different. Some participants during the discussion explained how their organizations had implemented a performance index based upon the team members’ personal perceptions of the sprints. Ratings from the team members were the foundation for further discussions about improvements until upcoming sprints. An example was mentioned where team members were asked to rate their perception regarding the quality, output, and value of the sprint. Another example was mentioned where team members evaluated their overall perception of the sprint. The results from the team members, the product owners and the scrum masters were kept apart in order to detect differences which might imply a potential problem area. The common feature of both these ways of working was the discussion which followed the sprint evaluations.

4.4 Input from Michael N. Kennedy

This section summarizes the answers from an e-mail conversation with Kennedy, described in section 3.5.6. The questions and answers are found in Appendix E.

Implementing RLC into a hardware design process in an established organization can be carried out on a small scale, such as with one project or one system design. Without dramatic interruptions the learning can be developed and refined into a broader usage within an organization. There are two important conditions which have to be fulfilled in order to succeed with this.

1. The project leader has to be committed and should support problem solving to assure that all necessary knowledge is gathered before decisions are made, and knowledge overrules schedules.
2. The engineers must possess the expertise, methods and tools to identify all knowledge gaps in order to solve them robustly.

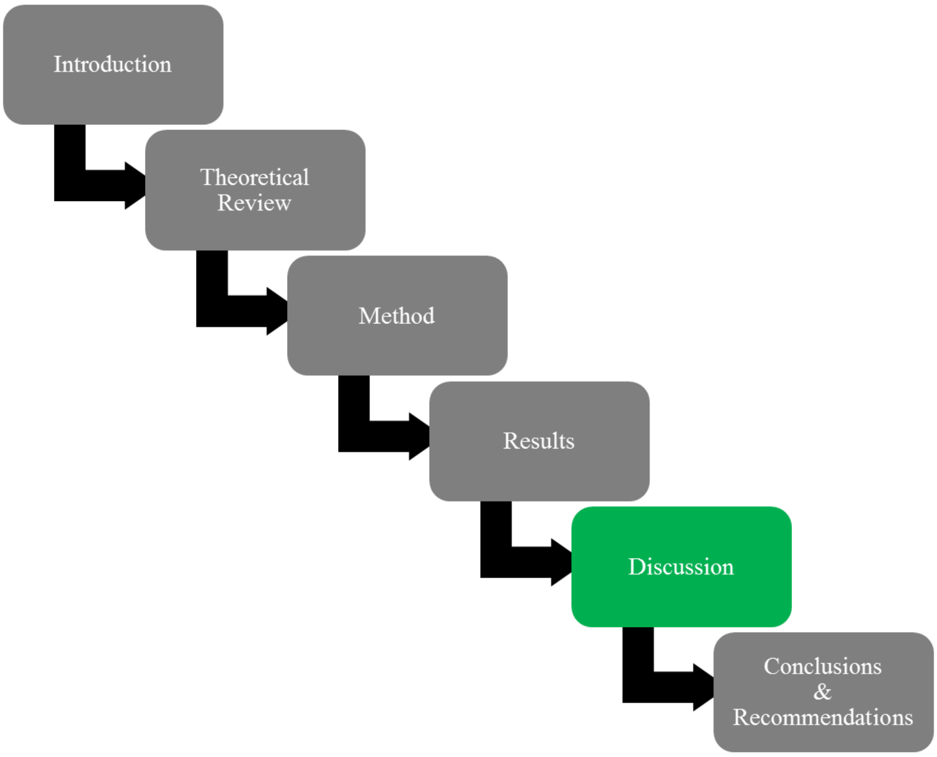
According to Kennedy, the main obstacle is to not have both 1 and 2 in place, otherwise decisions will be made upon wishful thinking. The team must gather around a common purpose, and it is also critical that integrating reviews are held with a cadence and followed to maintain a sense of urgency. A new learning methodology should be defined and then proven on a small scale. Expanding the methodology should be carried out subsequently. However, the conditions of 1 and 2 must be in place first.

In order to avoid unknown knowledge gaps in late development phases, the primary focus should be to identify and expose all critical knowledge gaps early in a visual and rapid way. To achieve this, the team must define critical targets, promote innovative ideas, understand the limits of the required decisions, and understand trade-offs among targets and decisions. To achieve this, the impact of decisions upon multiple customers´ interests must be addressed and made visual. When knowledge gaps are on the surface, elimination of weak options can be executed in a set-based manner.

To achieve a front-end learning environment the focus should be on identifying and eliminating knowledge gaps rather than executing tasks. If visual planning tools are based on managing tasks and not cycles of learning, they might be counterproductive. Visual planning in learning cycles should support to maintain a cadence of learning, decisions and adjustments.

5 *Discussion*

In order to interpret results from data collection, theoretical review, and the case study, these are analyzed in the context of RTLR and the R&D organization at Scania. Different aspects upon findings from research are addressed and their implications in the case of integrating new ways of working at RTLR are discussed. The discussions contribute to the final conclusions and recommendations for RTLR.



5.1 Rapid Learning Cycles

Findings from interviews at Scania indicate a need for more frequent decision points in development projects, where cross functions review the current state. Currently, cycles between design reviews in C1 part 2 are nine weeks long. However, as observed during study visits at Ericsson 3G, cycles of three weeks are utilized both within software and hardware development. Radeka (2011) argues that learning cycles should be between two and eight weeks long. Hence a suitable length of learning cycles to utilize at RTLR might be identified. From interviews, and also as proposed by principles from LPD and the Scania house, there are indications of a need of flow and predictability within development at RTLR. In order to avoid the risk of having learning cycles too long, the thesis group argues that the cycles should not be far from what is already successfully utilized at Ericsson. Thus, between two and five weeks might be reasonable as an initial learning cycle length.

Even though there are both evident and non-evident positive yields from working knowledge-based in product development, there might be barriers to a change of focus from the product to knowledge. These barriers might arise from both personal preferences and characteristics, as well as inherent organizational barriers.

5.1.1 Risk for personal criticism & speaking up in front of the group

During events when learning cycles are finished, reviewed or initiated focus should be on identifying, discussing, and planning for closing new knowledge gaps. During these activities, there might be a tendency for co-workers to experience themselves as being in vulnerable positions. Focusing on what is not known within the team might be experienced as focusing on what co-workers do not know individually. Hence this might be experienced as criticism towards the competence and knowledge of a co-worker, or even as personal attacks. This has also been discussed together with the TL at RTLR within C1 part 2, who agrees that this issue requires attention. The measures from co-workers experiencing personal criticism during learning events might contradict potential positive yields from a knowledge-based development procedure. Hence, the nomenclature and the approach towards individuals at these learning events should be carefully chosen. For instance, using “knowledge gaps” and focusing on individuals´ performances might not be as powerful as focusing on the common knowledge gaps of the group which individuals are assigned to investigate until the next learning event. Thus nomenclature such as “risks”, “possible problems”, or similar might be considered to use instead.

Another area where careful considerations are needed is the way of initiating discussions during learning events. Since co-workers differ in their eagerness to speak up in front of the whole team, some might hesitate to raise their concerns and opinions about critical issues. Important comments and insights might not be heard and the learning cycles will not be carried out as efficiently as possible. Thus, the learning events should be arranged in a way which also supports co-workers, who would normally hesitate to speak up in front of the group, to bring their experience and knowledge to the table. The learning events might therefore be arranged in a workshop-like manner. This might create interactions which in turn support discussions that would not come up if co-workers were to speak up in front of the whole group. An option to carry out these learning events might hence be to list a number of bullet points about issues, knowledge gaps or risks and divide the participants into sub-groups. These sub-groups are then allowed to freely discuss and come up with thoughts upon the relevant issues, which are brought back to the whole team.

5.1.2 Discrepancy between expectations from management and rapid learning cycles

The development process at Scania involves a few major reviews; the VIP. These constitute opportunities for management teams to get informed about current statuses of projects. When working according to a learning-first procedure, virtual and physical fully functional models are not generated as early as in the case of a point-based and product-focused development. In early phases of development, when building knowledge about a set of different concepts, virtual and physical representations of several alternative solutions are generated. The main competitive advantage is not the rapid generation of fully functional prototypes of one single alternative solution. Instead, it is the insight and knowledge which reduces the risk for costly loop-backs in later phases of development. However, this might not be what stakeholders, financiers, customers and so forth expect in late development phases. An engineering team which states that success is assured might not be satisfying when significant resources have been invested into a development project. This contradictory characteristic of knowledge-based development might not be the easiest strategy to convince management to pursue. A point-based development strategy might result in an optimal solution. However the probability for sub-optimized products or loop-backs in late development phases is significant compared to when building knowledge and unveiling a larger part of the design space before generating virtual and physical prototypes.

During the interview with the CDM, ways of working within hardware development at Scania were discussed. There is an internal drive at Scania to move from methods and procedure supporting point-based development into a development organization which learns first and integrates cross functionally early during development projects. Partially, the ways of working in C1 part 2 mirror the CDM´s and management´s vision of how projects should be carried out within chassis development at Scania. Building knowledge through short design loops in early development phases, and to include relevant cross functions early, is one of the keys to success of development projects. Hence, an alignment can be identified between the vision of management at Scania and indications from results from data-collection and literature review. Further, the CDM supports challenging ways of working in order to improve the development organization. Thus the ripple effect from change efforts at RTLR might, in the long run, have effects on the overall performance of the development organization at Scania.

During the interview with the PM, the organization and working procedures of C1 part 2 were discussed. The collaboration and integration with cross functions such as calculation and testing was significant during the project. This has also been emphasized during interviews with the CE as well as the TE. Emphasizing cross functional integration is one of the keys to allow for relevant learnings, in order to avoid mistakes discovered in late project phases.

Due to the positive experiences from different functions involved in C1 part 2, the PM and the CDM support the change from point-based and product focused development into a knowledge-based development. The cross functional integration, as discussed by the CE, also involves expanding the own knowledge base. Early cross functional integration between functions in projects inherently involves learning about activities and issues which are not already familiar within the own function. An example mentioned by the CE is the discussions between RTLR and purchasing, which is a domain that simulation and calculation teams do not work with on a regular basis. Another positive effect from the cross functional integration in C1 part 2 was to involve calculation departments in the conceptual design. This further improved the motivation and sense of ownership among calculation engineers, and supported optimizing the mechanical durability of concepts. Despite these strengths, the potential barriers discussed in this section should be considered and managed with close attention.

5.1.3 The relation between documentation and rapid learning cycles

As seen during the theoretical review, Toyota invests significant resources in training junior engineers to become technical specialists. These engineers would correspond to senior engineers within product development at various technology organizations around the world. The thesis group has observed that at RTLR and other groups within chassis development, many engineers are relatively young with little experience. The senior engineers are relatively few and contribute with technical knowledge and experience in various technological fields. In addition, at RTLR along with several other groups, a significant part of the engineers are externally hired consultants. Of these, many will change assignments and also working places as frequently as, or more often than engineers permanently employed by Scania.

As derived from discussions with the thesis group´s supervisor, there seems to be a culture of developing employees at Scania, with a long-term mind-set in order to ensure the future competence base within the organization. Hence, co-workers rotate between different roles in order to build competence and experience in accordance with their personal competence development plans. In combination with consultants, who tend to work on the same assignment at the customer´s site during relatively short time periods, the turnover of co-workers within several groups is substantial.

Accordingly, the groups are not able to keep the knowledge "in the heads" of the employees as they rotate frequently. A project with a duration of several years may change major parts of its team. Hence there is a major challenge for the organization to secure that knowledge is created, utilized and stored. To utilize knowledge capture which has already been undertaken is key to avoid unnecessary re-work related to creating the same knowledge several times. It is therefore a need for a documentation system and format which supports engineers to utilize already gained knowledge. The aspects of documentation and formats of documentation are further discussed in section 5.3. A documentation system should facilitate a learning-first culture. Indications from both literature and interviews with co-workers at Scania point out the availability of the information as an important feature. Further, visual and simple communication is supported by principles of lean. Thus, development of a documentation system should be undertaken, with learnings and already captured knowledge stored in an available manner.

5.1.4 Sense of ownership & motivation from rapid learning cycles

As indicated by the CE, the ways of working within C1 part 2 have improved the sense of ownership as well as the motivation within the calculation department. The design reviews, carried out more frequently than what is usually practiced within chassis development at Scania, as well as the ability to affect designs in early conceptual phases has a positive impact on these psycho-social aspects.

During the interview with the TE the impact of the ways of working within C1 part 2 was discussed. The TE indicated that increasing the responsibility of each function involved would be a more effective way of working. Currently, the design departments have responsibility for all properties, and cross functions are involved as support within certain areas. The TE believed that if an increased property responsibility was delegated to functions involved in a project, a better dialogue between the groups will be achieved and the quality of the decisions would increase. This aligns with the discussion by Bergman and Klefsjö (2010), who state that, in order to make co-workers committed to their job and thereby receive a higher quality of the final product, it is important to delegate responsibilities and allow them to experience professional pride. As mentioned by the CE, the calculation department being involved earlier in concept development and working more closely with the design engineers increased the motivation and sense of ownership of the products.

Schön (2016) stated that, at Ericsson 3G, co-workers work closer to the end product due to more frequent integrations of new features and improvements, as well as reception of feedback. The increased motivation among the co-workers might be directly derived from an increased sense of responsibility and professional pride when it is evident that the own efforts directly affect the end product.

There is a similarity between the ways of working at Ericsson 3G and within C1 part 2 in the sense of a rapid feedback and a more evident relation between the end product and the own efforts. The rapid cycles where improvements and new features are integrated with the end product result in feedback which is directly related to the end customers´ experiences. Hence, there should be a strong correlation between these ways of working and the sense of motivation and ownership of the products.

A perspective of the decision of top management at Ericsson 3G to dedicate 30% of the time to learning and innovation is the confidence shown to the co-workers. They do not need to ask for permission to take part in relevant self-development learning or innovation activities. Considering point of views from Rubenowitz (2004), this is relevant in the sense of management having a positive attitude to their subordinates. This is important in order to achieve a good psycho-social working environment. Also, according to Rubenowitz (2004) it is important to have an optimal work load. When planning for 30% learning and innovation, these activities will be a part of the total work load. Hence to actively plan for learning increases the potential to achieve an optimal workload, thus also a good psycho-social working environment.

5.1.5 Duration of rapid learning cycles

The alignment between the theoretical view of RLC and the ways of working in C1 part 2 indicate the relation between RLC and the sense of ownership and motivation. The cycle between design reviews in C1 part 2 is nine weeks long. Radeka (2011) suggests between two and eight weeks. Assuming that hardware development brings an inherent optimal RLC time span longer than for software development, a cycle of nine weeks is short enough to demonstrate the advantages of RLC. However, even shorter development cycles and simple experiments within hardware development should be advantageous. Study visits at Ericsson, where sprints of three weeks are used, imply the usefulness of learning cycles shorter than eight weeks. At Ericsson, these sprints are integrated within both hardware and software development.

5.2 Daily Management and Digital Visual Planning

DM is a way of informing about the daily work and to highlight problems in order to receive feed-back and support from the rest of the team. It was also identified as an opportunity to coordinate and synchronize tasks among team members. These aspects were in turn considered as some of the key factors to successfully meet deadlines, and to ensure functionality of a product system. Thus they also support fulfilling requirements at certain milestones in the development process.

DM meetings and a VP board was already implemented and used at RTLR. However, when analyzing the ways of working, several improvement areas were identified.

5.2.1 Planning at RTLR

One drawback with the current planning is the location of the planning board and the layout of the room. Since the board was located in a bookable room the accessibility to the planning was very limited. The room was occupied during large parts of the day. The furniture in the room also created limitations. One of the key factors for an efficient meeting is to keep it short and instead frequent (Mascitelli, 2011; Lindlöf & Söderberg, 2011). Removing the furniture might support shorter and more active meetings, since team members can move freely in the room and the meetings can be conducted standing-up.

The content of the personal planning was rarely discussed during DM meetings at RTLR. Instead, team members briefly presented their planning status. Hence the planning board was rarely up-to-date and old activities were not re-planned or removed. This might be caused by unclear instructions of what to discuss during the meeting, which was an aspect that was brought up during the group discussion described in section 3.5.4. It was also noticed that it was not possible to read the content of the sticky notes during the meetings. In addition the degree of detail varies between the notes and thus the work load for each team member was difficult to determine. According to the working procedure described by Mascitelli (2011), see section 2.5, it seems to be important to share the content of the personal planning with the rest of the team. This theory was also supported by Stenholm (2016) who stated that for homogeneous groups this could contribute to further understanding of each other's work.

