Self-organization in a hardware context

A case study at Volvo Cars investigating how increased self-organization in R&D affects product- and organizational structures

Master of science thesis in the Quality and Operations Management Programme

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Abstract

An increasing speed of technological advancements have, during the last decades, led to increased demands for improved flexibility and reduced time to market for companies in a spread of industries. In response, several companies have investigated alternative organizational methods to cope with the change, where agile methods have largely dominated the software industry. One of the cornerstones within the agile methods is self-organization (Beck et al., 2001), where the team members owns activities as prioritizing, planning, execution and delivery of tasks (Hoda et al., 2010). As organizations within other industries now see the benefits that has been gained by working with agile methods in software, the question has been raised if self-organizing teams are applicable in an environment developing hardware products in large scale. In order to explore the application of self-organization in hardware, this study investigates what effects an implementation will have on the organizational- and product structure in a hardware product development department.

To describe and understand the current state of the organization, a map of the communication patterns was created based on interviews and on-site observations. The map provided insights on how the organizational structure is designed and how it relates to the product structure. In addition, the interviews and observations provided insights into the existing capabilities of self-organization at the studied section, PSS140.

The study was able to identify several changes in the organizational structure that would occur as a result of increased self-organization at PSS140. By investigating the mirroring hypothesis at PSS140, the study identified that the current product structure was a reflection of the organizational structure. As this relation between product structure and organizational structure was deemed to remain in the future, the researchers were able to forecast changes in the product structure as an effect of changes within the organizational structure

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Many people has been part of making this study possible and the authors would like to thank all of you for contributing. First, we would like to thank our supervisor at Volvo Cars, Lars Fält, who has contributed with his knowledge about the organization and products at VCC and has always been available for discussions. A big thank you is also directed to Johannes Berglind Söderqvist, supervisor at Chalmers, who has guided us through the execution of this study. Johannes has contributed with deep knowledge in the field of self-organization and has constantly challenged us with interesting and productive arguments.

The authors would further like to thank all the people at Volvo Cars that, in some way, has contributed to this study with their knowledge and opinion. Special thanks, to the employees at PSS140 who has been part of the interview study and who let us conduct the observations of work conducted at the section.

Last, we hope that the insights and results of this study brings useful information to meet challenges faced by Volvo Cars in the near further.

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Johan Edström Daniel Söderberg

Gothenburg, May 2018

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1- INTRODUCTION

This chapter will introduce the reader to the subject of this thesis and motivate why it is relevant for further study. First, a background is presented to make the reader familiar with the subject and to describe the current state of research in the field. Second, the purpose of the study is clearly outlined in a purpose statement. Further, the research questions which guides the study throughout execution is presented. Lastly, some delimitations are presented to further precise the purpose of this study.

1.1- BACKGROUND

In order for companies to compete on an increasingly global market, innovation and the frequency of new market introductions has become more important. Commonly used methods in product development, *e.g*. the stage-gate method, have not provided enough flexibility in the downstream process as they are to linear to adapt to unforeseeable disruptions of the process (Cooper & Sommers, 2016). Therefore, companies have requested shorter time to market and larger creativity from their employees (Cavusgil, 1993). This challenged the formerly effective organizational methods, and many companies have started to look for more effective ways of managing their product development activities. In the software industry, this sparked the creation of several new development methods, such as scrum and eXtreme Programming (XP). These new software development methods, which were later gathered under the name agile (Rico et al., 2009), all shared some similar attributes which were unveiled in the agile manifesto (Beck et al., 2001).

One common tendency within agile methods is self-organizing teams, where the team members owns activities as prioritizing, planning, execution and delivery of tasks in the backlog. In software development, positive effects that enhance development efficiency has been recognized in association with self-organizing teams since the decision authority is distributed to the team (Hoda et al., 2010). Organizations working with self-organizing teams have seen effects such as increased employee satisfaction, efficiency and delivery accuracy. Hoda, (2011), draws a parallel between autonomous teams, self-managing teams and self-organizing teams where the decentralized decision power and motivational factors is key aspects. Moe et al., (2008) describes the potential effects from increased self-organization as *"Autonomous teams stimulate participation and involvement, and an effect of this is increased emotional attachment to the organization, resulting in greater commitment, motivation to perform and desire for responsibility."*

The subject of self-organizing teams in a software environment has been well covered in studies and academia. As other industries now see the need of more rapid development and that they are affected by faster technological shifts, the question has been raised if self-organizing teams are applicable in an environment developing hardware products in large scale. This subject does not have the coverage in studies and it is therefore interesting to investigate further. Using the definition of self-organization capabilities by Takeuchi & Nonaka (1986), an organization was investigated and analyzed. In addition, the hypothesis of the mirroring effect was used to describe the current product structure in the organization to identify potential relationships between organization and products and how it is affected by self-organization. By using the mirroring hypothesis, this study will aim to understand how this relationship can be used to assess and predict how the product and the organization is affected by increased self-organization.

1.2- PURPOSE

The global market trends in recent times has created a demand for shorter product life- and development time. These trends have also affected Volvo Car Corporation (VCC), whom have responded to the challenges by initiating an agile transformation project. The agile transformation at VCC aims to implement SAFe (Scaled Agile Framework). As many other agile methods, SAFe emphasizes the importance of self-organization. However, some departments at VCC, *e.g.* PSS140, that works with research and development in hardware development have expressed difficulty to estimate the effects from implementing self-organization in their work environment. Similarly, most recent studies of agile implementation have focused on cases where companies develop software or a mix of software and hardware. Thus, it is interesting to investigate what consequences a change to self-organization will have on a section developing hardware products, which has led to the following purpose statement;

Identify how a change towards self-organization would change the product- and organizational structure in a hardware product development department

1.3- RESEARCH QUESTIONS

Self-organization is currently an active subject in a variety of industries, where their methods and applications differ. Although the concept of self-organization itself is older, recent use and studies of the concept have mainly occurred within research focusing on agile methods. In addition, most research on the effects of self-organization has focused on its application in software environments (Moe et al., 2008; Crowston et al., 2007; Hoda & Murugesan, 2016). As VCC is aiming to become an agile organization, the effects on organizational structure from increased self-organization, therefore, has great importance for departments within VCC. Based on this, the following research question was created;

RQ1: *In what way would increased self-organization in product development change PSS140's organizational structure?*

To determine what effects an organizational change will have on the product structure, the current relationship between the product and organization needs to be understood. The mirroring hypothesis suggests that a map of a product and a map of the team creating the product should be identical (MacCormack et al, 2012). However, previous studies have provided varying results when validating the hypothesis (Colfer & Baldwin, 2016). As PSS140 is a department that handles products with the possibility to trace a subcomponent to its creator, it is ideal for testing the mirroring hypothesis. It is, therefore, interesting to investigate the relationship between product and organization at PSS140. The relationship can then be used to evaluate how the product and organization is affected by increased self-organization. This has led to the following research question;

RQ2: *What is the relationship between product structure and organization structure at PSS140?*

Since VCC is currently performing an organizational change, it is important for them to be able to understand potential consequences of such efforts and to identify implications and possibilities accompanied with such a change. If the connection between product structure and organizational structure can be understood, it might enable an organization to identify what effects an organizational change will have. Furthermore, no previous research combining the relationship between product- and organizational structure and self-organization was found which makes it interesting to investigate further. This has led to the formulation of the following research question;

RQ3: *How can the current relationship between product and organization be used to understand what effects an organizational change towards self-organization would have on the product- and organizational structure?*

1.4- DELIMITATIONS

This study focuses on mapping the current situation and to give insight of what effects the current organizational change can have. Hence, no considerations regarding the implementation and transition period is to be included in this study. Further, this study aims to contribute to research in self-organization in hardware development, hence focus is not on agile methods at large. This study does not aim to develop a generalized framework or application method for the mirroring hypothesis but rather to find important patterns between products and its developing organization.

2 - THEORETICAL FRAMEWORK

This chapter presents relevant literature on the subject to which this study will contribute. Supporting information of connected subjects are also presented for the reader to get a broad grip of this study.

2.1- THE MIRRORING HYPOTHESIS

The definition of a product varies across different industries and authors. However, many definitions do agree that a product is something that needs to be refined or processed in order to create a larger value (BusinessDictionary.com, 2018; Oxford dictionaries, 2018). The refinement of a product generally requires the use of several different technologies, which can be distinguished from each other. This enables the view of technologies in a product as a modular system, where the different technologies are separate but interdependent and communicating (Langlois, 2002). Similarly, the organizational architecture of a firm can be disassembled into separate parts that communicate and share dependency to each other. This enables a mapping of both the technologies in a product and their relations as well as the architectural structure for the team and organization that develops the product. If these are separated in a similar structure and on the same level of depth, there is a possibility to compare the maps. When this is performed correctly, the mirroring hypothesis suggests that these maps should be replicas of each other (Mac Cormack et al, 2012; Colfer & Baldwin, 2016). This connection is shown below in figure 1, where a map of the organizational structure of a project team and its department is compared to the main development tasks for a product.