5.2.2 Digital visual planning

Some of the issues mentioned above might be addressed using digital visual tools. At RTLS, where a DVP tool is utilized, the content of the personal planning was visible for all meeting participants. Tasks became clear and because of the digitalization team members could see the planning independently of geographical location. Hence, such a solution would probably not only support transparency of the planning, but it also solves the problem related to limited room access, which is an issue at RTLR. The digitalization also provides a more accurate estimation of each team member's workload and it is thereby easier to distribute the workload across the team. Further, the DVP tool allowed everyone to see whether tasks were initiated or not. When tasks were finalized they were deleted from the DVP board. This feature adds to the transparency and gives the rest of the team an indication of when tasks are expected to be finished. Also, barriers towards adding activities to the personal planning board are probably lowered when planning is done directly from the personal computer. Thus DVP should support more accurate and up-to-date planning than analog planning boards.

However, even though DVP tools have many benefits it is important to keep them as simple as the sticky-note-system. Otherwise the tool might be too overwhelming (Lindlöf & Söderberg, 2011). The tool used at RTLS was simple, clear, and easy to use. It seemed to only include the most vital functions and team members simply registered new tasks and estimated the time. Despite these positive aspects with the tool, several improvement areas remains. The visualization is one aspect where potential for further improvements exist. The current design only made it possible to view one co-worker´s planning at the time. Further, only one week at the time could be visualized, which made it hard to identify deadlines for tasks and therefore which tasks to prioritize. According to Stenholm (2016) the digital solution should solve the same issues as analog VP tools before implementing additional functions. Hence DVP at RTLR should preferably provide the same functions as the current planning board. More specifically, it should provide the possibility to extract the same data as from the analog VP tool. This also aligns with one of the LPD principles by Morgan and Liker (2006), who states that organizations should adapt technologies to fit the people and processes, not vice versa. However this might be possible with both the tool used at RTLS and with Yolean.

There is an internal drive to implementing a DVP tool for DM at RTLR, and due to the advantages such a tool might provide critical aspects should be considered. As previously mentioned, a DVP tool should at least provide the same functionality as the analog tool, and additional functions should be added due to the need of the team. Adding of functions needs to be established through collaboration within the team, for instance through discussions of workshops.

In order to correspond to the functionality of the current analog VP planning board, a DVP tool for RTLR should preferably provide a visualization reminiscent of an analog VP board. Such a tool should thus allow visualization of all team members´ personal planning. The estimated planned time for each week should be visible in order to determine if tasks need to be distributed across the team. Based on feedback from the evaluation meeting at RTLS, see section 4.3.2, it might also be favorable to visualize how many hours of the week that remain when marking tasks as completed. Such functionality would increase the ability to gather an overview of the week. Tasks should also be easy to change if, for instance, a previous task is delayed or if a task needs to be assigned to other team members. An issue identified at RTLS was that the DVP tool might have a start-up time, compared to an analog planning board which is ready to be used at all times. This aspect should be considered when managing DM meetings, in order to avoid waiting time when opening the DVP tool.

5.2.3 Digital visual planning with Yolean

During the interview with Stenholm (2016), Yolean was demonstrated. The software replicates a physical planning board, which allows for changes in planning simultaneously without delays despite working from different sites. Further, the virtual planning board made viewing of the planning with varying resolution possible, in order to visualize both long term and short term planning.

Even though the digital planning board in Yolean is visual, all activities (the virtual “sticky notes”) are of the same size independently of the estimated work that they represent, with an indication in the lower right corner representing the time. The digital planning board in Yolean is visualized in Figure 5.2-1. The software does not provide a visualization of how many hours have been assigned to each team member, which is automatically generated in the software utilized for DM meetings at RTLS. Yolean lacks the functionality to support real-time estimations of the workload across the team. This functionality is a vital difference compared to an analog planning, which is one of the strengths with the software utilized at RTLS, according to the thesis project group.

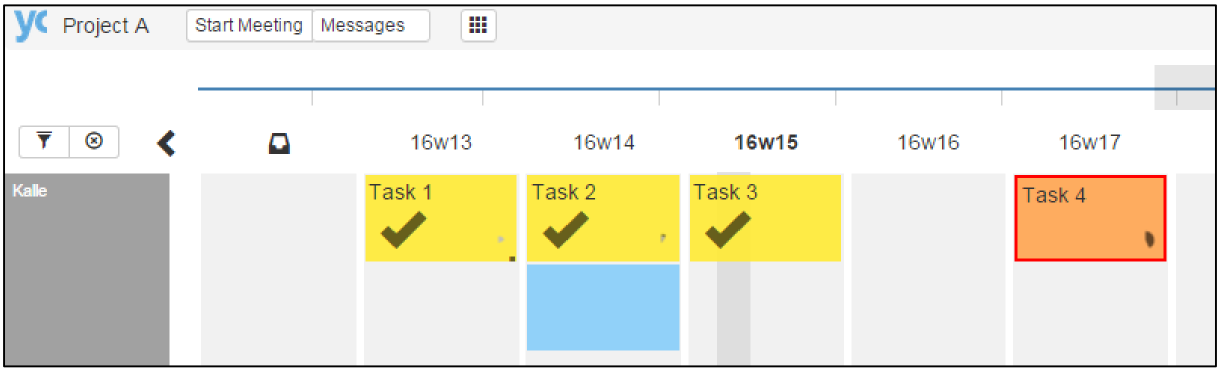


Figure 5.2-1 - A screen shot from Yolean. The completed tasks, task 1 to 3, are marked as completed. The estimated time for the task is visualized in the lower right corner in each box.

According to Stenholm (2016) digital planning boards in Yolean can be modified and functions can be added. However, procedures for modifying the software seem to be complicated, hence the ability for customers themselves to adapt the tool is limited. The DVP tool utilized at RTLS, on the other hand, is developed by co-workers at Scania and can therefore be modified by individual team members.

If implementing a DVP tool at RTLR, the ability to rapidly customize the tool is highly relevant. When finding an optimal set of functions which fulfill all specific needs, the team must be able to adjust the tool itself. Opinions about needed functions are gathered through discussions and workshops, and these ideas should be implemented for evaluation before the next DM meeting. Hence, the thesis project group argues that the tool utilized at RTLS should be the most suitable to use when implementing DVP at RTLR.

5.2.4 Daily management meetings

It is not possible to solve all problems by simply having a visual planning board, since the planning board itself can never give an exact representation of the reality (Catic, Stenholm, & Bergsjö, 2016). In order to gain all advantages of a planning board the meeting around it needs to be structured and efficient. The three questions from Mascitelli (2011), listed below, could provide a structure to the DM meetings. These questions guide an overview of what has been done and planning for the upcoming weeks.

1. What has been done since the previous meeting?
2. What needs to be done until next meeting?
3. What issues could possibly obstruct the team members from completing the tasks?

Answering these questions during DM meetings would support a visual and transparent planning. When answering these questions the resolution of the planning must be balanced towards the size of the team. If the planning is broken down into too small and specific pieces, the planning might be more disturbing than supporting. Thus the DM also risks to become more disturbing than supporting. Breaking down the planning into tasks of suitable length, as mentioned by Stenholm (2016), should generate improved coordination and synchronization of tasks. Thus the DM becomes more supporting than disturbing.

5.3 Documentation

An effective documentation seems to be one of the keys for organizational learning and thus a key for successful projects without major loop-backs. Furthermore, several of the team members at RTLR argued that the existing documentation guidelines were insufficient and that it was difficult to find relevant information. Thus it was often easier to redo the work, which is a significant waste.

A limitation in the thesis project regarding documentation was to not consider PDM systems utilized at Scania. During interviews with co-workers at Scania, the availability of information was highlighted as a crucial feature of a documentation system. Thus, the system used to store the document is probably more important than the documentation format when finding information of interest. However, investigations of the PDM system would expand the scope of the thesis project significantly, and could thereby not be included.

5.3.1 Different documentation formats

The possible formats identified during the thesis project were technical reports, handwritten notes, PowerPoints, and A3 reports. The first three are currently utilized at RTLR, which was identified through interviews and a case study. A3 reports was identified as an effective documentation method during the theoretical review. Handwritten notes do, due to obvious reasons, not support organizational learning, since possibilities to effectively share the notes are limited. However, handwritten notes could probably be a good complement for each co-worker´s own learning.

During the literature review it could also be concluded that using detailed reports as the major information carrier would not be appropriate. Due to large amounts of information, detailed reports are hard to digest. Also, findings from interviews indicate that detailed reports tend to be written after completion of projects. Thus, the probability for co-workers reading these reports is low, and they rather re-build the same knowledge again. This issue was also mentioned by Morgan and Liker (2006) as a major waste within PD. It could also be a problem that writing reports is considered as an obstacle from the author’s perspective and thus the content might lack quality. Hence documentation for communication purposes needs to be transparent, including only the most important facts. This approach would enable a more frequent reuse of knowledge since the knowledge recapture would probably take less time.

5.3.2 A3 reports and design guidelines

Most research within LPD supports the A3 format as the most successful documentation format for sharing knowledge. During the thesis project several A3 reports were created in order to evaluate the format and to understand its usefulness. A3 reports were also used by the thesis group to summarize books and articles during the theoretical review. The thesis group realized that the format had great potential for this purpose since it visualized the most essential facts. The format is very transparent and gives the reader a good overview of the content. Most of the time all details are not of interest. It could therefore be argued that A3 reports better supports the purpose of communication and recapturing of knowledge than detailed reports.

In order for the A3 report system to be efficient, with an increasing number of A3 reports, knowledge gained during the learning cycles could be extracted from the A3 reports and implemented in design guidelines. Update of the design guidelines might thereby be carried out regularly, which generates design guidelines that are up-to-date. Since the learning cycle concept supports exposing of knowledge gaps, compared with traditional development processes where knowledge is identified through mistakes, design guidelines will help avoiding pit-falls. Thus development of new, similar products, will consume less time since the level of detail and the relevance of the design guidelines will increase.

The relationship between time for knowledge recapture and the elapsed time since the knowledge creation is visualized in Figure 5.3-1. The model is based on a hypothesis derived during the thesis project and shows that with poor or inefficient documentation (the upper curve) the time for knowledge recapture will increase until it reaches a steady state when the knowledge is more or less forgotten. The lower curve shows the time for knowledge recapture using a more efficient documentation method, as for instance A3 reports. This curve reaches its steady state earlier but the time for knowledge reception is consistently lower. In between these curves, there is a curve representing the knowledge recapture using detailed reports.

It is believed that design guidelines are more robust towards employee turnover than detailed reports. It would be easier for new recruits to find, for instance, essential facts for design decisions and the essence from previous projects. The other alternative, to read a pile of detailed reports, would most likely be too overwhelming for new recruits. Observations made during the project also indicates that the employee turnover seems to be relatively high within chassis development at Scania. There is a significant fraction of junior engineers and it is common to change department or working assignments within the organization. This results in a significant loss of knowledge since the existing documentation system cannot replace the knowledge gained by experience.

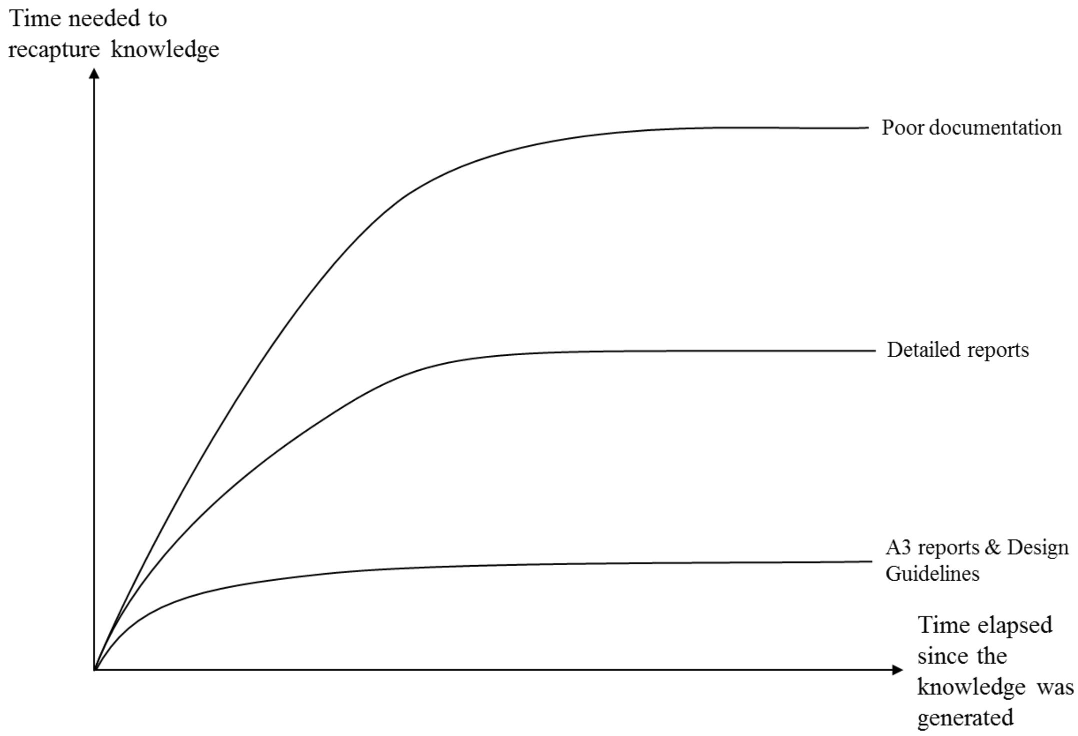


Figure 5.3-1 - The relation between time to recapture knowledge and the time since the knowledge was created as a function of different documentation and communication formats.

The most obvious drawback of the A3 format identified during the thesis project was also believed to be its most significant strength. Since it could only contain a limited amount of information, it is not possible to document all details. However the limited space available requires that the author of the A3 report has to carefully select what information to include. Thus, only the most important information is documented. Thus, A3 reports facilitate to rapidly identify the most important information, without the need of digging into unnecessary details. The selection of which information that should be included can however be difficult to make, since the relevance of certain information might not currently be apparent but might increase for future development.

There is, in addition to the content of the A3 report, meta data occupying valuable space which does not contribute to the content of the report. However, this is necessary for the traceability of the report. In order to select which information to include in an A3 report, it might be useful to utilize standardized templates. A standardization is also recommended by Holmdahl (2010) in order for the reader to more rapidly identify the information of interest. A standardized template limits the freedom for the author, and it might therefore be useful to consider a template that is standardized but still allows adjustments to fit specific needs. Furthermore, if RLC will be integrated at RTLR, A3 reports could be continuously written during the learning cycles. If the A3 reports are standardized and if these documents are continuously updated during learning cycles, the barrier of documenting compared to writing a detailed report after a project might be lowered.

In order to fully gain all advantages from A3 reports, they should be visual including descriptive figures and graphs which enable the readers to rapidly grasp the information (Holmdahl, 2010). This visualization could also be achieved in detailed reports and on PowerPoint slides. The PowerPoint format has already been used at RTLR to communicate, for instance, results and design solutions. However both PowerPoint files and detailed reports lack the possibility to show all relevant information on one and the same page. Further, these formats lack an inherent space limitation and do therefore not prevent unnecessary information from being included.

For RTLR, A3 reports would probably be a useful tool for several applications. Currently no standardized documentation system is used. Thus there is a need to integrate a standardized documentation procedure at RTLR in order for everyone to know where and how to find necessary information. The procedure needs to be clear and specific, and needs to be seamlessly implemented in the daily work. Documentation could be carried out continuously during learning cycles.

The communication through PowerPoint, which is already utilized at RTLR, works well and could probably be a complement to A3 reports when describing ongoing work. It should be easy to get an overview of results and decisions when reviewing ongoing work. For this purpose the one side format with the essential facts is a promising alternative. New knowledge from A3 reports could be utilized to continuously update existing design guidelines. Thereby a system in which the design guidelines are always up-to-date could be developed. Utilizing RLC could increase the frequency of updating the design guidelines and thus their validity could be ensured. Thereby development lead times might be shortened.

5.4 Rapid Learning Cycles & the Development Process at Scania

In order to integrate new ways of working at RTLR, these should align with the current development process. The framework of RLC does not include obvious development activities or milestones. Instead it relies on a well-defined process, such as the one used at Scania.

The development process at Scania is the main guide for development efforts at RTLR. When studying the process in detail all activities and milestones serve a purpose. Also the arrangement and sequence of activities and milestones support development of high quality products. However, all product development teams rarely follow the same sequence of predefined activities, since development of different products and services differ. Thus the sequence of the predefined activities may be inappropriate for specific product development teams.

If the development process instead is used as a guide and RLC are integrated to achieve a cadence in development, the development work should become more robust toward changes. Continuous reviews, the RLC, will highlight risks and changes along projects. This approach could be paralleled with orienteering, where the design process represents a map, see Figure 5.4-1. The map describes how the development will proceed and which control points (milestones) should be passed. It also indicates which obstacles and pit-falls to manage. However the map is a simplified representation of the reality. Therefore, it is important to continuously compare the map (development process map) with the real terrain (the real situation) in order to avoid obstacles (risks and knowledge gaps) which might cause delays and major detours (loop-backs).

The best way to run a project is not always the shortest way; the runner should not always follow the straight lines, visualized in Figure 5.4-1. There might be obstacles, such as lakes, mountains, or dense forest which slow down or forces the runner to take detours. A corresponding phenomenon within PD might be engineers who immediately start designing when goals of a new project are announced. This might lead to major loop-backs due to insufficient knowledge about which direction to go and which knowledge gaps to close in order to develop a successful product.

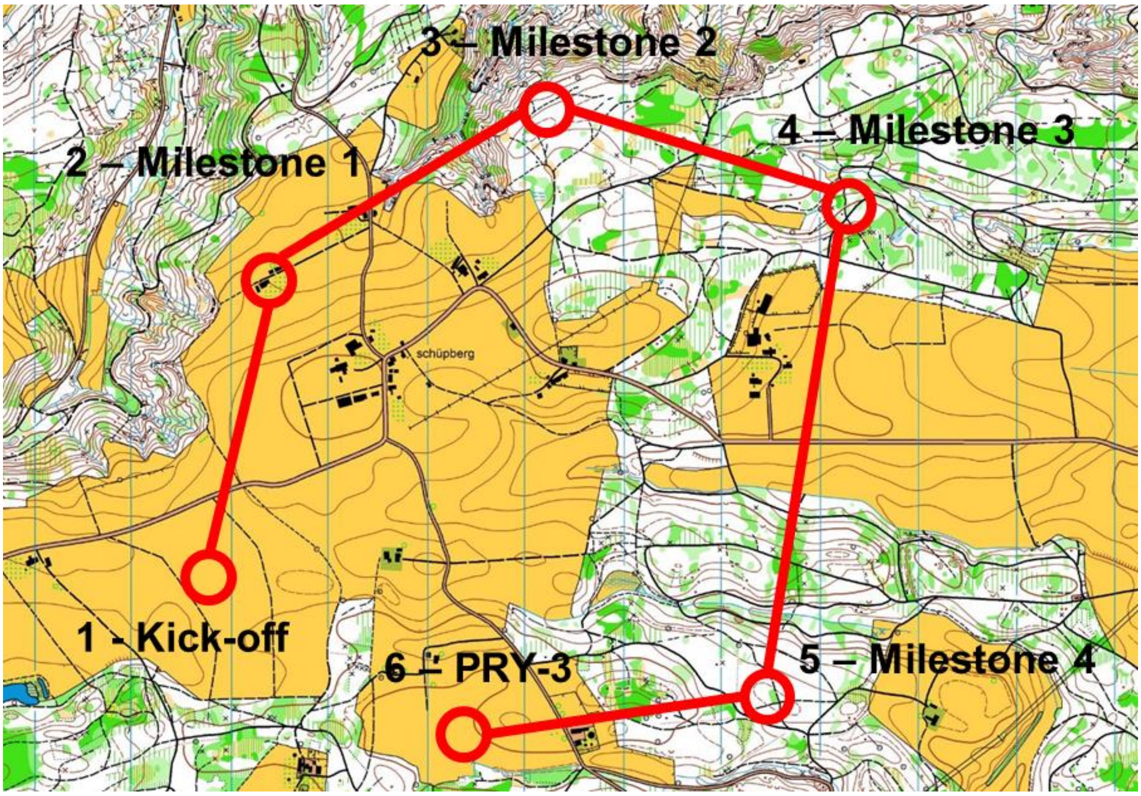


Figure 5.4-1 - Orienteering maps provide the runner with rough representations of reality. The milestones which have to be passed before reaching the goals correspond to milestones in a development process which have to be passed in order to secure the quality of the end product.

Better education and introduction might support engineers in sufficiently understanding the development process, and they will thereby be able to make better decisions. In addition, the continuous learning from RLC will support a better understanding of how the development process relates to reality. Thus, the capability of predicting difficulties in development will increase.

A well-functioning DM and a continuously updated VP board would probably contribute to an updated view of the development as well as possible obstacles and risks. If activities and milestones from the development process are related to the personal VP during DM meetings, the relation between own efforts and the development process might become more obvious.

In addition to team specific activities, the development process includes general milestones common to all across the R&D organization at Scania. Theses milestones provide a framework describing what should be achieved during different phases in development. RLC could contribute to dividing deliverables into manageable pieces, through frequent reviews of the current and the desired situation. Consequently, the quality of deliverables when approaching milestones will be ensured.

The design process should not be neglected. A possible drawback with RLC is that risks and problems, out of scope relative to the original assignment, will be identified. This might continuously broaden the scope of development projects. It is therefore critical to highlight the development process, the original goals of development efforts, and to prioritize tasks which drive development projects forward.

5.5 Methods & Limitations

In this section methods and limitations used to complete the thesis project are discussed and critically reviewed. Advantages and disadvantages are highlighted and also how limitations have affected the execution and the output of the thesis project.

Results from this thesis project implies suitability and usefulness of RLC and DM. These theories and practices could also have been of great use for completing this thesis project, in order to continuously reflect on and improve the methods used. However, since the results were not known until late phases in the thesis project and because of the time limitation, there were no possibilities to try and evaluate RLC and DM.

Even though DM was not used for the daily planning within the thesis group, the initially established plan was followed without any major deviations during the thesis project. This might depend on the short term plans which were established updated and rescheduled every second week, but also since the thesis project group only consisted of two people.

5.5.1 Limitations

The main limitation in the thesis was the time frame. There were no clear deadlines from Chalmers or Scania, but the thesis project group early specified desired time limits, internal milestones, and deadlines.

In early phases of the thesis project discrepancies of expectations between Chalmers and Scania were identified. Chalmers required a certain degree of academic depth while Scania put more emphasis on tangible results and applicable recommendations. This initially seemed to require a trade-off in order to satisfy both parties. However, as the project proceeded the gained results appeared to provide both academic and practical qualities. The results from data collection proved to be aligned with relevant theory. This enabled development of practical recommendations which to a large extent could be based on interpretations of previous research.

Investigations of the PDM system used at Scania were excluded. The PDM system impacts the sharing and finding of knowledge. Thereby this subject could have been relevant in order to improve learning and quality of deliveries at RTLR. However, this would also have broadened the scope and it would have been difficult to manage within the specified timeframe.

5.5.2 Theoretical review

The major parts of the theoretical review were carried out in the early phases of the thesis project. The reason was to gain understanding about relevant areas, in order to identify deviations between the actual working procedures at Scania and suggestions from theory. This approach of building an initial knowledge base early in the thesis project was useful for subsequent activities. It provided the thesis project group with a mindset of the principles within LPD. However, since LPD was in focus at this stage comparable areas of knowledge, which could have provided different useful facts and insights, might have been neglected. The choice of LPD as a major focus area was based on the principles in the Scania house, see section 1.2.1, which are aligning with principles of LPD. Thus the barrier towards implementing recommendations related to these principles are most likely lower than implementing principles related to other research areas.

5.5.3 Data collection

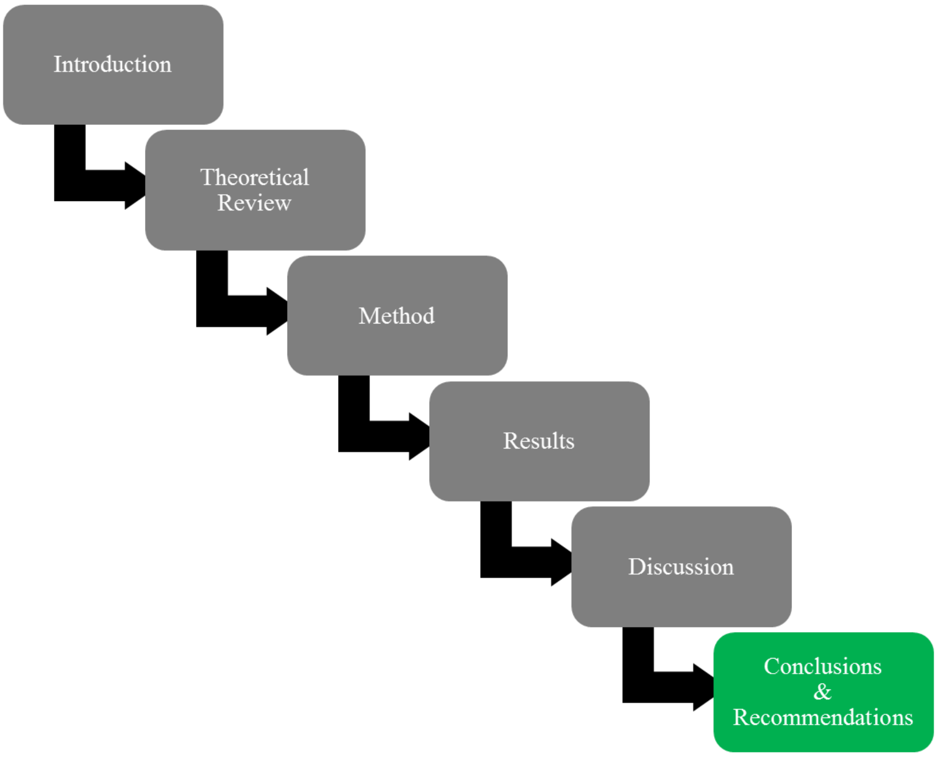
Several different views upon working procedures at Scania, and significantly working procedures at RTLR, were collected. Hence interviews with several co-workers related to C1 were conducted. In addition, cross functions and supporting functions were interviewed in order to contextualize the working procedures. However, few interviews with co-workers at RTLR who were not involved in C1 were carried out. Thus, the identified ways of working might not be representable for the entire RTLR. This possible issue was mitigated to a certain extent through regular meetings with RTLR where findings were discussed in order for the thesis project group to correctly interpret results from the data collection. Hence, a future area of research might be a comprehensive comparative study between working procedures within different teams at RTLR.

5.5.4 Presentations and discussions

Presentations were useful in order to collect opinions and feedback on the thesis project, in order to ensure that findings were supported by RTLR. This also supported co-workers at RTLR to reflect upon their way of working. Furthermore, the presentations divided the information into manageable sizes in order for the co-workers at RTLR to accept and understand underlying reasons for the final conclusions and recommendations. Thus, the final presentations and workshops did not have to address details of the supporting theories. Instead they focused on how to implement recommendations and how these changes could support a better quality at milestones in the development process.

6 Conclusions and Recommendations

This section includes conclusions and recommendations for how to proceed with RLC, A3 reports, and DM, at RTLR. These recommendations should guide the integration of new ways of working at RTLR as well as help identify areas in which additional research efforts might be conducted. The conclusions and recommendations for RTLR include utilization of RLC, A3 reports and a DM procedure with more focus on transparency of the personal planning. Also, recommendations on possible areas of future research and improvements are given.



6.1 Structure for Rapid Learning Cycles

RLC have been identified as a key to increase the quality of deliveries at PRY-3 at RTLR. Through building the right knowledge early, sets of alternative solutions could be decreased based on facts rather than gut feeling. Cross functional learning events facilitate frequent feedback on development progress, and thus eliminate waste related to working with non-promising solution alternatives. Hence, RLC should increase the quality of deliveries to milestones in the development process.

RLC events guide what activities to conduct during the learning cycles. The structure of these events should be tailored to the specific application, such as team, project, product complexity, and so forth. The main purpose of the RLC events, independently of contextual setting, is to identify risks, problems, and knowledge gaps, in order to establish action plans for each of them.

6.1.1 The initial kick-off event

All cross functions which might contribute to or pay stake in a project should be invited to the kick-off event. The project scope is presented and reviewed, the current situation is discussed, and an action plan for subsequent continuous learning events should be established. This initial event also supports distributing responsibilities among cross functions involved in a development project. A recommended structure of the kick-off event is described below.

1. The project definition and scope are presented.
2. Critical knowledge gaps and obstacles which have already been identified are presented.
3. Through group discussions conducted in a workshop-like manner, additional knowledge gaps and obstacles should be identified.
4. Collect and document knowledge gaps and obstacles which are identified.
5. Establish the frequency, time and place, which cross functions to involve, and the character of the continuous learning cycle events.
6. Establish how a meeting protocol should be distributed and managed during learning cycles.
7. Establish an action plan until the subsequent continuous learning event, described in section 6.1.2.

6.1.2 The rapid learning cycle events

When working according to RLC, reaching a common understanding of why RLC events are conducted is crucial. During the events the current situation should be presented, possible obstacles for reaching goals should be understood, and an action plan for how to reach the goals should be established. The events should be carried out with learning cycles of two to five weeks in between, at a predefined weekday and time in order to avoid unnecessary wasteful planning and administration. The desired frequency of the RLC events should however be established through iterations, in order to be adapted to the context. The thesis project group recommends RTLR to initiate learning cycles with more frequent meetings than first considered as suitable, and to decrease the frequency if needed. This approach supports identifying the most beneficial RLC frequency.

The thesis group has developed two conceptual examples of how RLC events might be conducted. The concepts are developed in order to minimize waste and to support co-workers, who usually do not prefer to speak up in front of the whole team, to raise their concerns and opinions. One concept is adapted to when the number of involved parties in development of a product system, and the number of product sub-systems, is limited. When to or not to apply this way of working should be determined by the complexity of the product system, which might not always be dependent on the number of involved components or sub-systems.

The second concept is adapted to when the number of involved parties is higher. The number of involved parties in a development project depends on the complexity of the product and the number of sub-systems involved. Which structure to utilize within specific projects should be decided upon the needs and the size of the project team, in order to minimize waste related to co-workers listening to non-relevant presentations. The RLC event concepts are described in sections 6.1.2.1 and 6.1.2.2.

6.1.2.1 When the number of involved parties and product sub-systems is limited

During these events, involved parties from cross functions which pay stake to subjects brought up should participate. Experts within certain areas might also be invited if necessary. The conceptual structure of such an RLC event is described below.

1. Follow-up from the previous RLC event, according to the meeting protocol.
2. Responsible co-workers present the current state, issues, knowledge gaps, problems, and successes of their product systems.
3. After each presentation areas of interest are discussed. Opinions about the current state of product systems and possible risks are collected.
4. When impressions and opinions are gathered, deliveries until the next meeting are established and agreed upon.
5. The meeting protocol is updated and distributed to all invitees to allow for planning whether or not to participate during the next RLC event.

6.1.2.2 When the number of involved parties and product sub-systems is higher

When the number of parties from cross functions involved in development or paying stake of a product system increases, the number of participants during RLC events also increases. An event structure allowing for demand-driven discussions is hence needed. A learning event where sub-systems are showcased concurrently allows cross functions to discuss the sub-systems of their interest, rather than listening detailed presentations about all sub-systems.

1. Follow-up from the previous RLC event, according to the meeting protocol.
2. Current issues, knowledge gaps, problems, and successes related to development of a product system and its sub-systems are briefly introduced. This allows for co-workers to choose which product sub-systems to discuss and give feedback upon.
3. A small scale exhibition is conducted. The current state of sub-systems are showcased and descriptions of current issues, problems, knowledge gaps, and successes, are visualized. Cross functions and stakeholders choose which sub-system they should discuss and give feedback on, therefore sub-systems out of interest are neglected.
4. Impressions are collected during the exhibition using visualizations as mediating tools. For instance, writing of sticky notes and attaching them to visualizations of product sub-systems is an efficient way to collect feedback.
5. Deliverables for the next learning event are decided upon, based upon identified knowledge gaps, risks, and problems.
6. The meeting protocol is updated and distributed to all invitees, to allow for planning whether or not to participate in the next learning event.

6.1.3 Administration of rapid learning cycle events

A learning event protocol should be distributed to all invitees, preferably via e-mail, after each event. The protocol should describe what was managed during the last event, decisions which were taken, and what should be done until the subsequent event. This supports cross functions to assess whether and how to prepare for the next event, thus the protocol system is a demand-driven system. Through discussions with the thesis group´s supervisor, such protocol might be a spread-sheet which is continuously updated and a link to a protocol is attached to the e-mails distributed to all learning event invitees. Further, the protocol spreadsheet file might include links to A3 reports used for closing knowledge gaps, risk mitigation, and problem solving. Recommendations for A3 reports are described in section 6.2.

6.2 Using A3 Reports in Rapid Learning Cycles

The thesis group recommends utilizing A3 reports to carry information about knowledge gaps, risks, and problems, which are managed between the RLC events. The A3 reports should allow for utilizing the LAMDA methodology as a structured way of approaching issues. Deliverables to RLC events might be a fully or partially completed investigation of an issue, resulting in new knowledge. If relevant and applicable, these findings should contribute to updating design guidelines in order to update ways of working. The main purpose of A3 reports is thus not detailed documentation, but a format to share and visualize the most relevant information about issues managed during learning cycles.