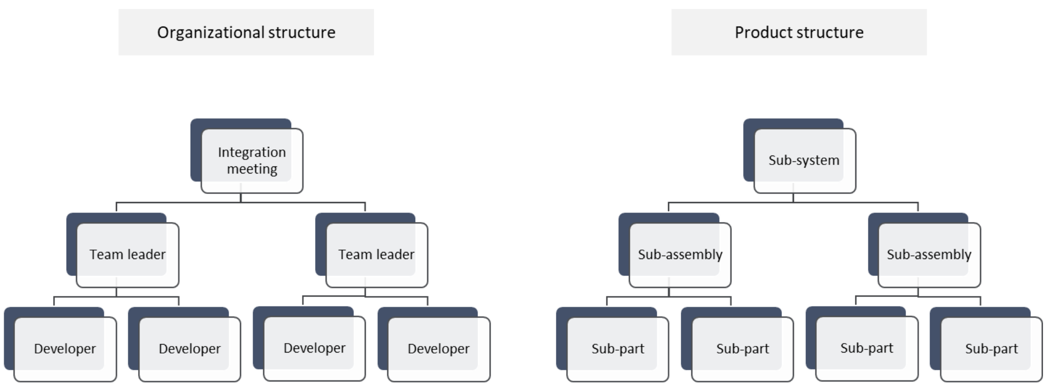

Figure 1- Theoretical representation of the mirroring hypothesis

The theory further suggests that a change in the product structure should be reflected by a change in the organizational architecture. This can be exemplified by comparing an integrated product to one with high product modularity. The mirroring hypothesis suggests that a product with lower modularity requires more communication and formal connections between the developers of the product, which should be reflected in its organizational structure (Cabigiosu & Camuffo, 2012). Modularity is a prerequisite for the mirroring hypothesis to hold and modularity is, therefore, something desirable to investigate in many cases. However, a highly modularized product will still need to be gathered into a final product. This will require communication between the developers (Colfer, 2007), although it might happen in a formal forum with lower frequency than an integrated product would require.

Existing literature on the mirroring hypothesis suggests three main recommendations to support this binary dependency between products and organizations (Colfer, 2007). First, the product should be modularized with standardized interfaces between different sub-components. Second, the organization should be organized so that it reflects the modularized product on the same level. Lastly, the communication pattern and the organizational setup needs to be assessed frequently in order to evolve along with the product design (Colfer, 2007). Creating a modularized product may sound easier than it is and many iterations may be needed in order to identify interfaces within the product. Since developers and managers are not able to anticipate the effects their internal design decisions will have on the surrounding interfaces often more than one iteration is needed in order to identify necessary communication patterns to other entities in the organization (Sosa et al., 2007). A product with higher complexity naturally inhabits more problems regarding iterations and re-work since there is a limit of how much a development team, or single individual, can trace interdependencies within the product or handle the information about the product and its components (Colfer, 2007).

2.1.1- RELATIONSHIP BETWEEN PRODUCT AND CREATOR

Sociomateriality studies both technical and social functions in an organization with specific focus on the interrelationship in between them (Cecez-Kecmanovic et.al, 2014). Sociomateriality as conceptual view is defined by Orlikowski & Scott (2008) as the fusion of technology and work in organizations. Orlikowski (2008) stretches the concept of sociomateriality and provides a broader view. Physical things and people are not seen as separate entities which are projected in each other, rather they are seen as nodes in a system where they work together (Cecez-Kecmanovic et.al, 2014). The view of Orlikowski (2008) focuses on the ontological relationship between entities, humans and technology which argues that relationships are relational and that working systems of people relies on the web of relationships that is created and developed from day one of existence. These insights by Slife (2004) and Orlikowski (2008) are important in order to understand the strong correlation and connection between people and technologies (Cecez-Kecmanovic et.al, 2014) *i.e.* In a product development context.

The model described by Orlikowski (1992) stresses the need to widen the perspectives of the relationship between an organization and its products. Instead of the strict "developer - product" relationship, Orlikowski (1992) provides a model where the technology affects the humans who develops it and vice versa. The model suggests a two-way system between the Social actors (Humans) and the technology (product) with overall processes provided in the organization (the built-in configuration). Orlikowski claims that positive development effects, where new and more efficient ways can be found in connection to understanding the model, specifically when the interdependence of social actors and technology is being recognized. See a further explanation in figure 2 below;

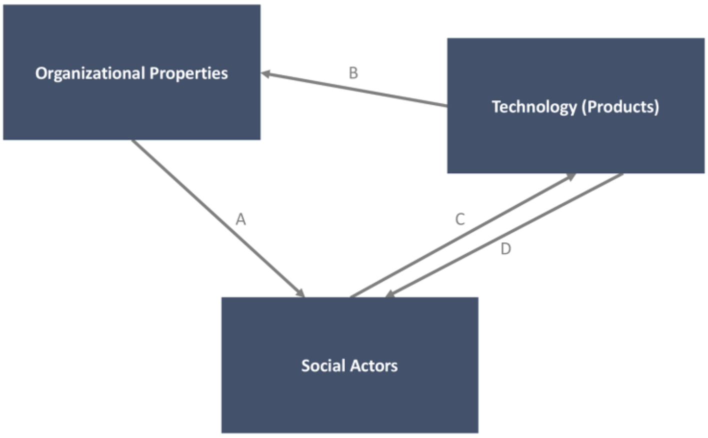

Figure 2 - Visual representation of the structurational model by orlikowski (1992)

A. *Institutional properties that affects the interaction between social actors and the technology, resources in terms of i.e. knowledge, money or time.*
B. *Exploring new technologies affects the total knowledge of the organization and provides it with new norms and possibilities.*
C. *Design of a product is an consequence of a developers efforts to build in knowledge obtained by the engineer who is responsible for the development.*
D. *The technology supports the engineers in their effort to develop new innovative products and it is affecting their knowledge and utilization of it.*

2.2- Self-organization

Self-organization was popularized by the increased use of agile methods, more specifically agile methods used in software development were short development loops, *i.e.* sprints, was identified as a solution to the emerging demand of speed and flexibility by software consumers (Cohen et al., 2004). For teams to deliver on customer demand, the development processes needed to be more perceptive for change in the same pace as new demands arose (Cohen et al., 2004). Self-organizing teams are teams managed, organized and steered by the group of people who are included in the team and leadership is distributed within the team (Hoda et.al., 2010). Takeuchi & Nonaka (1986) provides three main criteria which should be fulfilled in order for a organization to be self-organizing. First, the aspect of autonomy which gives the team space to explore and organize in accordance with present challenges and adapt to present needs with little or no involvement from top management. The second criteria is self-transcendence which enables the team to find its own way towards the main goal. By letting the teams set up their own goals and to be responsible for follow-up and review an active and iterative processes is created. The third criteria is cross-fertilization, which enhances the team’s ability to be innovative and to break patterns and also to create new contacts and knowledge within the team. Cross-fertilization also includes co-location of competence, which is a key factor to gain efficiency in self-organizing teams. Furthermore, Hoda et al. (2010) has shown that these teams can vary in size, where their study included teams with between 4 and 15 members.

An expansion of the agile concept into other industries currently occurs as a consequence of a wide spread digitalization trend and more rapid technical development (Limpowsky & Schimdt, 2016). The question of how agile methods and self-organization can be adapted to a development process of complex products has been raised. For developers, for example in the car industry, to cope with the challenge of short development times and short product life time, there is a need to find ways of organizing that provides flexibility and efficiency. This has often been resolved in the software industry by incorporating self-organizing teams into the organization, which has provided the organization with autonomy and flexibility (Cohen et al., 2004) and has in several cases provided a positive outcome (Cooper & Sommer, 2016).