A3 reports should be archived in a traceable manner, not in order to constitute detailed reports from investigations, but to summarize the solving procedures of issues managed during learning cycles. The A3 report should hence be the “magnifying glass” into more detailed descriptions of issues. The thesis group recommends that links to A3 reports should be attached to RLC event protocols. However, due to time and scope limitations, the thesis project group has not developed a proposal for such a documentation and administration system.

The A3 report should be utilized to manage knowledge gaps, risks, and problems, which are approached by development teams in order to proceed with development of product systems. Proposals of A3 reports for each purpose are visualized in Appendix F. The LAMDA cycle is used as a framework to approach any of these cases. When managing problems or knowledge gaps using LAMDA-based A3 reports, findings might be directly applicable to update existing design guidelines, or to manage risks using risk-mitigation A3 reports. Using the LAMDA framework in A3 reports support co-workers to know which questions to answer. Thus, such a framework should lower the barrier towards writing the reports. The standardization also generates a traceability of information, since an equivalent kind of information is included in all A3 reports of the same type.

6.3 Daily Management and Visual Planning

Theoretical review, interviews of co-workers at Scania and a researcher within the area of VP and DVP have been conducted. From the findings, the thesis group has developed recommendations for RTLR on how to conduct DM and how to approach an implementation of DVP.

During DM meetings, the planning should be transparent. Thus activities inserted into the personal planning by each co-worker should be briefly described to the rest of the team. Sticky notes on an analog planning board, or the corresponding representation of activities or deliveries in DVP, should be readable for all team members. Three main questions should be briefly answered by each team member during DM meetings.

1. What activities have I carried out and what deliveries have I managed since the last DM meeting?
2. What activities should I carry out and what deliveries should I manage until the next DM meeting?
3. What obstacles (risks, problems, and knowledge gaps), to complete my planned tasks, have been identified?

During observations, indications were identified that mainly the third questions was managed during DM at RTLR. By answering all three questions, the planning becomes more transparent and understandable for other co-workers. By reviewing which obstacles are currently identified in the personal planning, distribution of resources within the team can be done in order to efficiently manage these issues. Also, issues which are explained to the team might be common among other team members. Thus planning for managing these issues might be done efficiently.

For a future implementation of a DVP tool at RTLR, the thesis group has developed recommendations to approach these efforts. A main finding is that the focus should never be to integrate as many functions as possible. In order to achieve a smooth transition into using a DVP tool for DM, the tool should provide a similar set of functions as the current analog solution. When teams have familiarized themselves with the DVP tool, desired functions might be added or removed. However, teams should reach a consensus on which functions to add or remove through discussions where the specific needs of the team are identified.

6.4 Future Research

In order to achieve additional positive yields from integrating RLC at RTLR, further research and improvement efforts should be undertaken. The thesis group has identified key areas where further research and improvement efforts are recommended, listed below.

- The relation between utilization of A3 reports during RLC and ways of documenting and storing information. Preferably the relation to PDM systems and other systems currently used at Scania should be considered, in order to achieve a documentation system which supports reusing of knowledge.
- As a follow-up on this thesis project, measurements of the yields from integrating RLC, A3 reports and DVP should be carried out. For this, methods for measuring the yields should also be developed.
- The ways of communicating within projects might be a significant area of interest. To identify ways of communication, ways of making decisions, and ways of managing knowledge gaps, might support the improvement of managing projects within chassis development at Scania.
- Investigations whether re-arrangements and co-location of cross functions, such as calculation engineers and design engineers, are possible and which yields might be exploited. Since the frequent contacts between cross functions and design engineers at RTLR during C1 part 2 supported to an increased sense of ownership and motivation among the co-workers, co-location might also be beneficial in a similar manner.
- As addressed by the TE during the interview, an increased delegation of product property responsibilities across functions might be beneficial. Possibilities for re-distribution of responsibilities, and possible yields from such change, should be investigated.

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Appendix A

Table 2 - Long-term plan

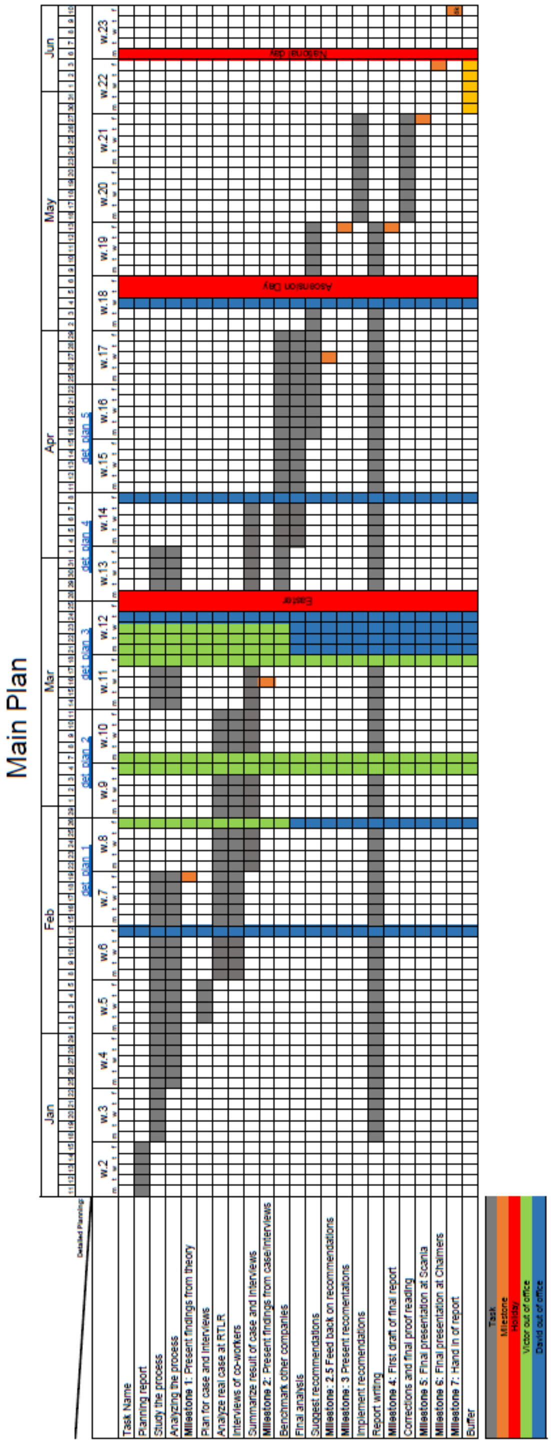
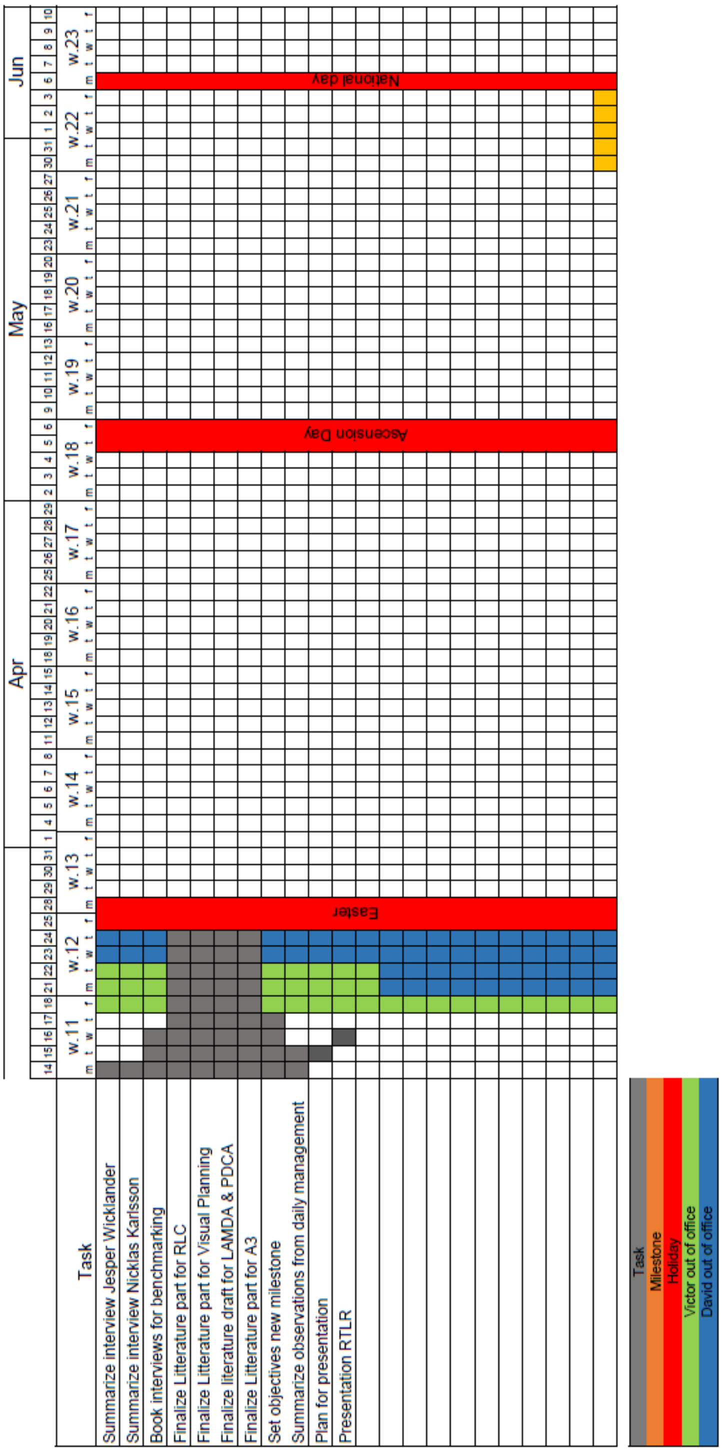


Table 3 – Detailed plan



Appendix B

Questions to the CE

1. For how long have you been at RTLC?
2. How long have you been at Scania, and any previous experiences?
3. What is your understanding and opinion of the C1 project?
    a. C1
    b. C1 part 2
    c. What is or has been the main issue(s) with the project, according to you?
4. What is and have been your role in the project?
5. How has the information and the results from your group and your calculations been handled by RTLR?
6. What has been the input for your calculations?
7. How does the C1 project group use your results?
    a. Are issues identified by you managed or ignored?
8. How do you manage recurring problems when you encounter them more than once?
    a. For instance the [redacted]?
9. How is information transferred between you and the project group?
    a. Sending reports?
    b. Discussions?
    c. One-way or two-way communication?
10. Differences in information flow C1 part 2 and for C1?
11. How are your recommendations managed by the project group?
12. Are there any differences between this project and other projects with respect to information flow?
    a. Any good examples?
    b. Any terrible examples?
13. How familiar are you with the R&D-process?
    a. The local calculation process?
    b. Does that process match the hardware design process?

Questions to the TE

1. Hur länge har du jobbat på RTRD?
2. Hur länge har du jobbat på Scania, och har du jobbat någon annan stans innan dess?
3. Vad är din uppfattning av C1?
    a. C1
    b. C1 part 2
    c. Vad har varit de största problemen i projektet?
4. Vad har varit och vad är din roll i projektet?
5. Hur har informationsflödet sett ut mellan dig och projektmedlemmar från RTLR?
    a. Provrapporter?
    b. Möten och diskussioner?
    c. envägs-, eller tvåvägskommunikation?
6. Är det någon skillnad i informationsflöde från C1 till C1 part 2?
    a. bättre eller sämre?
7. Hur hanteras provningsresultat av RTLR?
    a. hur hanteras rekommendationer?
    b. Hur hanteras oväntade problem i angränsande områden?
8. Hur hanterades [redacted] och utfallet på dem?
9. Hur insatt är du i R&D-processen?
    a. Testnings R&D-process?
    b. hur matchar testnings process hårdvarudesigns process?

Questions to the PM

1. Hur länge har du varit på Scania?
2. Hur insatt är du i R&D-processen?
    a. Hur förhåller du dig som projektledare till processen?
    b. Vilken roll spelar processen för dig i projektet?
3. Hur länge har du varit involverad i [redacted]-projektet?
4. Vad är din uppfattning av C1?
    a. C1?
    b. C1 part 2
    c. huvudsakliga issues?
5. Vad är din operativa roll i projektet?
6. Hur ser beslutsvägar ut i projektet när man passerar milstolpar i projektet?
    a. Hur mycket fakta presenteras och hur mycket beslutas på magkänsla?
    b. Hur läggs fakta fram till dig?
    c. Hur mycket påverkan har tidspress?
7. Hur ser ditt samarbete ut med RTLR?
    a. Hur sker kommunikation?
    b. Envägs-, eller tvåvägskommunikation?
8. När man stöter på problem, hur hanteras detta?
9. Hur hanterades problemen med produkten i C1?
    a. När upptäcktes problemen med produkten i C1?
    b. vilka åtgärder togs?
10. Hur tas beslut om carry-over av artiklar mellan projekt?
11. Hur hanteras problem med artiklar där beslut har tagits om carry-over?
    a. Hur lyfts problem som uppstår i testning eller simulering?
12. Hur hanteras kunskap från tidigare projekt?
    a. Hur dokumenteras kunskap från projektet

Questions to the CDM

Vilken är din uppfattning av C1 part 2?

- Allmän uppfattning?
    - Positiva aspekter?
    - Negativa aspekter?
- Vad är din roll i förhållande till C1 part 2?

Hur ser du på framtiden på RTL?

- Din vision/förväntning?
- Hur ska vi arbeta i framtiden?
- Lyfta kunskapsluckor?
- Fokus på att bygga kunskap?
- Hur ska det genomföras?
- Hur ska resultatet mätas?
- Positiva följder?

Questions to the BMM

1. Vad är din uppgift gällande processen?
2. Övergripande om processen
    a. Varför togs den fram?
    b. Hur var den tänkt att användas?
    c. Hur togs den fram?
    d. Beskriv innehållet i de olika delarna av processen.
3. Om den togs fram med best practice, från var togs inspirationen för detta? Vilket case?
4. Hur bekant är du med LPD?
5. Finns det något i processen som supportar tänk från LPD?
    a. Set based
    b. Kunskapshantering
6. Hur är processen relaterad till Scaniahuset?
7. Inspiration från annat företag/annan bransch?
8. Hur ser du på PRY-3, vilken status har produkten då? D.v.s. hur färdig är den?
    a. Bakgrund till milstolpen (behov, förväntningar etc.)?
9. Beskriv F-gen, V-gen.

Appendix C

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?
2. Är processen ett stöd i ditt arbete?
    a. På vilket sätt?
3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
    a. Hur använder du tidigare kunskap?
    b. Hur dokumenteras kunskap som byggs upp nu?
4. Vad får du ut av daglig styrning?
    a. Får du ut det som du vill få ut?
    b. Vad är det huvudsakliga syftet med daglig styrning?
5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?
6. Hur väljer man koncept?
    a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
    b. När i processen väljer man eller eliminerar koncept?
    c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?
7. Hur tas beslut om höjande av status osv. i C1?
    a. Tidsplan eller fakta? (anpassa efter svar på 7:an)
8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
    a. varför (säker eller osäker)?
    b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

Appendix D

Interview with alias A

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?

Jag har fått introduktion i början. Tycker jag har tillräcklig koll på det hela.

Man behöver färska upp den då och då, så att man ser så att man inte jobbar utanför PD-processen.

2. Är processen ett stöd i ditt arbete?
   a. På vilket sätt?

Ja det är den. En trygghet man kan falla tillbaks på. Checka av så att man är i fas med det man ska göra och att man inte missar något. Blir mest som en checklista.

Använder som en checklista och planeringsverktyg.

3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
   a. Hur använder du tidigare kunskap?
   b. Hur dokumenteras kunskap som byggs upp nu?

Hade hand om [redacted] i [redacted] i [redacted].

Jag var inte med från första början. Men det fanns ju kunskap på gruppen från tidigare projekt, [redacted] och ännu längre bakåt. Pelle och Magnus har varit med och har hållit ihop det från början. Ja, vi har tittat tillbaks.

Om du har använt tidigare kunskap:

Bra fråga. Inte direkt kanske. Jag var med en liten del i EURO 6, det var lite senare i EURO 6 med annat läge. Kortare ledtider och man skulle bara slänga fram lösningar. Så nej, det gjorde jag nog inte.

Hur dokumenteras kunskap som byggs nu från projektet?

Bra fråga. Det är ju lite sånt som vi diskuterar nu i på förbättringsgrupper och sånt. Vi är bra på att dokumentera men har saker i lite olika system.

ECO:t är ju grundbäraren för allting. Men det är skillnad från konstruktör till konstruktör.

Man använder samma verktyg, men mängden är olika hur mycket man dokumenterar. Det är något vi diskuterar nu på gruppen, att ta fram ett dokument där vi lägger in all information från alla olika system. Det finns ett behov av att få all information samlad, så att man slipper göra detektivarbete varje gång man ska ta reda på någonting.

En bra dokumentation skulle vara kort och koncis, ett huvuddokument där allt finns samlat.

4. Vad får du ut av daglig styrning?
   a. Får du ut det som du vill få ut?
   b. Vad är det huvudsakliga syftet med daglig styrning?

Det är ju den dagliga styrningen man får ut. Man har chans att eskalera punkter som man behöver hjälp med. Det är nog huvudsyftet att man snabbt kan lyfta upp frågor. Och så får man också en inblick i andras arbete och man kan stötta varandra på plats. Också min egen planering. Får känsla av om jag är i fas eller ej.

Får ut allt jag behöver av daglig styrning.

Det bakomliggande syftet med DS är nog de punkter som jag har nämnt. Man ska ha koll på varandras delar och lyfta upp frågor och problem.

5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?

Det är väldigt varierande.

Man har någon konceptgenerering i början, säg att man har en 7-8 koncept. Sen går man ner på kanske 2-3.

6. Hur väljer man koncept?
    a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
    b. När i processen väljer man eller eliminerar koncept?
    c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?

När eliminerar man koncept i processen:

Har varit med i tre olika projekt, det har sett annorlunda ut från gång till gång.

[redacted] *som exempel. Där hade vi problem och så skulle vi ta fram en lösning till* [redacted]*. Det är ett bra exempel på när man inte ser en tydlig lösning från början, då får man ta till alla verktyg. Där körde vi ca 7-8 lösningar och försökte ta fram en matris med alla möjligt faktorer som skulle påverka utfall. Sen hade vi någon KG. Där fick folk tycka till och då fick vi gallra bort vissa. Mycket pris, hållf som styr och vi fick vikta om.*

Det var CAD-modeller, försökte räkna på dem också. Så att vi kunde genomföra GASen.

Det varierar jättemycket hur mycket man har hunnit genomarbeta koncept.

Fakta ligger till grund för beslut, i vissa fall också magkänsla också. Ibland ser man Ibland ser man tidigt att något inte fungerar, då är det ingen ide att satsa på det.

Specifikt om [redacted]*. Jag var med i* [redacted]*, och det har hänt mycket till* [redacted]*, i och med att vi höjer kraven ytterligare.*

Vi jobbar mycket närmare beräkning nu som är den stora skillnaden. Vi är även fler konstruktörer vilket gör att det blir svårare att synka. Men det funkar bra och vi takta igenom bra. Men det kan vara problem nu i början när man tar fram olika koncept som man vill testa med varandra. Det är en utmaning där.

I [redacted] *jobbar jag med* [redacted]*, så jag är i kontakt med 6-7 olika konstruktörer som är i kontakt med dessa. Så det kan bli lite komplicerat.*

Hur man valde koncept i [redacted]*:*

När jag kom in så hade vi ett grundkoncept som vi jobbade på. Vi stötte på problem i skakprov men vi jobbade vidare med detta konceptet, utvecklade vidare detta.

När han kom in: Vi hade ett koncept som vi började skaka, så hade vi ett antal prov där vi fick jobba med delarna. Det är ju en del grejer som vi har lärt oss av det, som har med lagkrav och sånt att göra också som vi försöker dokumentera nu.

Nu försöker vi se till så att vi kan ha gränssnitt, information och sånt för just [redacted].

7. Hur tas beslut om höjande av status osv. i C1?
    a. Tidsplan eller fakta? (anpassa efter svar på 7:an)

Det är ju projektet, där vi har milstolpar som säger vilken status vi ska ha. Har man tydliga avvikelser så får man lyfta upp det och se om man verkligen är mogen för en höjning.

Framför allt tidsplan som säger när.

Om man känner på sig att det inte funkar: det krävs en viss mognad när man ska upp i vissa faser, konceptet satt i första fasen. Det finns ju tydliga riktlinjer i vilken status man ska vara som ska spegla sig i ECO-, och artikelstatus. Men det är ju inte alltid vi är i fas, då får vi diskutera det på plats. Besluten kan variera ibland, om man väljer att höja statusen. Men det har vi blivit bättre på under projektets gång, vi är noggrannare med att inte lyfta upp någonting som inte är i fas.

Vi har blivit lite mer strikta på att följa processen nu. I vissa fall kan man ta avstamp från processen, då måste man ju lyfta upp beslutet.

Som med [redacted] *så var det en lösning som vi tog bort som inte lever kvar. I och med tiden så bestämde vi att vi skulle räkna hem det till* [redacted]*, det är ett exempel på där vi inte skakade då vi inte hade tillräckligt med provningstid. Beslutet togs genom att räkna hem det, vilket var ett avstamp från processen.*

8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
    a. varför (säker eller osäker)?
    b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

Det var i det skedet som vi såg att vi inte nådde till målen, och då får man lyfta att man inte har klarat kraven. Det blir ett avstamp från processen.

Man får lyfta at man inte klara målen, men man specificerar datum då man räknar med att klara målet. Det var då [redacted]*-arbetet började ta form.*

Då skriver man hur många skakvarv man klarar på det olika delarna osv.

Det uppdagades nog tidigare som man såg att vi inte kommer nå upp till målen. Jag tror att det är vid den tidpunkten man fastställer med en genomlysning om man klarar målen eller ej. Då tar man beslut om man ska gå vidare med projektet eller ej.

Generellt när man passerar milstolpar i R&D-processen: Jag tror att man är lite osäker vid leveranser vid milstolpar. Men det lyfts ju upp på gruppmöten osv så vi vet ju vad som ska uppnås. När informationen kommer ut och vi vet vad vi ska göra, så antingen så har man uppfyllt det eller inte. Det finns nog inte så mycket osäkerhet.

Interview with alias B

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?

För det jag gör nu så har det räckt, men jag tror att det är alltid bra att ha en övergripande helhet av processen för att lättare förstå sammanhanget. Tror man bör lägga mer krut på detta.

Har själv sökt fram det som jag kan. Jag tog ju över efter en annan kollega, överlappningen beror ju på vad man fokuserar på. Där skulle man kunna ha fördjupat sig.

2. Är processen ett stöd i ditt arbete?
   a. På vilket sätt?

I och med att jag inte har jobbat så mycket enligt de processer som finns, med genvägar osv. vi har ju inte följt processen till punkt och pricka. Vi hat inte haft tid eller kunskap till att följa processen.

3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
   a. Hur använder du tidigare kunskap?
   b. Hur dokumenteras kunskap som byggs upp nu?

Tanken var att mitt uppdrag skulle vara på de låga [redacted], sen så såg vi så många problemområden i [redacted]. Då startades upp en fokusgrupp framför allt mot [redacted] som jag var med och jobbad i. I och med det så fick vi släppa det långsiktiga målet med [redacted], och det blev mer att släcka de bränder som var där. Ett fokuserat hållf-relaterat område på [redacted]. Gällde att så fort som möjligt få fram prototyper till skakprov osv. Då tog man så många genvägar man kunde ta. Men det har ju hela tiden eskalerats genom andra kanaler som teknikmöten och konstruktionsgenomgångar osv. i den normala processen.

Från tidigare projekt så är jag dålig insatt i hur Scania gör detta. I normala fall så har man ju sådant som refererat bakåt. Tidigare dokumentationer av skakprov osv. och gamla beräkningar har ju funnits på gruppen som man har använt.

Jag har försökt att ta med så mycket som möjligt. Pelle som var med i stort sett utvecklingen hade jag tät kontakt med iom att jag skulle hålla ihop [redacted]. Där hade vi kunskap som vi skulle ärva in från [redacted] in i en [redacted]. Den information som vi hade kunde vi utnyttja men det fanns mycket information som vi inte hade som vi har fått dra fram själv.

Med de tuffare kraven där vi inte kommit i hamn än, då har vi haft mer resurser och kapacitet att landa projektet. Hade man gjort det tidigt så hade hälften så många kunnat jobbat fram en bättre prestation. Men det blev lite omvänt i resursfördelningen. Det som gjordes för tre år sen straffar sig nu om man inte kunde motivera att man behövde det här utrymmet och de resurserna.

Kunskap som byggs nu. För min del; det vi dokumenterar nu – en ganska intensiv utvecklingsperiod. Vi kör generationer på [redacted], avstämning var tredje vecka och generationssläpp var nionde vecka. Genomgång var tredje och konstruktionsgenomgång var nionde. Där får man en väldigt bra samlad bild av hur långt man har kommit. Sen beror det lite på hur djupt i varje komponent man är intresserad. Dessa genomgångar är lite mer på [redacted]. Jag håller ju på med hela [redacted]. Men för varje enskild komponent så får man gräva djupare i gamla beräkningar osv.

4. Vad får du ut av daglig styrning?
   a. Får du ut det som du vill få ut?
   b. Vad är det huvudsakliga syftet med daglig styrning?

Vad jag får ut: ganska bra att få koll på vad andra gör och hu belastningen ser ut i gruppen. Tycker personligen att man bryter ner det för mycket. På [redacted] så hade man daily team leadership. Någon form av pulsning kanske mån, ons, fre. Så har man längre planeringsövning, ca 8 v. en gång i veckan. Det är ju tidskrävande at håll ett sånt här schema igång (scania) och det är ganska tidskrävande, minst ½ h varje dag. För mig så har jag ganska bra koll på min egen planering men det är alltid bra att lyfta blicken och få koll på vad andra gör.

Huvudsakliga syftet: Att få fram eskaleringar, och även balansera belastning så att vissa inte går på knäna och andra inte har något att göra.

5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?

I det jag har hållit på med på [redacted] så hade vi ett grundkoncept, och så var det versioner av det. Det höll vi på med hela hösten, men kom inte framåt för att grundkonceptet inte höll visade det sig. Det konceptet var ju redan valt så att gå ifrån det utöver versionerna av det konceptet blir ett väldigt stort omtag i projektet. Man vill in i set sista slippa backa och göra ett sådant omtag, men det blev vi tvungna att göra. Vi försökte rädda det konceptet men det lyckades inte.

6. Hur väljer man koncept?
    a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
    b. När i processen väljer man eller eliminerar koncept?
    c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?

Vi väger in olika aspekter, mest hållf-relaterat och gjort olika koncept för att se hur det slår på systemet i helhet. I samband med detta så identifierades linjeringsproblem, vilket var en problematik som visade sig bli allt viktigare. I kombination med hållf så kunde vissa koncept sållas ut.

Det är en anledning till att vi har bytt koncept helt nu, för att kunna möta kraven. Egenskapsdriven utveckling.

Mestadels fakta och data. Men man har ju viss känsla också, man kanske vill utvärdera något ganska grovt, men man försöker alltid bottna i de koncept som man tar fram.

7. Hur tas beslut om höjande av status osv. i C1?
    a. Tidsplan eller fakta? (anpassa efter svar på 7:an)

I det här fallet mestadels beräkning innan vi gick vidare. Eftersom att det mest handlade om durability och hållf. Även toleranskedjeberäkningar för att nå krav på linjering osv. Sedan så kunde vi blanda in leverantör och höja status.

Vi höjde ingenting innan vi blev säkra. Eller inte helt säkra, men det bästa vi hade att gå på beräkningsmässigt. När vi hade detta så höjde vi. Vi visste att vi hade leverans, men sköt på den för att inte tumma på kvaliteten.

8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
    a. varför (säker eller osäker)?
    b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

Status [redacted] på grejerna. Allt var i princip i [redacted] när jag började här. Så PRY-3 för [redacted] gicks igenom innan jag började. De artiklarna vi tittade på hade ju redan serieverktyg beställda.

Den stora boven i dramat är nog att man inte hade fångat det dynamiska beteendet i beräkningar. På det underlaget man hade så var de nog tillräckligt för att gå igenom PRY-3, men det visade sig att det kanske var för mycket förenklingar i beräkningarna.

Nu kör vi 9-veckors-looparna. Så det är väldigt tight om man tittar på omtaget för [redacted]. Vet inte riktigt var PRY-3 ligger där.

Har inte varit med på någon direkt passering av milstolpe, någon sån genomlysning. Så har inte riktig tillräcklig koll där.

Största förväntan: höja andelen som följer processen. Man vill ju ta genvägar, men processen ska ju vara genvägen. Det vore det ultimata.

Interview with alias C

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?

Är väl insatt i snarlika processer, men inte ås insatt i Scania process. Har i huvudsak varit på västkusten men är van vid liknande grindar. Mycket [redacted]*. Men vet inte exakt var PRY-3 är. Vad det innebär borde jag läsa på. Hänger på lite när folk pratar om det här och snappar upp då. Varit mest på*[redacted]*, men även* [redacted]*,* [redacted] *och* [redacted]*. Gick ut skolan 96. Varit på Scania i dryga två år.*

Har mest sett processen i planeringsrummet på tavlan. Är inte jättemycket inne på [redacted]*, men går in när det behövs inför övningar osv. Är ganska fokuserad på konstruktion nu.*

I vissa uppdrag så har jag haft annat ansvar. Men här så får man mycket hjälp av objektledare när det är något.

Här eftersöker jag en mer långsiktig planering. Här är det mycket fokus på den kortsiktiga planeringen. Varje dag. Men det är sällan vi tittar på den långsiktiga planeringen. Jag är van vid att man jobbar mer med den långsiktiga planeringen och att man tar den kortsiktiga planeringen ute i kontorslandskapet. Erfarenheter från andra företag.

2. Är processen ett stöd i ditt arbete?
   a. På vilket sätt?

Det är ju den röda tråden för vad som ska ske och vilka leveranser som ska in. När man ska ha hårda verktyg, prototyper osv. Utan den så blir det svårt att leverera. Den står ju också för den långsiktiga planeringen. Utan den så blir det ju mer kortsiktigt arbete med "lappa och laga".

3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
   a. Hur använder du tidigare kunskap?
   b. Hur dokumenteras kunskap som byggs upp nu?

Jobbade från början med [redacted]*, i det andra teamet.*

Tror och förutsätter att man använde tidigare kunskap. Inte för min egen del, kanske på grund av att jag inte hade det utan var lite mer färsk. I början när jag hjälpte till i [redacted] *så hjälpte jag mycket till och omkonstruerade inte så mycket. För* [redacted] *så omkonstruerade jag en del. I* [redacted] *så avlastade jag mycket i teamet.*

Jobbade någon månad med [redacted]*, sedan* [redacted]*. Hoppade på* [redacted] *för ett år sedan drygt.*

Frågar mycket senioren. I början så var det bara jag och en konstruktör till och en senior. Sedan har teamet vuxit. Efter [redacted] *så har projektet öppnats upp lite för nya idéer. För* [redacted] *så körde man på det som redan var påbörjat.* [redacted]

Nu är det lite mer medellånga insatser.

Har inte varit med och skrivit någon vitbok från[redacted]*. Dels så har vi inte gått i* [redacted] *ännu. Vet inte om någon gör det riktigt. Sen så har jag bytt arbetsuppgifter precis, så det blir lite hoppigt. Började med struktur, sedan plast. Sen renodlade vi så att man hade ett ansvarsområde. Nu ska jag nog gå över till struktur igen.*

Jag kanske hade kunnat skriva vitbok för det året jag har varit på projektet. Seniora hade nog kunnat skriva ner mer med grundorsaker osv.

En utmaning med krav från marknad osv. Det är svårt att få till en optimerad konstruktion, men efter [redacted] *så kommer det nog bli mer optimering av produkten.*

Önskar att tidigare skriva en kravspec. Skulle hellre se att det fanns begränsningsytor att förhålla sig till. Vi har inte haft någon utrymmesmodell att jobba efter direkt. Har funnits för vissa delar informellt, men det skulle behövas uppdateras.

4. Vad får du ut av daglig styrning?
    a. Får du ut det som du vill få ut?
    b. Vad är det huvudsakliga syftet med daglig styrning?

Huvudsakligen lära sig vad de andra gör.

Det är inte så ofta jag lyfter saker, kanske en gång i veckan eller varannan vecka. Det mesta sker i landskapet utanför mötet, att man löser det dagliga där. Skulle hellre se en mer långsiktig daglig styrning. Kan bli lite väl tight att gå på fredag, åka tidigt och sen så är det samma möte igen på måndag morgon. Kan bli en aning tätt mellan möten då.

Tänker att man skulle hålla planering under arbetsåret ungefär. Fram till hårda verktyg, prototyper eller ej osv., vad behöver jag göra nu för att ha en leverans om någon månad. Det finns post-it-lappar men det är inte ofta man tittar på dem.