2.2.1- Leadership in self-organizing organizations

Large corporations have, during the last decades, organized in function or matrix organizations with strict hierarchies to be able to control a diverse set of competencies and functions (Galbraith, 2008). In such environment, a manager is usually responsible for project delivery and reporting higher up in the hierarchy. In an Agile organization, however, a project team is supported by two roles; the Scrum Master and the product owner. In agile teams, which is a form of self-organizing teams, there is no traditional manager or specific leader. The Scrum master acts as a facilitator and support function for the agile team and the main task is to remove obstacles that could hinder the development team to work efficiently (Srivastava & Jain, 2017). The product owner provides the team with customer insight and is responsible for business aspects of the project. This is similar to the leadership in self-organizing teams described by Takeuchi & Nonaka (1986), where team leaders are decoupled from the top management. Instead of continuously reviewing the progress of the product, the leaders support and work alongside other team members. The supportive and collaborative role of the team leader becomes apparent when a decision is taken, where Moe et al. (2008) claim that the members of a self-organizing team should share decision authority. A similar statement regarding leaders in self-organization is given by Plowman et al. (2007): “Leader enable rather than direct change”.

2.2.2- Barriers, Benefits and Success Criteria for Self-Organization

Implementing new organizational methods can be difficult, were Ashkenas (2013) claim that up to 70 percent of change projects fail to deliver the desired outcome. The author further states that the fail rate has been remained the same since the 1970’s, which makes it likely to remain stable in the future as well. It is, therefore, important to understand potential pitfalls and success criteria from implementing self-organization.

2.2.2.1- Barriers for Implementation of Self-organization

In March 2004, the University of Southern California gathered agile developers and specialists together with engineers and representatives from academia for a seminar with aim to collect generalizable barriers for the use and implementation of agile methods and Self-organizing teams. The findings were summarized under three main topics, namely, development process conflicts, Business process conflicts, and people conflicts (Boehm & Turner, 2005).

Development process conflicts regards issues connected to the combining of traditional stage-gate methods and project teams with agile self-organizing teams. These problems are mainly connected to the scalability issues inherent in agile methods, where agile and self-organizing teams are sufficient on small scale and has proven to be successful in small, pilot projects. However, the contributors at the seminar agreed on insufficiencies when trying to scale-up. Regarding business process conflicts, one main finding was identified, the traditional business process demands accurate predictions and handles the ambiguity poorly. The agile approach is developed around an ever-changing environment and the horizon is short and traditional firms often get scared by the high level of uncertainty. The last identified topic, people-oriented issues, occurs at all firms at all times, however in varying intensity. The main finding in this topic is that it is hard to recognize and reward important individuals enough during and after pilots for them to become champions for the new way of working. The main conclusion from the seminar is that communication and education is key in order to have a successful implementation of Self-organizing agile teams. The day to day communication is important and to continuously bring up discussion on the topic to keep it alive. The education and information are also key in the implementation process to lower the ambiguity regarding internal processes.

Moe et al. (2008) has identified several barriers for working in self-organizing teams, the three most important being; High specialization, Individual focus and Decisions from the outside. The first barrier, High specialization, refers to the team members high specialization in a narrow area. If team members have too narrow areas of expertise, it reduces the flexibility of the team and the possibility to cooperate to reach solutions. However, developing and recruiting team members that are multi skilled in a variety of areas is both complicated and costly (Kakar, 2017). The second barrier, Individual focus, refers to team members tendency to focus on individual goals instead of the team's joint goals or mission. When team members put too much effort on individual goals, it might result in people taking less responsibility for the team's delivery. The final barrier is Decision from the outside, which refers to times when decisions regarding the delivery are made outside of the product team. The author claims that this can make the team members identify less with the project and, therefore, contribute less to the solution.

2.2.3.2 - Criteria for succeeding with self-organizing teams

Working in self organizing teams has several differences compared to working in traditional project teams. This requires team members to adapt and develop themselves to fit the new structure. Hoda et al. (2010) shows that self-organizing teams need to build focus, mutual trust and respect among its members. Expanding on this, Hoda et al. (2011) also claims that customer involvement is key to succeed with self-organizing teams. To develop the three main criterias of self-organizing teams within an organization there is, according to Kakar (2017), important that employees feel trusted to be able to contribute. Teams that are able to be in charge of their own development is more likely to develop new capabilities and take on new initiatives and responsibilities. Furthermore, engagement and loyalty to the organization will be increased which leads to a greater commitment to the overall delivery.

2.2.2.3 - Benefits of Self-organizing teams

The missions with most organizational change is to improve the current state, which is why it is important to understand what benefits can be gained from said change. Therefore, the benefits of implementing self-organizing teams needs to be understood. One benefit is identified by

Hoda et al. (2010), who claims that the speed and accuracy of problem solving can be improved in self-organizing teams because the authority for decision making is moved to executing levels of the organization. Teams can avoid lengthy wait times from decision forums if they can steer their project themselves. If successful in a hardware environment, Self-organizing teams could lead to decreased lead times, time to market and internal friction in the organization (Schilling & Hill, 1998).

Self-organizing teams can also create a sense of ownership for the team members, since they involve all members. Moe et al. (2008) claims that members of self-organizing teams have a greater motivation to perform in comparison to traditional project teams. The author also claims that self-organizing team members have a greater desire for responsibility. Another benefit from self-organization is derived from autonomy, where quick reactions can be achieved as a result of removed bureaucracy (Patanakul et.al, 2012).

2.3- Agile

At the end of the 20th century, many industries started to experience a more rapid rate of technological change. This meant an increase in changes from customers throughout software development, as customers were unable to specify correct demands at the start of projects (Cohen et al., 2004). The reaction from the software industry was to create new software development methods, which enabled quick changes within a project. These methods were named as ‘Agile methods’, and included Scrum, Extreme Programming, Dynamic Systems Development, among others (Rico et al., 2009). Although these methods were developed for similar purposes, there was a lack of agreement between them. To create cohesiveness for the movement, several spokesmen for the agile methods decided to meet in 2001 to find a common ground (Beck et al., 2001). The result of this meeting was the Agile Manifesto, which four major statements are presented in figure 3 below;

1. Individuals and interactions over processes and tools
2. Working software over comprehensive documentation
3. Customer collaboration over contact negotiation
4. Responding to change over following a plan

Figure 3 - Statements of the agile manifesto

Agile has since become popular within the software industry, where it provides companies with flexibility and adaptability in their product development activities according to Cooper & Sommer (2016). They also claim that hardware developing companies are investigating the application of agile methods based on the previously mentioned benefits. In addition to the four major statements in the agile manifesto, the spokesmen also presented a list of 12 principles which contain the core beliefs of the agile methodology (Beck et al., 2001). One of these principles regards self-organizing teams and is expressed as following “The best architectures, requirements, and designs emerge from self-organizing teams”.

2.3.1- SCRUM

According to Cohen et al. (2004), Scrum is one of the most common Agile methods. The creation of Scrum can be traced back to 1993, when the first scrum team was assembled at Easel Corp. (Sims & Johnson, 2011). The method is based on work performed in 30-day cycles, referred to as “sprints” (Larman & Basili, 2003). In these sprints, the developers take customer demands into consideration and break them down into work tasks that can be accomplished within the time frame. The work is later prioritized, and developers can choose a task to work on from this collection (Cohen et al., 2004). The work group also maintains constant communication, where meetings are held every day throughout the sprint.

2.3.2 - SCALABILITY ISSUES IN AGILE ORGANIZATIONS

As previously stated, agile methods originate from the software and IT industry, where many successful user cases and implementations has shown the strengths of working with varieties of the agile methods (Cooper & sommer, 2018). As other types of corporations now investigate how to apply agile methods into their operations, a difficulty arises, scalability. The need for large corporations to be able to adapt current methods to be more flexible and at the same time remain control and insight into details is a recurring problem. To be able to implement agile methods into large scale development of physical products the teams and processes needs to be scalable in a suitable way for the specific company.

Cooper and Sommer, (2016) provide three main challenges connected to the scalability issues that separates software and hardware development processes. First, long term planning and targets must align with the short-term flow desired in the agile process. Consequently, the company needs to find the “right” balance between the two. For this to happen management needs to trust the development teams enough and not specify deliverables too early in the process and planning activities needs to be adapted to the new flow focused process. Second, defining where to implement agile methods. Since Cooper and Sommer (2016) are suggesting an agile hybrid approach it becomes highly important to identify parts and processes of the organization that are compatible with such methods. The authors claim that the traditional stage-gate methods can be sufficient for projects in mature and known markets whilst agile methods should be utilized in projects with high level of ambiguity and uncertainty. This is also strengthened by Dybå & Dingsör (2008), who claim that agile methods can be combined with traditional processes, such as stage-gate. The third highlighted issue, according to Cooper and Sommer (2016), regards implementation. To avoid complication during implementation it is important to align management by-in and to develop an implementation processes that builds on learning within the firm.