På [redacted] kör man gruppmöte en gång/vecka, där är det kanske en eller två som presenterar händelser. Bjuder in några som förbereder presentation av projekt. Inte alla presenterar. Kanske 1/3 som pratar. Lite längre perspektiv.

På [redacted] hade de några gånger i veckan, lite mer likt daglig styrning.

Jag får ut mest av att lyssna på objektledaren, där är det lite längre perspektiv. En del informellt, och ibland på tavlan bakom daglig styrning; långsiktsplanering. Den skulle jag vilja titta lite mer på den, än på den dagliga. Det dagliga har jag någorlunda koll på själv, med egna tanka för dagen. Den tavlan är svår att uppdatera eftersom att den ändrar sig ofta.

Post-it-lapparnas längd förirrar planeringen. Alla lappar ser ut som att varje uppgift tar en dag. Men så är inte fallet. Som om man vill att det ska se ut som att man har en dags planering. Men i vissa fall så har man 8 veckors konstruktion och 4 veckors ledtid på prototyp. Lapparna kan inte representera hur lång tid uppgifter tar.

5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?

Det är ganska olika. Just nu är jag tillbaka till konceptandet efter [redacted]. Har nu två lite olika koncept, en snarlik och en som har ändrats många gånger.

Är van vid att ta fram många koncept som jag gör en enkel beräkningsmodell på. Oftast många snabbt, och sen så utkristalliserar det sig vilka som funkar eller ej.

6. Hur väljer man koncept?
    a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
    b. När i processen väljer man eller eliminerar koncept?
    c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?

Brukar rita lite under veckan tills jag inte kommer på mer, och sparar det som är bäst. Brukar tänka på det på kvällar och helger.

Brukar tänka på vad jag har sett på andra fordon, på mässor osv. De flesta grejerna finns ju, även om man kommer på det själv så är det ofta någon som redan har ritat upp samma sak innan.

Är förvånad över att det inte är så mycket konkurrentbevakning här. Förr så hade man ju en tjänst som fotade all fordon och la ut på internet. Tillverkare kunde hyra deras tjänster. Men man slutade prenumerera, vilket är synd, för då kunde man gå in och kolla på foton på alla detaljer på specifika komponenter. De tog in bilar och både mätte och vägde komponenter.

Kör oftast många små enkla beräkningar, som jag kör med exakt samma parametrar och jämför. Alternativt tröghetsmoment eller egenfrekvens osv.. ibland kan jag också gå på att det ska ”kännas” bra. Om man vet att man exempelvis tittar på ett snitt så kan man veta att vissa snitt har bättre tröghetsmoment osv.

Ju fler är bättre, med många korta beräkningar. Det noggranna kan komma i slutet sen.

7. Hur tas beslut om höjande av status osv. i C1?
    a. Tidsplan eller fakta? (anpassa efter svar på 7:an)

En del diskuterande. Många är inblandade. Är osäker på vad som styr, om det är ledtid eller statusen på mognad. Ibland är grejer gröna, röda eller gula, de kan gå igenom även om det inte finns någon plan. Vet inte om det finns något bra svar på det. Kriterier ska ju vara uppfyllda. Och är de inte det så ska en plan ställas upp för att kunna återgå till att uppfylla kraven. På [redacted] *så finns det en hel del krav som inte är uppfyllda ännu. Men man har ju introducerat åtgärdsplaner för hållf osv.*

En kombination av tidsplan och fakta. Hållfen leder ju i regel till en åtgärd eller en avvikelse om den är mindre. Tidsplanen måste antingen följa projektet, eller stoppa projektet, eller brytas ut från projektet till en annan introduktion.

Initialt så försöker man lösa genom ökad arbetskraft. Men det är inte alltid som det går dubbelt så fort med dubbelt så många personer.

8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
    a. varför (säker eller osäker)?
    b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

Skakriggsresultat, beräkningar från det som vi hade jobbat vidare med från skakriggarna. Det var ju indikeringar på att man skulle höja prestandan men inte fullt ut. Det blev avvikelsegodkännande för produktionsstart. Fanns vetskap om att det skulle bli förbättringar från skakriggarna. Först så intensifierades arbetet mot [redacted]*, sedan så infördes introduktioner till övriga* [redacted].

Interview with alias D

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?

Är inte jätteinläst, men jag ska ju kunna den. Ska ju veta vad den består av och vad den handlar om. Däremot så kan jag erkänna att jag borde läsa mer om den, det kan ju aldrig skada. Man förlitar sig mycket på objektledarna och att de ska hålla reda på allt.

Har tillräcklig kunskap, tillräcklig introduktions.

Som konsult ([redacted]) på RTLR 2,5 år. Scania erfarenhet sedan innan, 12 år: verktygskonstruktion, produktionsberedning, bearbetningsdokument och ritningar osv.

2. Är processen ett stöd i ditt arbete?
    a. På vilket sätt?

Ett stöd genom att man blir påmind om vad man inte hinner med och vad man bör flagga. Den ger ju takten. Oftast när man har misslyckats ås har man hoppas över punkter i processen. Det är det som är bekymret att man inte stannar upp och ser över resursbehovet för att hinna ikapp. Det har man gjort inom RTLR med [redacted]. Däremot så såg jag att man inte riktigt har följt processen och därför fallerat.

Stöd i att jag vet när det är tänkt att jag ska vara klar med vissa saker; livslängdsindikeringar, ECO-mognadsgrad, material hemma osv. Utan processen så är det inte enkelt att hålla koll på detta.

Kom med i och med [redacted]. Varit med i [redacted] ca ett år.

3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
    a. Hur använder du tidigare kunskap?
    b. Hur dokumenteras kunskap som byggs upp nu?

Vet inte om man använde tidigare kunskap i [redacted].

Har ju erfarenheter sedan tidigare, men går inte runt och tänker på hur vi gör nu vs. Hur vi gjorde då. Följer mer den takten som processen ger.

Finns arbetssätt för att jobba med kunskap nu. T.ex. 5 varför, design guidelines. Dessa är framtagna för att säkerställa för att missar inte ska ske igen.

Trots det missar vi.

4. Vad får du ut av daglig styrning?
    a. Får du ut det som du vill få ut?
    b. Vad är det huvudsakliga syftet med daglig styrning?

A och O: jag får en snabb överblick över hur andra ligger till, ser på tavlan hur andra ligger till, chans att flagga och eskalera saker som vi har problem med eller som vi inte hinner med. Vi har oftast avdelningschefen där, TL och OB på plats.

Det jag saknar är en parallell puls där man (kanske inte pulsar) har en genomgång av teknik och konstruktioner också där man ser hur andra ligger till och vad andra jobbar med.

Huvudsakliga syftet är att omfördela resurser. Om jag har mycket att göra och har mycket lappar på tavlan så kan någon annan ta på sig att hjälpa till. Även informering och eskalering av issues. Men huvudsakligen omfördelning av resurser så att man hinner med allt.

5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?

Minst 3. Jag har mest jobbat med brandsläckning. Då är ju konstruktionen redan gjort. Oftast bara en shot, så man kör ett koncept man kör på. Men om jag skulle jobba i gulpil så minst tre.

6. Hur väljer man koncept?

a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
b. När i processen väljer man eller eliminerar koncept?
c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?

Det ger sig. Mest beräkningar som visar vad som är bäst.

När i processen: bra fråga, vet inte om det finns något bra svar där. Ibland så jobbar man med parallella spår, men det mäktar man inte med hela vägen. Jag tror att man börjar bestämma sig för ett visst koncept när man ha [redacted]*.*

Som det är nu så har vi flera [redacted]*, blir som att man har en grovgallring, sedan ytterligare en osv.*

7. Hur tas beslut om höjande av status osv. i C1?

Vi ska ju ha en visst status vid en viss tidpunkt. Beslutet tas ju när man skickar iväg till avdelningschef och den ska attestera detta. Ofta har den kort om tid på sig att göra detta.

Det finns alltid risker. Bra fråga, man kanske skulle ha lite mer diskussion inom gruppen innan man höjer till ex. [redacted]*. Kanske genom teknikmöte eller kanske på hela RTL för att kunna få ytterligare hjälp.*

a. Tidsplan eller fakta? (anpassa efter svar på 7:an)

Det jag har varit med om är att man presenterar någonting utifrån tekniken, ex. livslängdsökning, monterbarhet etc.. Tyvärr så har jag inte jobbat så tidigt i projekt så att man även tittar på ekonomi för att ta beslut därifrån utan mer inom brandsläckning. Då presenterar man detta själv på teknikmöte och tar beslut där om det ska föras in eller ej.

8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
   a. varför (säker eller osäker)?
   b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

Vet inte när PRY-3 var för [redacted]*.*

PRY-3 klarade vi inte, jobbade med [redacted] *då. Nu är det ju PRY-3 för* [redacted]*, där är jag med.*

Absolut mycket osäkerhet när vi passerar PRY-3. Just livslängdsindikeringen, man vet inte om man vill våga lita på grejerna. Det är ju simuleringar, och problem kan uppstå där. Ibland har man inte skakprov. Vi går oftast till PRY-3 utan att ha någon livslängdsindikering.

Det är det som händer nu: går sönder i skakriggen.

Tror man såg det ganska tidigt med [redacted]*.*

Interview with alias E

1. Har du tillräcklig kunskap om processen?

Jag känner mig rätt så bekväm i mitt dagliga arbete men jag vet inte om jag vet hur den ska va utan har lärt mig längs vägen under mina tre år på Scania. Där har jag snappat upp hur saker funkar men jag har säkert en hel del luckor egentligen. Sen tänker jag inte så mycket på processen under dagarna utan det går rätt så bra ändå.

   a. har du tillräcklig kunskap av processen, introduktion?

Nej, när jag började fick jag inte det, men sen införde de coin/PD 2.0 alltså någon förändring, då jobbade jag på RTG, då hade vi typ en halvdag med workshop för att gå igenom. Innan dess hade vi ingen introduktion så vet inte riktigt skillnaden. Tycker mer att det känns som att man har lärt sig med tiden, hur det brukar vara mer än att jag faktiskt har lärt mig hur det ska vara.

2. Tycker du att processen är ett stöd i ditt arbete?

Jag tycker att den är ett stöd, att man har de där olika milestonesen, det är skönt att ha lite olika hållpunkter att förhålla sig efter, annars känns det som om man kan hålla på med saker i evigheter. Man behöver tidpunkter att förhålla sig till. Det blir enklare att lägga upp sitt arbete. Alltså jag tycker det är ett stöd. Sen så är det ofta vi avviker från processen. Vi följer den inte till punkt och prickar. Men jag tycker ändå att den är ett stöd då man tänker igenom vad det är man inte gör då man avviker från processen. Jag tycker den är ett stöd men önskar att jag kunde följt den ännu mer än vad jag gjort med mina artiklar där vi har hoppat över många steg med ex. provning. Det hade känts mycket bättre att göra alla steg i processen. Men det är åtminstone bra att den finns, så man vet vad man borde ha gjort, man kan tänka att hade man gjort så har hade det nog blivit rätt.

3. I C1, användes tidigare kunskap från tidigare projekt då?

Jag har varit inblandad med [redacted]*. När jag började, då var vi redan i slutet av vad man tänkte då. Först när jag började, användes inte direkt, det man fick höra då var att det funkar nu. Sen började vi få massa utfall i skakriggen och då började jag läsa igenom gamla provrapporter från* [redacted] [redacted] *och kunde se att vi har sett de här problemen och borde ha väntat oss det. Det finns dokumenterat att det finns vissa svaga punkter. Då kunde jag ställa mig lite frågande till varför större förändringar inte påbörjats tidigare. Gammal dokumentation borde ha påvisat detta. ja redan i* [redacted] *går* [redacted] *sönder. Vi har ändrat vissa saker till* [redacted] *men vissa svaga punkter från* [redacted] *har vi inte ändrat på och dessa har vi fått utfall på. Jag vet fortfarande inte varför man tog beslutet och när det togs att de skulle vara carry over. Och när vi väl ändrade så kunde vi bara ändra lite grann. Jag tycker att vi var dåliga på det, att ta tillvara på gammal kunskap i början av* [redacted] *men det var innan jag började, så jag vet inte varför det blev så, det fanns säker skäl till besluten vad som skulle vara carry over men jag vet inte varför. Säkert ekonomiska skäl, men nu när man kollar igenom det borde man ha sett det tidigare.*

   a. Hur använder du tidigare kunskap?

Tja, när jag var ny på gruppen, kollade jag igenom gamla rapporter, beräkningar och skakprov. Sen var man ganska låst, det var för sent för att ändra något, det var mer bara att man kunde konstatera att det var inte så konstigt att det hände. Jag försökte med att sätta mig in i vad som har hänt förut för att inte upprepa samma fel.

   b. hur dokumenteras kunskap nu?

Av oss på RTLR, så vet jag…., eller så har vi ingen…, eller jag gör ju inte…, om man jämför med RTLC så skriver de skakprovsrapporter, men vi har väl inte haft något sånt sätt att vi dokumenterar med rapporter. Men jag har ju mina egna, när jag gasar t.ex. så samlar jag lite beräkningsresultat men det är ju bara för min egen skull, inte att jag sparar till någon annan. I FRAS, där rapporteras ju *problem in och vi skriver in information om hur vi löser problemen, det är ju ett sätt. Jag vet inte hur mycket den informationen som man svarar på hur mycket någon annan i framtiden kollar på den. Så det skulle ju kunna tänkas göras bättre. Sen Nicklas är ju väldigt bra på att dokumentera så han kanske gör det med* [redacted] *men från* [redacted] *har väl inte vi själva dokumenterat så jätte mycket. Lessons learned ska vi ju skriva tror jag men…, eller vi har ju våra design guidlines där vi ska föra in saker. Inte så jättesystematiskt att vi gör det eller jag har inte gjort det. men det är väl dom fastanställda, dom har ju förbättringsgruppmöten och där tror jag att de uppdaterar dem kontinuerligt. Jag har inte varit inblandad.*

4. Daglig styrning, vad får du ut av DS?

Man har ju en chans att själv eskalera om man har problem, det är ju bra tycker jag. [redacted] *är ju upptagen mycket så det blir ju en chans att om man behöver stöd högre upp så han väldigt bra med att hjälpa till med såna saker om han får höra dem och det får han ju på DS. Sen så hänger man ju med lite i vad som händer i vad de andra gör, det är ju bra. Men kanske, eftersom vi är så stort team att det kanske är lite tidsödande men det är bra ändå och det tvingar en själv att planera vilket jag tycker är bra, att sätt upp lappar o så fast jag tror att många bara tycker det är jobbigt.*

   a. Får du allt du vill, något du saknar?

Jag tycker att vi har ändrat på det ganska mycket, vad vi tar upp. Förut hade vi en period där vi alltid gick igenom fras och en dag i veckan då vi gick igenom olika deadlines för den veckan och kommande veckor. Det tycker jag var bra men det gör vi inte längre. Men jag tror att jag får ut det jag vill. Det är ju också bra att vi ändrar agendan efter behov, ex. inför PRY hade vi mer fokus på FRAS.

   b. Huvudsyfte DS?

Jag tänker att det är för att stämma av att allas arbete flyter på och att vi inte stöter på problem och att vi i så fall kan eskalera det.

5. Koncept hur många?

Mycket som vi gör är ju inte helt nya grejer utan vi förbättrar något som det har varit problem med, så till [redacted] *var det ju egentligen bara en grej som jag gjort från början. Där var det ju så tidspressat så där hann jag bara med en ide och så fick vi köra på den för den funkade i beräkningarna. Så där var det ju bara ett koncept. Sen har jag ju ritat om fästet i sig många gånger men det är ju egentligen samma koncept. Hade man haft mer tid hade man velat prova mer skilda grejer. Här hade jag en ide som verkade ha potential, så vi jobbade vidare med den till den funkade. Nu i* [redacted] *har vi drivit mer parallella spår. Jonas gjorde ett och jag gjorde ett. Där hade* [redacted] *gjort ett liknade* [redacted] *för framaxeln och då testade jag att prova hans koncept för att se om det funkade. Och det verkade funka. Men jag fick göra många iterationer.*

6. Hur brukar man välja koncept?

Nu i [redacted] *har vi bokat in KG med olika berörda personer som har fått ge sin feedback och sen har vi valt utifrån det.*

vad är den feedbacken baserad på?

Det beror på lite vilka man bjuder in, vi brukar få med produktion, montering, kostnad, vikt. Produktion är ju en viktig faktor ifall vi inte redan hunnit räkna eller skaka brukar vi rådgöra med RTLC och RTRD, de har ofta bra feedback om hur de tror att det kommer hålla. RTMX som gör toleransberäkningar. För [redacted] *är det viktigt.*

är det mest baserat på fakta eller är det mycket magkänsla om hur man tror att det kommer att bete sig?