2.4 - TRANSLATING SOFTWARE METHODS TO HARDWARE ENVIRONMENTS

There are some crucial differences in the creation software and hardware products. Although some of these differences can be derived from a variation in mentality between hardware and software industries, there are also clear limitations for developing hardware compared to software. For example, Laanti (2016) suggests that there are clear barriers in flexibility for hardware development. Software development methods, such as iterative software development and scrum, involve building the product in time boxed iterations (Jalote et al, 2004; Cooper & Sommer, 2018). This differs from traditional product development methods, which is often more linear. However, Both Laanti (2016) and Punkka (2012) still claim that hardware products can be built in iterations, developing the product one step at a time.

The use of up-front prototyping is suggested by Punkka (2012) as a means to work iteratively with hardware. This means that prototypes are continuously built and revised throughout the development process, instead of just building them in the end to test a finished solution. The process of creating a prototype and receiving feedback on it can be interpreted as one iteration or cycle. The success of some product development cases can be related directly to the speed of these cycles (Laanti, 2016). A development project can, consequently, gain success by improving their cycle speed. This is similar to traditional agile methodologies and SAFe, where iterations are time framed for efficiency. In addition to this, Punkka (2012) further states that agile methodologies can be used in hardware to create more optimized designs.

2.5 - Operationalization of Criterias for Self-Organization

The following operationalizations aims to explain how this study has interpreted self-organization. By breaking down the capabilities for self-organizations presented by Takeuchi & Nonaka (1986), this study has created eight subcategories for assessing self-organization. In the following section each subcategory is elaborated upon with a short sentence describing the meaning of each statement.

2.5.1 - Autonomy

One of the three criteria for self-organization suggested by Takeuchi & Nonaka (1986) is Autonomy. Oxford dictionaries defines autonomy as “The right or condition of self-government” (“Autonomy”, 2018). A similar definition is expressed by the previous author, who claims that an important part of autonomy is a team’s freedom from senior management. This research will study autonomy based on the following aspects;

Ability for team members to create or steer their own work tasks.
Although the team might have goals that they work towards, the team members still control which tasks they chose to contribute towards that goal.

Self-controlled work processes
When a team member has chosen or received a task to work on, they can decide how they want to accomplish that task themselves.

Detached senior management
Senior management has little or no say about the work on a team-level so long as the team accomplishes their mission.

2.5.2 - Self-transcendence

Takeuchi & Nonaka (1986) mentions self-transcendence as the third criteria for self-organizing team. The author states that self-transcendent teams are on a “*never-ending quest for the limit*”. The term can be interpreted as the ability of one individual to work for the good of the group or organization instead of their own personal gain. This research will assess self-transcendence based on the following criteria;

Problem ownership
The team possesses full ownership of the product and its connected problems. It is their responsibility to make necessary adaptations in order to reach a better result and to outline their capacity.

Holistic problem solving
Members of the team actively try to reach solutions that will benefit the larger deliverance rather than their own sub-component.

2.5.3 - Cross-fertilization

The final criteria for self-organizing teams in The new new product development game (Takeuchi & Nonaka, 1986) is Cross-fertilization. The authors elaborate on the term and states that it refers to teams that are composed of members that are different from each other in; functional specialization, thought patterns and behavior patterns. This research will analyze cross-fertilization based on three criteria;

Un-homogeneous groups
Teams consist of members that are different in the three measures mentioned above.

Accessibility
Information that is relevant for the project is spread to all team members, where the core members are also co-located.

Team member involvement
All team members are encouraged to take part in problem solving activities and knowledge sharing is part of daily work.

2.6 Maturity Assessment Matrix (Assessing maturity for S-O)

The Enterprise Maturity Matrix (EMM) was first presented by Albu & Panzar (2010). It was developed by combining different operation assessment tools with the aim of creating a more comprehensive model. The EMM model was developed for assessing the maturity level of an organization based on different elements. Elements are the important aspects of the organization that is being rated based on four maturity levels. Albu & Panzar (2010) further explains the importance of maturity alignment, which in the context of the EMM model means alignment between the different organizational elements. For an organization to deliver high performance and live up to its vision missions and goals, it is important to align maturity of each element of the organization (Albu & Panzar, 2010). By assessing the organization based on these different stages a line can be drawn through each level, which then represent the assessed maturity of the organization. This line should preferably be straight from top to bottom to gain desired maturity alignment.

2.7 - DEFINITIONS

2.7.1- SELF-ORGANIZING TEAMS

This study examines organizational and product related challenges for implementation of self-organizing teams. As has been previously stated, self-organizing teams has great similarities to other autonomous setups, *e.g.* autonomous teams and self-managing teams. Self-organizing teams are defined as teams that are managed, organized and steered of the team itself.

2.7.2- MODULARITY

Modularity in a product is described by Baldwin & Clark (2003) as "*Building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole"*. The authors further state that companies have adapted this approach to handle the increasingly complex technology in modern products, which requires the product to be divided into smaller subsystems. The development of a product will, thus, require less ongoing communication between the developers and, therefore, less coordination between the development teams according to Sanchez & Mahoney (1996). The same authors also state that some companies are looking to adapt modularity to create self-organizing processes within their organization. Other benefits from modularity includes increased flexibility in product development and an increased variation of end products (Sanchez & Mahoney, 1996; Baldwin & Clark, 2003).

The definition of modularity that was used throughout this research is presented by Marion (2010) as "Product modularity is a method of designing a product based on well-defined interfaces and architecture that fosters the organization of complex designs and process operations more efficiently by decomposing complex systems into simpler subsystems". This definition entails that a sub-system becomes increasingly modular the stricter defined its external interfaces are, where the autonomy of development activities for a subsystem are related to its degree of modularity.

3 - Case Description

The following chapter aims to explain the setting in which this case study was carried out. The chapter starts by introducing Volvo Car Corporation (VCC). The contextual information regarding project and product structure is later presented followed by a final section covering the organizational challenges and trends within VCC. The information in this chapter was deemed necessary support for the reader to understand conclusions drawn throughout the remainder of the report.

3.1 - Introduction of Volvo Car Corporation (VCC)

VCC is a global car manufacturer which was founded in Gothenburg, 1927. The company still has a substantial amount of their business located in Gothenburg, including production, research and development and, their headquarters. VCC was acquired from Ford by Geely Holding Group in 2010. The new ownership has, among other things, transformed VCC into a more global company, where some research and development departments have expanded to China and production now runs global in USA, Europe and China. The acquisition by Geely Holding Group has also affected the long term strategic goal of VCC. One of the new main targets is to become one of the large manufacturers of premium cars.

3.1.1- Organizational structure of VCC

VCC's operational work has been divided into twelve main business functions, where each function is focused on one specific delivery. One of these functions is Product and Quality, which is responsible for delivering the entire car and its design. Product and quality is divided into six subunits, specializing in different areas. Among these is Vehicle Hardware, which delivers hardware solutions to the car. Vehicle Hardware is composed of six departments, where each department is responsible for one delivery to the complete vehicle hardware. Interior, which is one of these departments, is responsible for the development of all interior hardware in a car. The organizational breakdown of VCC can be seen in figure 4 below.

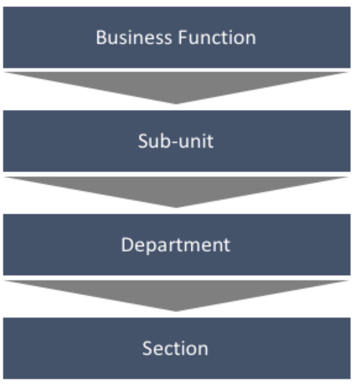

Figure 4 - Breakdown structure of vcc's organization

Finally, the interior department is divided into four sections with different deliverables. This research has been carried out at one of these sections, Cockpit and Surface materials, which will, henceforth, be referred to as PSS140. This section is responsible for delivering all hardware in the instrument panel as well as the tunnel console of the car.

The organizational structure on section level is divided into two main areas; the project and the line. In the line organization, the employees are divided into groups, *i.e.* Tunnel Console, which are connected to their work specialization. Each group is controlled by a Group Manager (GM), which has the ultimate responsibility for the technical delivery in their field. The employee with the utmost authority is the Section Manager (SM), who, similarly, has the ultimate responsibility for the technical delivery of the whole section.

The work on section level is, however, structured around projects. The project teams have their own hierarchy, where the member with the utmost authority within the section is the Section Project Leader (SPL). Although the SPL has a GM which they report to within the department, their project related responsibility is towards their Unit Program Leader (UPL) and Technical Project Leader (TPL), both located outside of the section. The direct effect is that each employee has a minimum of two entities that they report to. An illustration of the difference in hierarchy between the project and line organization can be seen in figure 5 below.

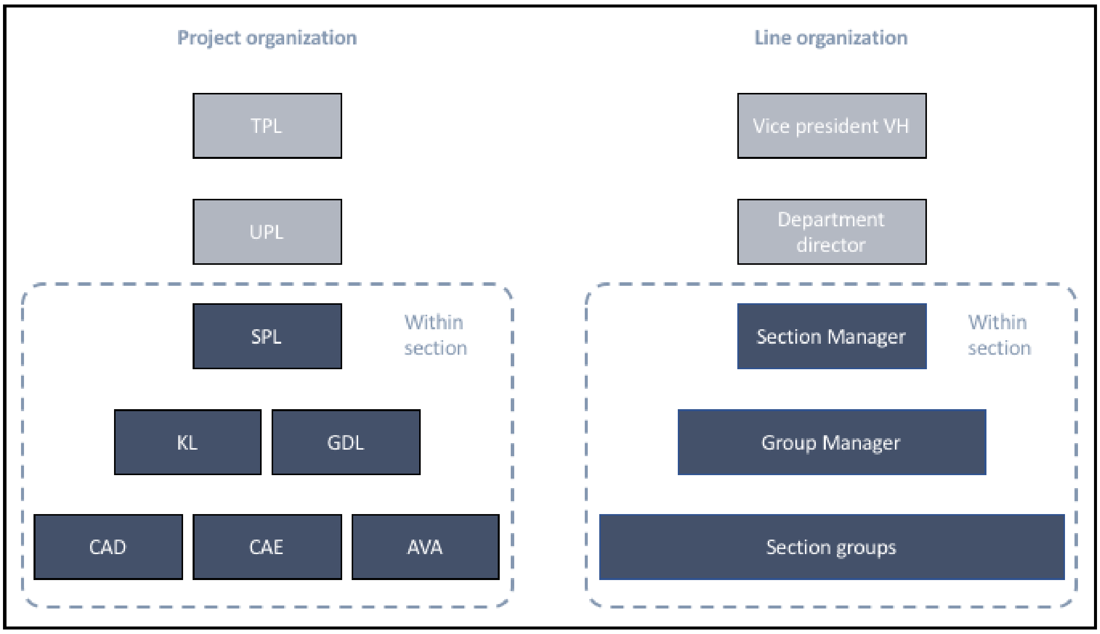

Figure 5 - Illustration of line and project organization on department level

3.1.2 - Introduction to PSS140

PSS140, Cockpit & Surface Materials, is responsible for developing the instrument panel in the cars together with the tunnel console between the front seats in all ongoing car projects at VCC. This means that there are several ongoing projects in parallel. Furthermore, PSS140 is not only responsible for new models, as they also handle updates and changes in existing models. In total there are approximately 140 persons working at PSS140 and they are divided by areas of competence into seven different groups focusing on different parts of the instrument panel and tunnel console projects, see figure 6 (the surface material group is excluded from this study hence it is not included in the figure below). All groups except the project execution group are similarly structured with several group design leaders (GDL), design leaders (DL), and design engineers (CAD) in each group. The project execution group consists of some other competences *e.g.* system program leaders (SPL), Analysis and verification engineers (AVA), and system answerables (SA). These roles work cross functional through several projects simultaneously and has a more holistic project perspective and do not work with specific technical problems. These six groups belong to the line organization who then assigns resources to the project organization. By using resources from different groups, the project organization is provided with the competence needed in each of the ongoing projects. The specific project analyzed in this study is a new platform project. This implies that more resources and time has been put into the project compared to a scaled or updated car model project.

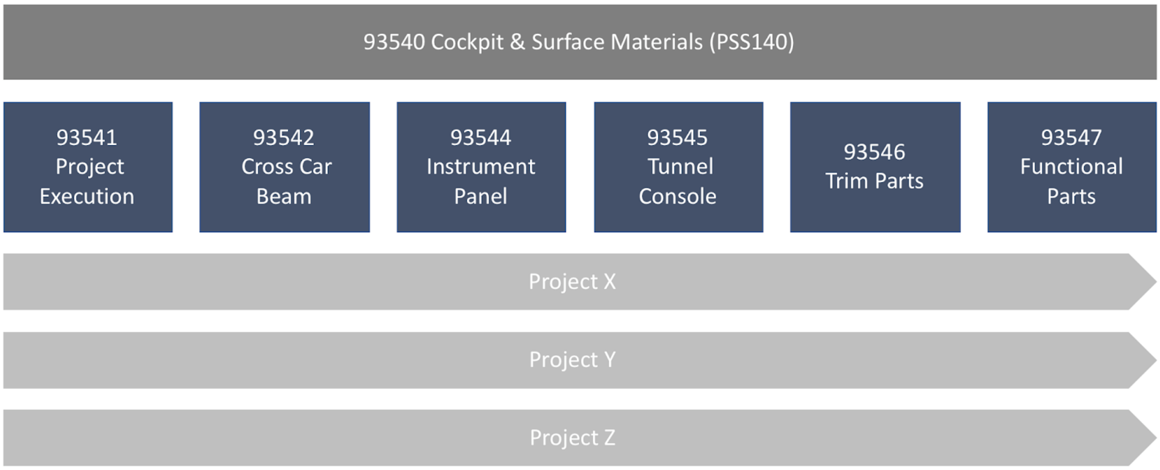

Figure 6 - Organizational structure on section level

3.2 - Project structure

The project development process follows a generic structure that synchronizes with the work outside the department. To coordinate activities among the different sections, they share several deadlines, often referred to as gates. In a broader spectrum, the work can be divided into four different phases; Program strategy phase, Concept phase, Engineering phase and, Industrialization phase. Among these, the latter three phases involve work conducted at PSS140, whereas the first phase is mainly conducted outside the section. Figure 7 gives a visual representation of the different phases.

Figure 7 - Development phases

3.2.1 – Concept phase

When initial strategic goals have been set and approved the concept phase starts. The concept phase aims to investigate what goals should be set for the specific project. At this stage, alternatives for both manufacturing and design solutions are tested. At the end of the concept phase, finances and program targets for the project should be set and communicated to the project group.

3.2.2- ENGINEERING PHASE

The engineering phase is where production of 3D-models, blueprints and project related content begins. This phase is focused on creating the product based on the targets set in the concept phase. However, as many projects need to adjust their budget or targets after some time has passed, the engineering phase allows for a business review during its progress. The engineering phase progresses until the development has reached a point at which tools can be ordered for manufacturing.

3.2.3- INDUSTRIALIZATION PHASE

The industrialization phase aims to transfer the developed concepts into manufacturable components. The focus in this phase is to verify what has been developed in the previous phase. One of the main focus areas during this phase is to ensure that the complete vehicle will work when parts developed separately are combined. The phase ends when mass production of the vehicle has been confirmed and lessons from the project has been incorporated into the organization.

3.3 - PRODUCT INTEGRATION

The developing departments at VCC deliver their product solutions to something called the block, where coordination towards other interfaces takes place. A block is a restrained section of the car, which includes a number of different sub-areas. To be more precise, a block is one part of the car that is limited by its physical constraints. VCC coordinates their development activities through seven blocks, that together creates a complete vehicle when combined. The block portioning of the car can be seen in figure 8 below. The aim of working in blocks is to coordinate the overall cost of the vehicle while simultaneously managing and coordinating the interfaces within the car. However, the block, does not have any economic responsibilities, only to coordinate the overall cost of all blocks.

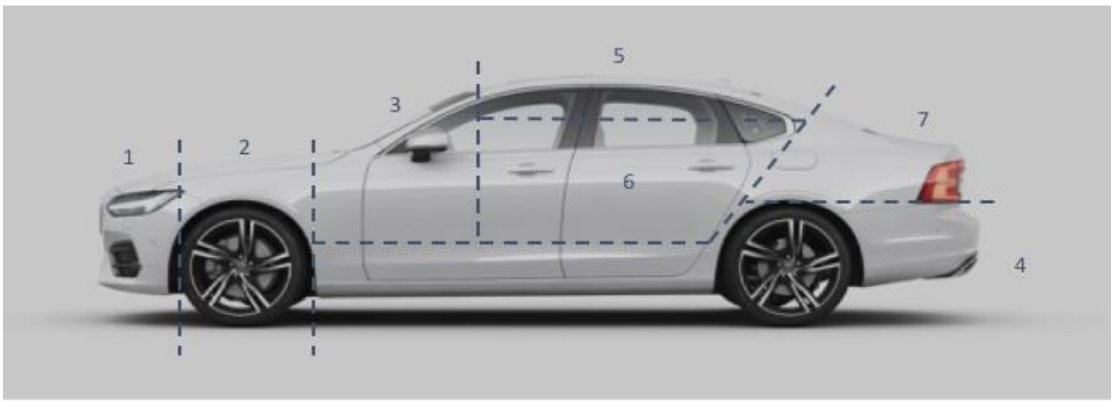

Figure 8 - Block portioning; 1. Front end, 2 . Engine bay, 3. Dash and cowl, 4. Floor, 5. Roof, 6. Side & door, 7. Rear end

3.4 - ORGANIZATIONAL CHANGES WITHIN VCC

The development process utilized at VCC is detailed and comprehensive and has been developed over long time. It has been revised and adapted to better fit the incremental changes that has occurred in the industry over the past decades. What the car industry encounters today, however, is a disruption that drastically changes conditions in the car industry. The market has changed along with the digitalization trend, electrification and shorter product life cycles. A product life cycle that 10-15 years ago lasted for 5 to 10 years only lasts for about 3 to 5 years today. In VCC's case, this has meant going from developing one car model or one platform at the time to doing several development projects in parallel. In addition, VCC currently develop all parts of the car internally and do not outsource development to suppliers anymore. As a consequence, VCC has recognized lead times, flexibility and responsiveness to late changes in the process as core issues within the company, which has led to an initiative for organizational change.