I det läget vi är nu, [redacted] då är det mycket känsla om vad man tror, fast av människor med mycket erfarenhet som man har mycket förtroende för. De har ju väldigt mycket kunskap från andra projekt så det är ju inte taget ur luften. Men det är ofta innan vi har hunnit räkna, testa eller ha en prototyp. Men iofs när vi valde [redacted] för [redacted] då hade vi gjort ett enkanaligt skakprov.

7. beslut om att höja status, hur tas beslut, samma sätt?

Där finns checklista, så om man följer processen och den då gör man det när man är redo enligt deadlines. Sen om man avviker från processen, vilket jag gör ibland t.ex. med lisafästet, då har det ju varit p.g.a. tidsbrist. Vi har avikit från processen då vi inte hunnit med alla steg och då är det ett beslut som har tagits av typ [redacted] att vi får ta den risken för att hinna med. Men det kanske är baserat på att man har gjort någon beräkning som gör att man ändå tror. Men följer man process och checklista så ska det vara ganska självklart.

   a. mest baserat på tidsplan eller fakta.

Jag tycker faktiskt att det i [redacted] har varit mest tidsplan. Typ hela tiden, inte en enda höjning har varit enligt checklistan. I [redacted] har det varit bättre än så länge.

8. PRY-3, passerades den med säkerhet gentemot leveranser eller hur var läget när man passerade den milstolpen.

Jag tycker att det fanns en osäkerhet, med mina artiklar i alla fall. Där har man inte riktigt kunna veta…. eller man har snarare vetat att de inte lever upp till målen och att vi har avvikelser men då har man gjort en sån där [redacted] på det. Så vi har ju vetat att vi uppnår inte livslängdskraven och att vi har avvikelser som inte är lösta men att vi sänker tillfälligt kraven. [redacted] t.ex. där har man bara räknat på det och beräkning säger att det finns en risk då man inte har gjort några fysiska tester. Så jag tycker att det är lite läskigt. Men där har man ansett att man får ta de riskerna. Vi anser att problemet är löst.

Var det där de största osäkerheterna låg, att man inte hunnit skaka?

Ja det tycker jag, vi hade ju heller inte gjort någon riktig provmontering. Men där kan man ju kolla i GEO o så men här inför vi för första gången ett [redacted] i detta systemet och hur det beter sig vet vi inte riktigt och beräkning rekommenderar att vi testar det. Vissa risker kan man ju inte förutse. Vi har ju haft många utfall på de andra [redacted] så det känns inte orimligt att det händer något med detta. Sen upptäckte jag efter ett tag att det var någon [redacted] som påverkade andra grupper, det löste sig dock genom att de fick införa ändringar i sina artiklar. Såna saker kan också hända när man inför saker sent, denna han ju inte sitta på några [redacted]. Eller den kom in i [redacted], vissa har ju suttit sen [redacted]. Men nu hoppas jag att jag hittat allt.

Interview with alias F

1. Har du tillräcklig kunskap om processen?

Inte jätte, jag har sett den där bilden och tittat lite på den när jag började jobba för drygt ett år sedan. Sen blir det mycket att man kommer in i arbetet på en liten nivå och tänker sällan på hur hela processen ser ut.

Har du tillräcklig kunskap i processen, någon tydlig introduktion?

Njae, har kikat lite på den själv sen snappar man upp lite då och då, så jag känner inte att jag har jättekoll på den. Men man dras väl in i den men man ser kanske inte alltid sammanhanget. Det skulle ju vara bättre om man hade mer koll på den och att det var tydligare när man börjar. Nu sitter jag som konsult och då ser ju introduktionsprocessen lite annorlunda utom jämfört med om man börjar här.

2. På vilket sätt är/är inte processen ett stöd i ditt arbete?

Den är ju ett stöd i liksom de här milstolparna vi har för att planera upp arbetet med alla delar och aktiviteter man ska göra. Så att man får se till så att man får med allt. Hur den inte är ett stöd är väl t.ex. med [redacted] *som vi håller på med nu, där har vi ju skjutit på planen och ligger inte efter planen. Och när vi går ifrån planen så blir det ju inget stöd egentligen. Men vi får väl ta kunskap av hur planen ser ut när vi skjuter på planen. Så det är väl både lite inte stöd och stöd när man inte följer den.*

3. C1 involverad?

Nej, jag var med förra våren i en fokusgrupp med att ta fram de koncepten som vi har jobbat vidare på innan det blev en del i det vanliga [redacted]*. Sen till sommaren så tog vi in det utifrån den här fokusgruppen till ett vanligt projekt.*

Hur används tidigare kunskap från tidigare projekt?

Ja det används ju, i den här fokusgruppen började vi med ett nytt, annorlunda arbetssätt. Här jobbade vi väldigt tätt med RTLC mot beräkning för att snabbare få feedback från dom. Det var ett litet experiment för att testa nya arbetssätt. Sen har vi använt mycket av det även efter att fokusgruppen tog slut och vi började med det vanliga. Sen har jag ju inte gjort så mycket innan det här. Så för min del har jag inte använt så mycket från andra projekt men det finns kunskap inom Scania som det känns som om vi använder.

a. Hur använder du tidigare kunskap?

Erfarenhet, att man fattar beslut på andra sätt eller vet att så här kan vi inte göra för att det funkar inte eller att det här har funkat förut, så då kanske det är bra att göra så.

b. Hur dokumenteras kunskap som dokumenteras nu under projektet?

Det är väl mycket presentationer, när man presenterar för andra. Beräkningsgenomgångar finns ju o dom gör ju rapporter sen när de är klara med sitt arbete. För min egen del samlar jag ju information och antecknar. Men mycket gör jag ju i mitt block och det finns ju inte tillgängligt för andra. Men man får ju se till att sammanställa den information man har så att man inte gör samma misstag igen. Men det känns som att det varit lite dåligt på att ta tillvara på den information som finns från andra projekt. Man vet att någon har sagt att här det här gjordes av någon förut så kolla om du hittar någonting. Men vad jag vet sp finns det ingen gemensam kunskapsdatabas utan det är ju mer att man får kontakta personer eller höra från andra att det här har gjorts.

4. Daglig styrning; vad får du ut av det?

Jag tycker att det är bra, man får ju lite koll på vad andra gör och för mig som ändå är relativt ny så tycker jag det är bra när man hör vad andra gör för då får man mer förståelse när man själv ska göra saker. För egen del så är det bra att kunna ta upp frågor och [redacted]*,* [redacted] *och* [redacted] *finns där och kan ge* *råd i vad man ska göra i olika frågor. På samma sätt är det med tavlan och mina lappar. Jag tittar på den och ser till att det är uppdaterat och ser sammanfattningen om jag har hunnit det jag ska gör och blir påmind av vad man ska göra.*

a. Får du ut allt du vill av DS eller är det något du saknar?

Nej jag tycker det är bra, det är bra att man kan ta efterpunkter, lyssna hela tiden. Det känns som att man kan alltid fråga saker där, det tycker jag är bra.

b. Huvudsakligt syfte

Se till att vi ligger i fas och att inget trillar mellan stolarna, fånga problem tidigt och sånt som man kanske inte bemödar sig med att gå o fråga någon, men på DS får man tillfälle. [redacted], [redacted] *och* [redacted] *finns tillgängliga (annars ofta på möten).*

5. Hur många koncept?

Det känns som att man går ganska tidigt från några få koncept till ett koncept. Det är något jag tänkt på om man jämför med hur man gjorde när man pluggade. Om man ska säga en siffra så brukar det landa i 2-3 koncept för att utvärdera vidare. I början har man kanske fler koncept men det känns som att det är mycket på egen hand med att ta fram och utvärdera koncept och att det är först vid KG då det är ganska satt vad det är. I det projektet jag har jobbat med har man fått input tidigare när man fortfarande har några koncept.

6. Hur väljer man ut koncept?

Lite olika från fall till fall. Men det känns som om man gör det ganska tidigt, man har något koncept som man har jobbat med men så får man väl göra en utvärdering med för- och nackdelar och ibland blir det att man tar ett tvärfunktionellt möte med simulering och produktion där de får säga sitt. Ibland kan det bli ganska tydligt.

a. När i processen?

Känns som om det är ganska olika? Men de projekten jag har varit inblandad i har det varit när koncepten ändå har varit ganska mogna och det börjar närma sig att man behöver ha ett koncept och om man ska höja det till [redacted]*. Sen har vi haft några varianter då vi har kört två stycken i ett skakprov men generellt så är det innan skakprovet som man väljer koncept för att man ofta bara har möjlighet att testa ett.*

b. När man väljer är det mest fakta eller mest magkänsla

Lite båda och, kanske inte magkänsla utan snarare sunt förnuft att det här konceptet borde vara bättre och sen också fakta att det här är bättre i produktionssynpunkt eller att det här håller inte.

Är det baserat på beräkningar då att det inte håller?

Ja, och sen kan det vara tidigare kända problem att vi vill inte gå in i det här området och ändra för vi vet att det har gått sönder där från skakproven t.ex.

7. När man höjer status på ett koncept, hur tas beslutet?

Det är väl från tidplanen men sen ska komponenten ha en viss mognad och har man sett att det inte håller i simuleringar kanske man måste vänta innan man höjer.

a. Mest tidsplan eller fakta?

I mitt fall så känns det som, för då sköt vi på [redacted] *för vi hade inga beräkningsresultat och vi kan inte beställa något som inte håller. Men det är ju lite både och, det beror lite på om man våga beställa även om man inte är helt 100% säker.*

8. När PRY-3 passerades för i C1, var du med då?

Nej eller då hade vi skjutit på mina artiklar eftersom vi saknade beräkningsresultat, egentligen började vi med [redacted] *sen har vi skjutit till* [redacted] *och sen* [redacted] *så hela planen är ju lite förskjuten så det är lite specialfall.*

Var det stora osäkerheter?

Det var nog ganska mycket osäkerheter, för det började med att vi fick göra om små saker i systemet och sen fick vi göra om [redacted]*. Sen fick vi göra om strukturen så det har ju helt plötsligt blivit mycket mer som vi får göra om. Det är ju bra på sitt sätt att vi inte går på något som precis klarar kraven eller precis klarar kraven.*

Interview with alias G

1. Har du tillräcklig kunskap om processen, har du fått en introduktion om den?

Började 2007, PD-processen har utvecklats sedan dess. Den senaste blev officiell förra året. Har ganska bra koll på processen, jobbade som TL för [redacted] *på satellit i Södertälje. Mitt ansvar var att vi skulle hålla alla leveranser och även följa processen. Numera* [redacted]

2. Är processen ett stöd i ditt arbete?
    a. På vilket sätt?

Mestadels ja, men ibland upplevs den som en störning. Det beror på hur man ligger till. Skulle man tidigt komma fram till att ett koncept är bra och man kör på det så är processen ingen störning. Men står man och stampar på samma ställe och stöter på problem så kan processen bli en störning och en börda att hålla sig till den. Då får man komma överens med produktsamordning så att man lägger upp en plan för att klara leveranserna. Men i och med. att Scania är en så stor organisation så måste man ha en process som stämmer av alla mot varandra och synkroniserar alla inblandade.

3. I C1, används tidigare kunskap, från exempelvis föregående projekt?
    a. Hur använder du tidigare kunskap?
    b. Hur dokumenteras kunskap som byggs upp nu?

Gick med i C1 part 2. Vi försöker använda tidigare kunskap. Det har gjorts en massa simuleringar som kan indikera hur komponenter beter sig. Många sparar lokalt, men det finns material som pekar på vad som har gjorts i projektet.

Hur jag använder: beror på hur kunskapen ser ut och hur utfallet har set ut. Om något visat sig inte fungera så får man göra omtag. Sen kan det finnas områden som inte har fokuserats på i rapporter men som blir viktigt längre in i projekt.

Det finns produkt-data-dokument som man kan skapa med ett visst pd-nummer. Dessa är tillgängliga för andra och är sökbara med sökord. Jag försöker lägga in så många KG:n som möjligt, framför allt de som har tagits beslut på.

4. Vad får du ut av daglig styrning?
    a. Får du ut det som du vill få ut?
    b. Vad är det huvudsakliga syftet med daglig styrning?

Det som är bra med DS är två saker. Dels så får man överhörning, vi jobbar ju tight ihop och om någon exempelvis ska göra en provmontering så kan jag samordna min provmontering så kan vi samköra arbetet. Överhörningen är viktig. Man får också eskalera det som uppstår. Man ska eskalera direkt och inte vänta med akuta problem. Man kan avgöra hur den egna eskaleringen förhåller sig till andra som uppstår. Det säger även hur gruppen mår, är det bara jag som har eskaleringar eller har alla det tufft för tillfället?

Belysningen av hur gruppen mår, som inte bara chefen ser utan alla i gruppen ser.

Man ska hålla DS hårt, och lyfta diskussioner till efterpunkter. Annars så blir det en daglig störning. Alla måste hålla sig kort, så kan man takta av DS och får det gjort effektivt.

Det funkar bra med DS idag. Vi kör efterpunkter. Man vet hur medarbetarna ligger till och vi håller mötena på en nivå så vi kan takta igenom och ta diskussioner efteråt.

Tror att överhörningen är syftet med DS. Under de första fem åren på Scania så hade vi inte DS och det fungerade också. Alla hade sin egen planering i eget format. PEPP:ade på en annan avdelning där DS användes. Där var behovet större med olika eskaleringar. Alla jobbade med sina egna maskiner och processer på olika håll. Då var det bra att gruppen träffades en gång om dagen. På RTLR så sitter vi tight ihop, så jag var lite emot DS i början. Men vi har lyckats effektivisera det så nu fungerar det bra. Vi håller det kort. Som vi gör nu så fungerar det bra. Det är även viktigt för chefen, att chefen *vet hur vi ligger till. Man får chans varje dag att eskalera punkter istället för att vänta på att medarbetare ska eskalera punkter.*

5. Hur många koncept brukar man utveckla och hur länge håller man dem vid liv i processen?

Ibland har man utrymme och tid att utveckla olika koncept. Ibland är det svårt att få fram ett enda koncept. Jag brukar banta det till tre koncept baserat på den kravbild som finns. Sen tar man exempelvis upp det på en KG.

6. Hur väljer man koncept?
    a. Väljer man ut ett eller håller man fler vid liv längre och eliminerar? förtydliga på 6.
    b. När i processen väljer man eller eliminerar koncept?
    c. När man väljer eller eliminerar koncept, görs detta baserat på fakta eller på magkänsla?

KG är en väg att välja koncept. Då kan man kalla berörda parter till mötet. Ibland kan man ta beslutet internt på gruppen, men ibland är exempelvis servicebarhet eller design viktigt, då måste man köra på KG.

Kravbilden är det som avgör om ett koncept elimineras eller ej. Oftast har vi hållf, servicebarhet, produktion osv och väger upp dessa och ser vad som är viktigast. Oftast kan man inte göra avkall på montering för hållfen och oftast kan man inte göra den bedömningen själv. Digitala provmonteringar är billigast, sen finns ju [redacted] *där vi kan göra konceptuella provmonteringar. Då kan man ta med service eller produktion och prova konceptet på fysiska chassier mha plast-modeller.*

7. Hur tas beslut om höjande av status osv. i C1?
    a. Tidsplan eller fakta? (anpassa efter svar på 7:an)

Det är inga formella beslut, utan vi tittar på hur vi ligger till. Är artikelnummer klara, geo-publiceringar klara, osv. då kan man höja till [redacted]*. För att höja till* [redacted] *så är grejerna i* [redacted]*.*

Olika, ibland har man fakta och är säker på det konceptet man har. Andra gånger så höjs koncept pga tidsplan för att respektera deadlines. Då görs en best-guess baserat på nuläget.

I [redacted] *så har vi inte haft så mycket fakta. Vi har tagit fram de artikelnummer vi tror att vi behöver så GEO-publicerar vi de geometriska utrymmena vi behöver för att upplysa andra om det utrymme som vi tar i anspråk.*

8. När PRY-3 passerades, vad man då säker på att klara av leveranser eller fanns det en osäkerhet?
    a. varför (säker eller osäker)?
    b. Om du inte var med i PRY-3, passeras milstolpar med säkerhet eller med stor osäkerhet?

I [redacted] *så skulle vi ha livslängd indikerad, alltså ha simuleringar som stöder de krav vi har. Har vi skakprov så är det ett plus. Det är ingen katastrof om vi inte har hunnit skakprov. Vi ska ha en indikerad livslängd. För* [redacted] *så är vi inte riktigt hemma med beräkningen heller. Vi har passerat PRY-3 för* [redacted] *men har inte lyckats indikera livslängden ännu. Måste även göra omtag för* [redacted]*.*

Vi skulle vilja ha gjort provmontering för att säkerställa funktionen.