In order to shorten lead times and increase flexibility, VCC has identified opportunities in the use of Agile methods *i.e.* the Scaled Agile Framework (SAFe). However, as most of the agile methods originate from software environments, VCC has seen the need to adapt these methods to better fit hardware environment and their organization in general since there are no "on the shelf" solution for such large organizations working with hardware. One of the core concepts in many agile methods are self-organizing teams. It is, therefore, necessary for VCC to understand how self-organizing teams can be incorporated in a hardware environment.

3.5 - SCALED AGILE FRAMEWORK

VCC has started an agile transformation journey which aligns with the Scaled Agile Framework (SAFe) and, in order to understand the outline of the framework, a brief summary will follow. In appendix I a more detailed description of the SAFe framework can be found.

SAFe is a framework developed for agile implementations in large organizations where scalability is a prerequisite. The SAFe framework provides the organization with roadmap architecture for implementation as well as processes for an agile workflow. The SAFe framework provides guidance for role definition and who is responsible for what as well as for other activities important in order to achieve improved business performance. SAFe was developed as a consequence of the emerging situation where companies wanted to implement agile methods in more than one team. In, for example, the car industry, demands on lead-, development- and production times increased to the extent that existing processes and work methods no longer were efficient enough to deliver, and enterprises seeked for a new approach.

3.5.1 - ESSENTIAL VALUES OF SAFE FRAMEWORK

To get a basic understanding of SAFe and how it is supposed to be utilized, the following sections gives a brief description of the fundamentals of the framework and what it aims to provide. By dividing a corporation into different levels and moving responsibility downwards in the organization, SAFe aims to get a more synchronized and flow-optimized organization. Cross functional self-organizing teams are responsible for the delivery of work packages that, when put together, creates a product more focused around customer demands. Below follows a description of the most essential values of the SAFe framework.

3.5.1.1 - Corporate alignment

One of the core problems, and the reason why SAFe was developed, is that agility aligns poorly with the typical large corporation set-up with focus on control and utilization efficiency. Therefore, alignment at a business strategy level is where the process of SAFe begins. By aligning and debate portfolio management at the highest level of the organization satisfaction and commitment from all corporate stakeholder can be ensured at an early stage. This is further broken down into backlogs in different workstreams at program and team level to create customer focus and alignment within the organization.

3.5.1.2 - Transparency

Another aspect that do not align well with the typical large organization is true transparency. By trusting the organization with facts and the truth regarding aims and objectives a more transparent organization can be developed. On team level this means that corporate leaders are willing to lose control and by that, giving teams responsibility to deliver what they believe is important for the project or product they are developing. However, this can only be accomplished if mutual trust between teams are apparent and that there are alignment within the organization.

3.5.1.3 - Focus on Flow

SAFe advocates focus on flow rather than focus on utilization of resources. By letting teams find the most efficient way of solving problems they can focus on continuous delivery with all necessary support available at all time. The cross functional core teams are backed by support teams with a specific task. This means, while the core team are fully occupied with core activities the support team may be less utilized. However, in SAFe this is not seen as a drawback. By focusing on the continuous flow, efficiency can be accomplished through trust and availability of competence, which guarantees continuous delivery by the core team.

3.5.2 - Self-Organization in SAFe

SAFe is focusing on true self-organizing teams. Instead of that teams are appointed to different work packages or tasks it is, in SAFe, up to the team to decide what will be delivered during the coming iteration. By bringing the work to the teams rather than, teams to a specific project or work task SAFe differs from other agile frameworks and by that promotes the prosperity of self-organizing teams within the organization. The main result of working with self-organizing teams is long lasting teams that continuously can refine their way of working cross functionally towards delivering solutions to the product stream.

3.5.3 - Criticism of SAFe

Like many other commercialized frameworks, SAFe has been criticized from both academia and practitioners within the agile movement. The main aspect pointed out is SAFe’s way of prescribing and explaining to extensively what and how to practice the framework (Francesco, 2017). Second, SAFe is criticized for not letting the team work fully agile on a team level and having a top down planning approach. This reduces the flexibility on team level and the core of agility is being limited.

4 - Research Methodology

The following chapter provides a description of the approach used during this thesis project, starting with the overall research strategy and design which is followed by an in-detail presentation of the methodology. In the end, some comments regarding trustworthiness and credibility is given.

4.1- Research approach

In order to answer the research questions for this study, a deepened understanding about the organization was required. More specifically, a need was identified to understand the contextual settings for employees at PSS140, including the organizational culture and work routines. The main data gathering methods was, therefore, chosen as unstructured and semi-structured interviews together with on site observations. In combination with a lack of structured data from the organization, this meant that there was no quantified data for the project. As quantification of the data was further deemed unnecessary to answer the research question, a qualitative research approach was chosen for the project. According to Bryman & Bell (2011), the most significant difference between the two main research approaches is that quantitative research handles measurable data while qualitative does not. They further claim that there is a correlation between qualitative research and induction as well as quantitative research and deduction. The choice of research approach is, therefore, crucial for deciding the research design.

4.2- Research design

Bryman & Bell (2011) suggests a model with six main parts that describes the general steps of qualitative research. These steps are; 1. General research, 2. Select relevant site, 3. Collect relevant data, 4. Interpretation of data, 5. Conceptual and theoretical work, 5a. Tighter specification, 5b. Further data collection, 6. Write findings conclusion. This process was largely followed throughout this project, with one clear exception – this project did not start with a general research question. Rather, the research question was formulated after the relevant site had been chosen and it was based on the availability of data at the location.

This case study was conducted through three main steps, all of which supports the overall aim of the study. First, a study of the context where the study took place was conducted. By gaining deep understanding of operations and responsibilities of the studied department within the organization, accurate input to the main study was developed. Second, the information gained in the first step was used to test the mirroring hypothesis and also to make an analysis of the organization. This was done in order to answer the three research questions. Lastly, the analysis of the studied organization in combination with existing literature on the subject of self-organizing teams was used in order to create examples of how the organization could work with self-organization in the future.

The division between literature research, empirical research and developing the framework in this research has been managed based on what the project demanded. This process, systematic combining, is suggested by Dubois & Gadde (2002) for case studies, where the cases can be built incrementally. The authors argue that traditional case research limits possibilities for the researchers, because the cases rarely reflect the standardized procedures of the research process.

4.3 – Research limitations

The research questions above could be researched and approached in different ways, which could then lead to a variety of different conclusions. In this specific study, the scope is limited to only include research and conclusions which are directly linked to the included section at VCC. The effects of the organizational transformation currently ongoing at VCC would be interesting to investigate with a wider and more covering scope. However, the limitation only to include one section was made in order to gather enough empirical data, with enough depth, and at the same time be able to present findings within the time limits of a Master thesis project.

4.4- Research methods

4.4.1 - Purpose of interviews

The purpose of the interviews was to obtain an understanding about the current state of operations at PSS140. This was accomplished by investigating key communication patterns for the employees within the department and the current fulfilment of the criteria for self-organizing teams. This qualitative fundament was later to be used to create a map over the organization and how different roles interacts throughout project execution phases. Furthermore, an analysis was conducted to identify potential strengths and weaknesses for future organizational transformations towards a more flexible organization.

4.4.2 - Interview methods

This project incorporated interviews during two phases; The pre-study and the mapping phase. The interviews were conducted using two separate methods; semi-structured interviews and unstructured interviews. The unstructured interviews were held during the pre-study, when there was greater uncertainty about what information was needed from the respondent.

4.4.2.1 - Unstructured interviews

The main purpose of using the unstructured interviews at early phases was to fill the gap in knowledge needed between the pre-study phase to the first mapping phase. More specifically, they were used to gain the necessary information needed to formulate the interview question for the first mapping phase. This is supported by Bernard (2011), who suggests the use of unstructured interviews to create the interview guide for semi-structured interviews.

Bryman & Bell (2011) explains that unstructured interviews are similar to a conversation, where the respondent is asked to elaborate upon one or a few main questions. This method enables the respondent to speak freely about the topic in focus, and it is up to the interviewers to steer the conversation when needed. It is, therefore, also a useful method for finding new areas of research that the interviewers had not earlier considered important.

4.4.2.2 Semi-structured interviews

The semi-structured interviews were held during the mapping phase, after an initial understanding about the department had been gained. The main purpose of these interviews was to expand on the knowledge about the current operations at PSS140. The respondents were asked a series of questions from an interview guide, where the questions were covered in the same order for all respondents. Furthermore, the respondents were, as recommended by Bryman & Bell (2011), given much freedom in their reply to the questions, which provided an opportunity to discover further areas of interest. In addition to answering the questions from the interview guide, the respondents were also asked to create a visualization of their most important communication links. In order to minimize the researchers having influence on the visualization, the respondents were given much freedom in how to construct the illustration and were only provided with a pen and paper.

4.4.3 - WORKSHOP

After an initial map of the organizational architecture had been created, a workshop was held with employees from PSS140. The purpose of the workshop was twofold; First, it aimed to validate the initial organizational map that had been created. The respondents were provided with a printed picture of their role in the map, showing all direct connection of their role. An interactive version of the organizational map was also provided for the respondents, which could be used for greater clarification of the connections.

Second, the workshop aimed to uncover how the employees felt about implementing self-organizing teams in their section. The respondents were presented seven hypotheses, which forecasted changes connected to the three criteria for self-organizing teams. These seven hypotheses were consciously provocatively formulated in order to create an instant and honest reaction from the participants. The respondents were provided with a printed version of the hypotheses, which they were asked to read through and write down their initial thoughts regarding the different statements about the new organization. The respondents thoughts and ideas were then used in the evaluation and to identify potential threats with increased self-organization.

4.4.4 - OBSERVATIONS

This study has gathered information through observations at the contextual location, where the researchers have immersed themselves throughout the data gathering process. This is referred to as a "gemba study" in the lean methodology (Liker & Meier, 2006), where researchers are encouraged to make active observations at the floor level to find conclusions. Mulhall (2003) presents two methods for using observations in research; structured observations and unstructured observations. This research has followed the second method, where minimal assumptions were hypothesized about the results from the observations. Apart from providing valuable new information, the observations have helped to strengthen results from interviews and the workshop.

4.4.5 - SELECTION OF INDIVIDUALS FOR INTERVIEWS

The two phases of empirical data gathering for this study were conducted using separate interview methods. The selection of individuals for interviews during these phases are presented below.

4.4.5.1 - Pre-study

The main goal of the pre-study was to gain an initial understanding about the department where this work was completed. However, the pre-study was also used to create the interview guide for the first mapping phase. As the project aimed to understand how all the roles in the section was connected to each other, the first goal was to interview at least one person from each position. However, as the interviews progressed, it became apparent that some of the roles were cross-functional among project teams. Therefore, the focus of the pre-study changed to an investigation of the roles in a specific project team.

Respondents were initially chosen based on advice from one of the managers of the section. As the interviews progressed and an initial map of the projects was created, the respondents were later rather chosen based on their connection to other roles within the project teams. Based on this map, which was continuously updated between the interviews, it could be ensured that all communication paths were covered.

4.4.5.2 - Mapping phase

The selection of individuals for the interviews of the mapping phase was done systematically by choosing respondents connected to a specific project at PSS140. The respondents were chosen based on their role in the project. In such, interviews were held with employees from all roles in the analyzed project. As the interviews progressed, a need to interview representatives from external departments was identified. Based on this, interviews were held with representatives from three external departments; Design, ME and Service.

4.4.6 Literature review

The literature study of this research was performed incrementally throughout the entire project. This method for literature research is suggested by Dubois & Gadde (2002), through the use of systematic combining. The method suggests that literature studies should be conducted continuously during the entire research project.

Bryman & Bell (2011) states that business studies generally originate from literature provided to the researchers before a project is initiated, which is also correct for this study. This project was initiated on the behalf a supervisor at Chalmers, whom also provided a base of articles for the area of research. The remainder of the literature was gathered through searches in scholarly databases, such as Google Scholar and Chalmers library. The main keywords for the searches was; Self-organizing teams, Autonomous Teams, Agile teams, Agile, Agile in hardware, Self-organization and Mirroring hypothesis.

4.4.7 Mapping the organization

One of the main results of this research was a map of the organizational architecture at PSS140. The data for the map was mainly gathered through the semi-structured interviews, where the respondents shared communication paths connected to their role. The organizational map was created in neo4j, which is a graph database program. The database is based on nodes, which is given a label and several properties. A graph visualization tool, Linkurious, was used to create the nodes and edges in the database. The tool allows its user to create nodes and edges through an interactive visualization of the graph, see figure 9. Furthermore, Linkurious allows a user to edit already created nodes and edges by right clicking them in the visualization.

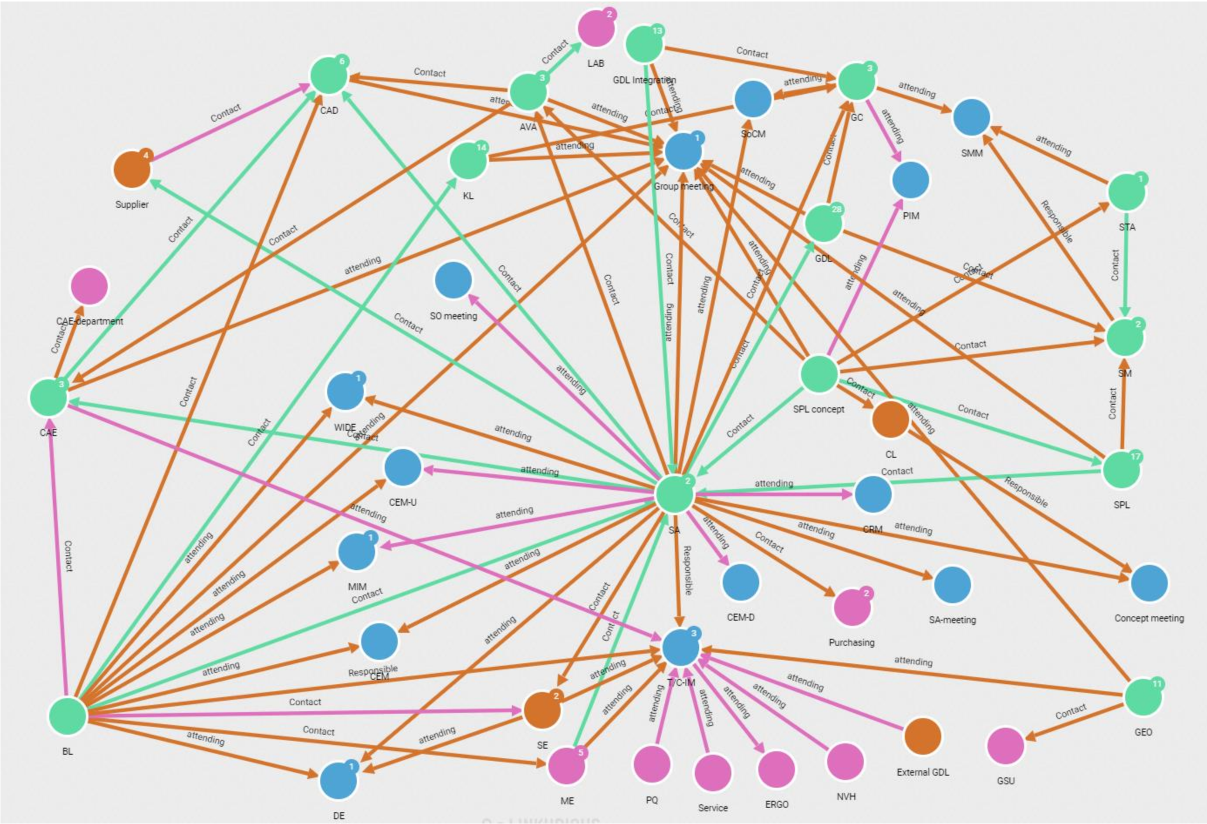

Figure 9 - Screenshot from Linkurious

The map uncovers primary and secondary connections to the chosen node. In figure 10, the role “SA” is centered, and all its connected roles and forums are showed. The color code of each node and edge can be seen in figure 10 below. For example, a green edge represents that there is a daily occurrence, each edge also as a displayed label which indicates the type of contact. Similarly, nodes have color coding representing what kind of role/forum it refers to. This method has enabled creation of a map representing existing networks of forums, roles and communication at PSS140.