GAS-beräkningar i all ära, men de beräkningar som beräkningsgrupperna kan göra med icke-linjära funktioner är mer noggranna.

Appendix E

1. What are the main obstacles when implementing Rapid Learning Cycles into the hardware design process in an established organization?

The good news is that rapid learning cycles can be implemented on a small scale: one project, one subsystem, or even one complex problem. This is great as the learning can be allowed to developed and refined organically and expanded without huge disruptions. However, in all cases, two things must happen; only one is insufficient.

1) the project leader must be committed and mentor proper problem solving to assure all the knowledge is known from all perspectives before making decisions. Knowledge overrules schedules. This includes all the trees and limits are understood.

2) the engineering team must have all the expertise and have the capabilities (methodology / tools) to identify all off the knowledge gaps and trade-offs and then resolve them robustly.

The main obstacles are not having both in place when starting; if you do not. then wishful thinking decisions will be made. Constancy of purpose within the collaborative team is critical. Also it is critical that a cadence of integrating reviews are established and followed to maintain a sense of urgency.

2. How and in which format should key decisions and gained knowledge be documented in hardware development projects?

Knowledge must be captured in context of limits of decisions to meet customer interests - usually in the form of trade-off curves. The reason is that allows the design space to be understood and what limits the decisions for future changing requirements. This enables set based thinking. The knowledge should be organized around the decisions to be made and owned / managed by the functional leaders responsible for the quality of the decisions.

3. What main obstacles might be encountered when transforming into Lean product development when the current process does not support early knowledge buildup?

In my opinion, a process that does not support early knowledge build-up cannot be lean and therefore must be changed to one that is. Then, my answer would be the same as the first question. First define a new front end learning methodology and prove it on a smaller scale; then expand: but both 1) and 2) above must be in place at every level.

4. Which would be the focus areas of your choice when implementing a lean thinking with focus on early learning into a hardware design process?

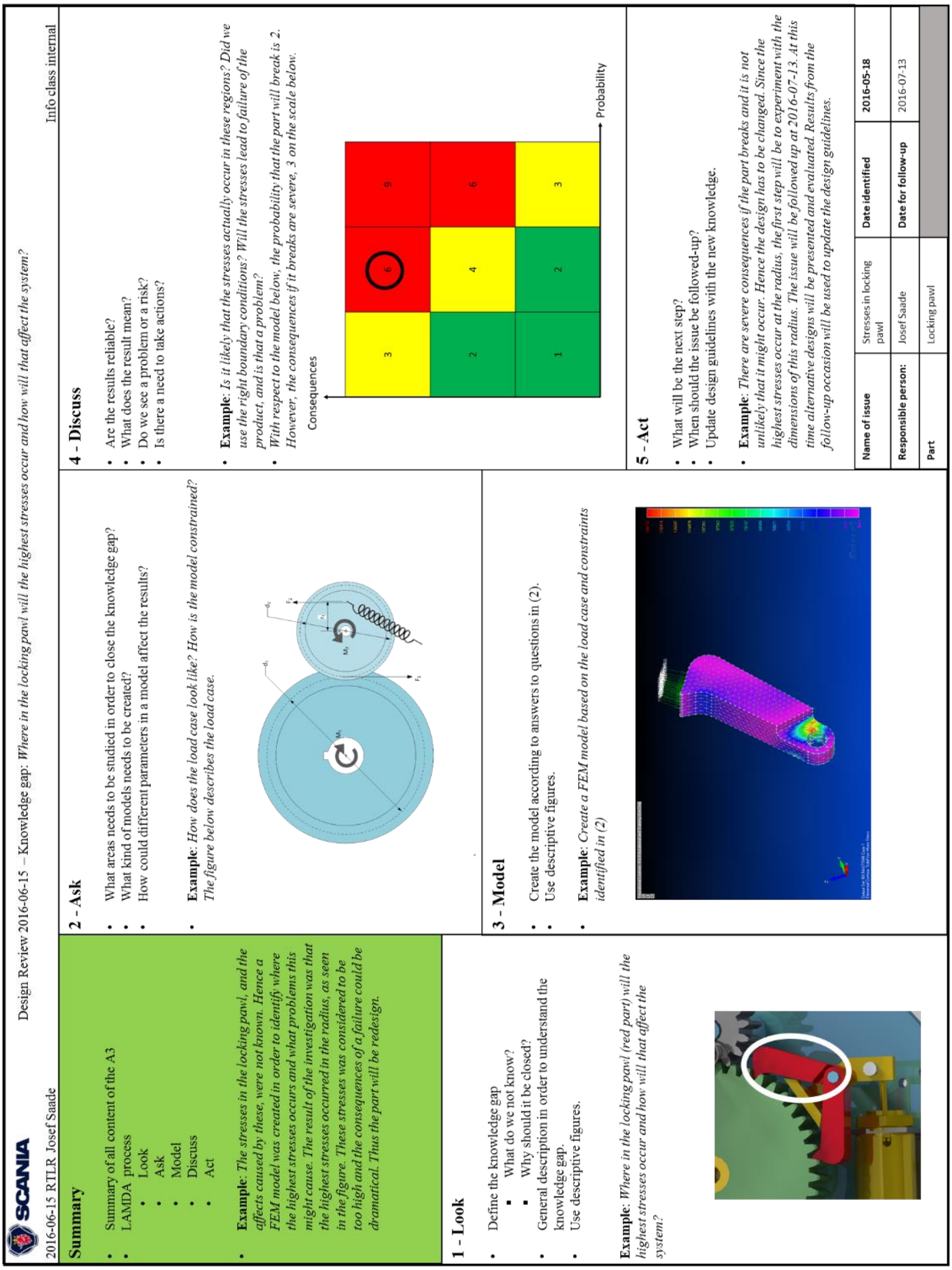
The primary focus would be on identifying and exposing all of the critical knowledge gaps up front in a visual and rapid way. Unknown knowledge gaps cannot be allowed to escape into detailed design; the faster they are exposed makes it a lot easier. To do so, the team must address all of the following right at the start: define the critical targets to be met; get innovative ideas on the table to meet them; understand the limits of the required decisions for achieving the ideas; and understand how the decisions trade-off against the targets. We have found the causal mapping is a great tool to do this; the impact of every decision across multiple customer interests must be addressed and made visual. Once, the knowledge gaps are on the table, then the resolution in a set based way can be executed by converging and systematically eliminating weak alternatives.

5. Which major drawbacks and risks are evident when planning with visual planning tools? Which are the most important features to get it right?

In a front end learning environment, the focus should be on identifying and eliminating knowledge gaps - not on executing tasks. If the visual planning tools are based on managing tasks rather than managing rigorous cycles of learning and adjusting, then the planning tools will be counterproductive. Visual planning in a learning cycle environment should be to maintain a cadence of learning, deciding, and adjusting.

Appendix F

A3 report for knowledge gaps



SCANIA

Design Review 2016-06-15 – Knowledge gap: *Where in the locking pawl will the highest stresses occur and how will that affect the system?*

2016-06-15 RTLR Josef Saade

Info class internal

Summary

- Summary of all content of the A3
- LAMDA process
  - Look
  - Ask
  - Model
  - Discuss
  - Act
- **Example**: *The stresses in the locking pawl, and the affects caused by these, were not known. Hence a FEM model was created in order to identify where the highest stresses occurs and what problems this might cause. The result of the investigation was that the highest stresses occurred in the radius, as seen in the figure. These stresses was considered to be too high and the consequences of a failure could be dramatical. Thus the part will be redesign.*

1 - Look

- Define the knowledge gap
  - What do we not know?
  - Why should it be closed?
- General description in order to understand the knowledge gap.
- Use descriptive figures.

Example: *Where in the locking pawl (red part) will the highest stresses occur and how will that affect the system?*

2 - Ask

- What areas needs to be studied in order to close the knowledge gap?
- What kind of models needs to be created?
- How could different parameters in a model affect the results?
- **Example**: *How does the load case look like? How is the model constrained? The figure below describes the load case.*

3 - Model

- Create the model according to answers to questions in (2).
- Use descriptive figures.
- **Example**: *Create a FEM model based on the load case and constraints identified in (2)*

4 - Discuss

- Are the results reliable?
- What does the result mean?
- Do we see a problem or a risk?
- Is there a need to take actions?
- **Example**: *Is it likely that the stresses actually occur in these regions? Did we use the right boundary conditions? Will the stresses lead to failure of the product, and is that a problem?*
- *With respect to the model below, the probability that the part will break is 2. However, the consequences if it breaks are severe, 3 on the scale below.*

Consequences

3	6	9
2	4	6
1	2	3

Probability

5 - Act

- What will be the next step?
- When should the issue be followed-up?
- Update design guidelines with the new knowledge.
- **Example**: *There are severe consequences if the part breaks and it is not unlikely that it might occur. Hence the design has to be changed. Since the highest stresses occur at the radius, the first step will be to experiment with the dimensions of this radius. The issue will be followed up at 2016-07-13. At this time alternative designs will be presented and evaluated. Results from the follow-up occasion will be used to update the design guidelines.*

Name of issue	Stresses in locking pawl	Date identified	2016-05-18
Responsible person:	Josef Saade	Date for follow-up	2016-07-13
Part	Locking pawl		

A3 report for problem solving

2016-07-13 RTLR Josef Saade

Design Review 2016-07-13 – Problem solving: Broken locking pawl

Info class internal

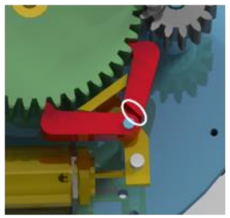
Summary

- Summary of all content of the A3
- LAMDA process
    - Look
    - Ask
    - Model
    - Discuss
    - Act
- **Example**: *One of the locking pawls broke during a static test. The breakage was initiated by a crack started in the radius. During a root cause analysis it was identified that the material thickness, the radius, and young's modulus are affecting the strength of the locking pawl. From the FEM calculation it was clear that the material thickness was too small. Thus the thickness should be increased.*

1 - Look

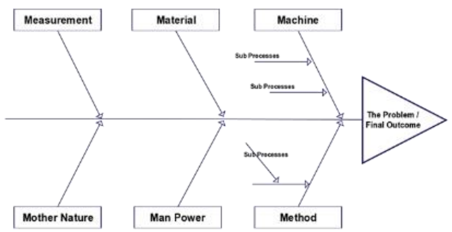
- Describe the problem and why it needs to be solved.
- Describe the context of the problem.
- Use descriptive figures to enhance the understanding.

Example: *During a static test one of the locking pawls (the red part in the figure) broke. When analyzing the breakage it was identified that it was caused by a crack which started at the radius, see figure.*



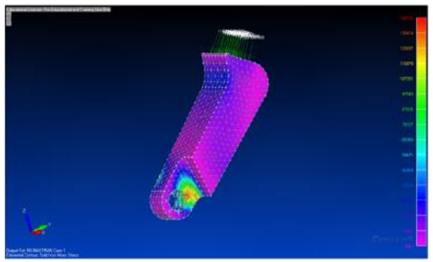
2 - Ask

- Find the root cause of the risk.
    - Fishbone diagram, 5 whys etc.
- Which factors contributes to the risk?
- **Example**: *A root cause analysis was conducted in order to identify which parameters that contribute most to the strength of the locking pawls. The parameters identified was: material thickness, young's modulus, and the dimension of the radius.*



3 - Model

- Create models to understand behaviors and to gain information of the identified root causes.
- Use descriptive figures.
- **Example**: *The parameters identified in (2) was analyzed using FEM calculations. From the calculations it was clear that the parameters should align with the following limits.*
    - *Material thickness: ≥5 mm*
    - *Radius: ≥ 1 mm*
    - *Young's modulus: ≥ 200 GPa*



4 - Discuss

- Are the results reliable?
- What does the result mean?
- Could the results solve the problem?
- **Example**: *The results from (3) showed that the material thickness was the reason for the breakage. The thickness used in the existing design was 4mm. Thus it needs to be increased with at least 1mm. The other parameters were already fulfilled and thus no changes will be necessary.*

5 - Act

- What will be the next step?
- When should the risk be followed-up?
- Update design guidelines with the new knowledge.
- **Example**: *The part needs to be updated with a new material thickness. Furthermore the design guidelines will be updated as described below.*
    - *Material for this application should have a young's modulus of at least 200 GPa.*
    - *The material thickness should be at minimum 5 mm for similar applications.*
    - *The radius needs to be at least 1mm.*

Name of issue	Stresses in locking pawl	**Date identified**	**2016-06-15**
Responsible person:	Josef Saade	**Date for follow-up**	-
Part	Locking pawl		

A3 report for risk mitigation

2016-07-13 RTLR Josef Saade

Design Review 2016-07-13 – Risk: Stresses in locking pawl

Info class internal

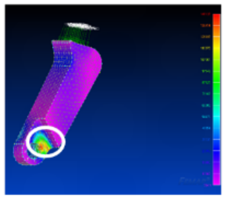
Summary

- Summary of the content
- LAMDA process
    - Look
    - Ask
    - Model
    - Discuss
    - Act
- **Example**: *A risk that the locking pawl would break was identified and the possible effects from such breakage was considered to be hazardous for the system. To mitigate this risk alternative designs and materials were investigated. FEM calculations were conducted in order to see how the different parameters contributed to the strength of the part. Parameters for this part should be:*
    - *Material thickness: ≥5 mm*
    - *Radius: ≥1 mm*
    - *Young's modulus: ≥200 GPa*
- Further the design guidelines were updated accordingly.

1 - Look

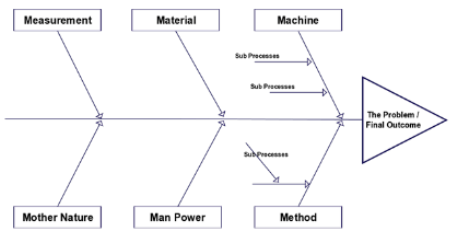
- Describe the risk and why it needs to be mitigated.
- Describe the context of the risk.
- Use descriptive figures to enhance the understanding.

Example: *A risk that the locking pawl would break was identified and the possible effects from such break were considered to be hazardous for the system. The highest stresses occur at the radius as seen in the figure below. If the locking pawl breaks the system might collapse and affect other surrounding parts.*



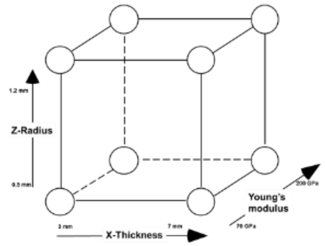
2 - Ask

- Find the root cause of the risk.
    - Fishbone diagram, 5 whys etc.
- Which factors contribute to the risk?
- **Example**: The stress concentration is located in the radius. From a root cause analysis it was identified that following factors probably contribute to the high stresses: material thickness, material properties, and the dimension of the radius.



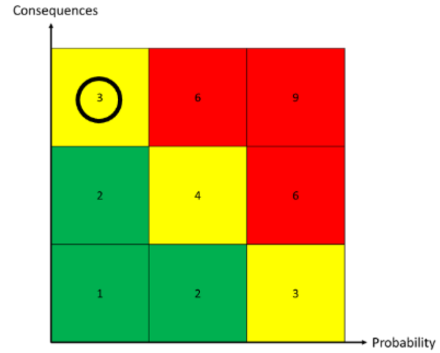
3 - Model

- Create models to understand behaviors and to gain information about the identified root causes.
- Use descriptive figures.
- **Example**: *To investigate the limits of the design a series of FEM calculations were conducted. From the calculations the following parameters were identified as the limits in order for the locking pawls to withstand loads.*
    - *Material thickness: ≥5 mm*
    - *Radius: ≥ 1 mm*
    - *Young's modulus: ≥ 200 GPa*



4 - Discuss

- Are the results reliable?
- What do the results mean?
- Could the results mitigate the risk?
- **Example**: *Varying design parameters through calculations showed possibilities to reduce stresses. When reducing the stresses, the locking pawls will withstand the loads. The probability that the locking pawls will break is therefore reduced, as seen in the figure below.*



5 - Act

- What will the next step be?
- When should the risk be followed-up?
- Update design guidelines with the new knowledge.
- **Example**: *The results from the calculations will be used to set the parameters in the design. Since the Young's modulus should be higher than 200 GPa steel is a good alternative for this application. Furthermore the design guidelines will be updated as described below.*
    - *Material for this application should have a Young's modulus of at least 200 GPa.*
    - *The material thickness should be at minimum 5 mm for similar applications.*
    - *The radius needs to be at least 1 mm.*

Name of issue	Stresses in locking pawl	**Date identified**	2016-06-15
Responsible person:	Josef Saade	**Date for follow-up**	-
Part	Locking pawl		