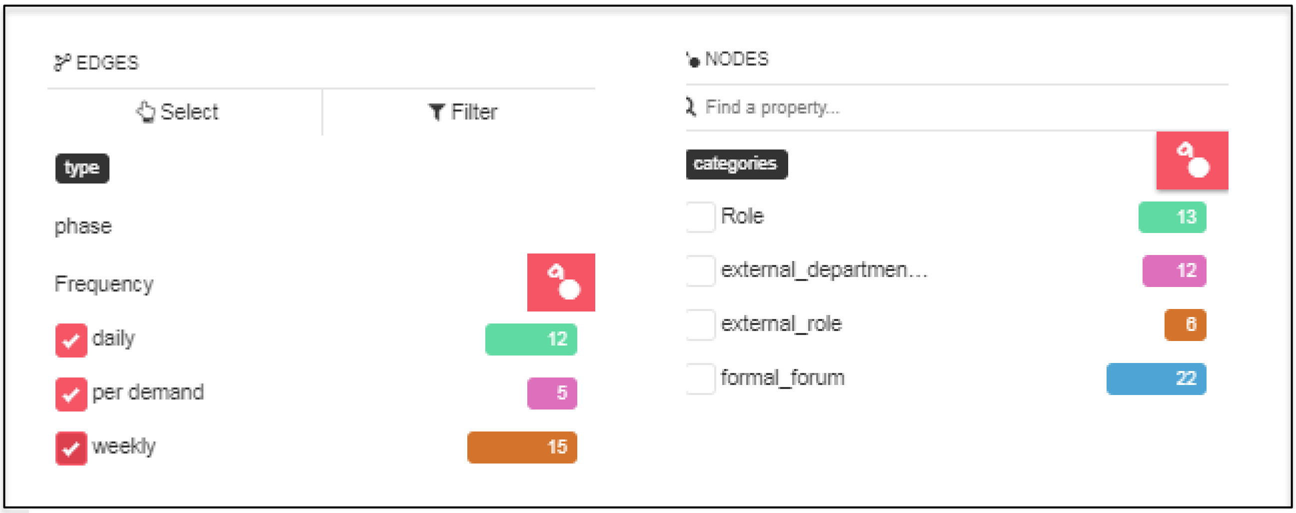

Figure 10 - Color coding for nodes and edges

4.4.8 - Maturity Assessment

When assessing the current state of PSS140, in respect to self-organization, a framework was developed for measuring the overall maturity level of the organization. The developed framework was influenced by the EMM model (Albu & Panzar, 2010) and the framework utilized by Turetken et.al, 2017. In order to make an assessment of the organization in this study, with regard to self-organization, some adoptions were made. Instead of using elements of operational character, the operationalizations of the three criteria of self-organization was used. Furthermore, each maturity level of each element was described with a short sentence of what to accomplish at each stage. Lastly, a summary of the general level of maturity for each criteria was formulated in the right column.

4.4.9 – Summary of research approach

This study aimed to investigate a department which develops complex hardware products, where a deeper understanding about the department was needed. As such, the study required data which explained the contextual setting, where a qualitative research approach chosen to be most appropriate. In order to gather the contextual data needed, interviews in combination with observations were chosen as the main data gathering methods. The complexity of the department and purpose of the study lead to the case being created incrementally. The research process, as such, was based on Systematic combining (Dubois & Gadde, 2002), where the literature research, empirical research and developing of the framework was conducted based on demand throughout the study.

4.5 - Trustworthiness

The quality of quantitative research is often assessed by measuring it on two criteria; validity and reliability (Bryman & Bell, 2011). However, as there are clear differences between quantitative and qualitative research, some frameworks for assessing the quality of qualitative has emerged (Shenton, 2004). One approach is presented by Bryman and Bell (2011) as “Alternative criteria for evaluating qualitative research”, which has two main areas; Trustworthiness and Authenticity. Trustworthiness consists of four criteria, which will be applied and discussed below.

4.5.1 - Credibility

When researchers attempt to describe the reality of a social environment, it is often done by the interpretation of the authors. The credibility of qualitative research aims to prove that researchers have interpreted the world correctly and by using the right methods (Bryman & Bell, 2011). This research has aimed to increase the credibility through two methods; a respondent validation workshop and respondent validation on a draft report.

The respondent validation workshop was held together with some of the respondents that was part of the semi-structured interviews. During the workshop, the respondents were shown a draft of the organizational map with their role highlighted in the middle. The attendees of the workshop were, thereby, able to confirm that the connections in the organizational map were correct. Some errors were found during the workshop, which were discussed and later corrected.

4.5.2 - Transferability

Qualitative research is often completed in single study cases with conditions that can make the results inapplicable outside the specific location or in another time (Bryman & Bell, 2011). The readers, therefore, need to understand the conditions under which the research was completed in order to determine the transferability of the research. This study provides the reader with specific case information in the case description chapter. The reader is, furthermore, presented with information about the specific department in the beginning of the result. With these sources of information, the reader should be able to determine if the results of this research is applicable in his or her environment.

4.5.3 - Dependability

The dependability of research refers to the possibility to confirm that the correct procedures have been followed throughout the project (Bryman & Bell, 2011). Dependability can be strengthened by auditing (Golafshani, 2003), where an external source verifies the integrity of interviews and other sources of data. This project has aimed to increase the dependability of the research by enabling a supervisor at Chalmers to verify all interview material continuously throughout the entire research process.

4.5.4 - Confirmability

Qualitative data is gathered by researchers in circumstances which often entails that complete objectivity is impossible. Confirmability refers to the possibility to show that the research has been carried out in good faith (Bryman & Bell, 2011). Similar to Dependability, this has been managed through allowing a supervisor at Chalmers to examine all empirical studies made during the research. To strengthen the confirmability of the research, data was gathered by both interviews and on-site observations. Interviews were, furthermore, held with more than one employee for every role when possible.

5 - RESULTS

The purpose of this chapter is to describe the current work environment for PSS140. This chapter has been split into three main parts. First, the current organizational structure is presented together with descriptions of the roles present at PSS140. The second sub-chapter focuses on product development, where the integration and structure of the product is described. The last sub-chapter aims to describe the current level of self-organization at PSS140.

5.1- ORGANIZATIONAL MAP

To find out existing capabilities at PSS140, from a Self-organizing perspective, an extensive interview study was conducted in combination onsite observations. The aim of the study was to create a map of the ‘real’ organization with focus on the formal and informal networks that naturally is created when people are working together towards a common goal. The following section will present the interrelationship between different roles and entities in the organization and the products they are creating. The dependency to each entity varies from phase to phase and, each phase has therefore been presented in a separate map. Furthermore, these maps represent the actual work structure and they provide insights on how the organization interacts during each phase of project execution. By gaining this understanding, the organization map can be compared to the product map. Form the result of the comparison conclusions can be drawn regarding the interdependencies between organization and product and how this relationship is affected by changes in each entity.

5.1.1- ROLE DESCRIPTION

The development process at PSS140 is carried out by a development team, consisting of a few key roles. In order to grasp their responsibilities and deliveries to the project, each role is elaborated upon below.

5.1.1.1 - SYSTEM PROJECT LEADER (SPL)

The SPL is the highest-ranking member of the project team within PSS140 and is therefore responsible for the projects delivery in time, cost and technology. Every project has one designated SPL within the section, which is responsible for the delivery from both cockpit and tunnel console. The work tasks for a SPL largely involves administrative and coordinating activities, where their strongest link within the section is towards the GDL’s. However, as the technical aspect of the project needs to be understood by the SPL as well, they also have strong communication with the DL’s.

5.1.1.2 - GROUP DESIGN LEADER (GDL)

The Group Design Leader (GDL) is one of the managerial roles within the project organization. The role can be divided into two main categories; Product GDL and Integration GDL. Although both roles have the same title, their jobs are clearly different. The product GDL is responsible for the time and cost for the development of a certain subcomponent. It is, therefore, their responsibility that the project is finished in time with the use of an appropriate amount of resources. In contrast, the integration GDL is responsible for the assembly of several subcomponents. Their tasks require them to work with interfaces both within the product block as well as between the blocks. As there is a division within the organization between Cockpit and Tunnel console, the integration GDL has significantly different role depending on where they are located.

5.1.1.3 - Design Leader (DL)

The DL, like the GDL, has a managerial role in the projects and they often work closely with the Product GDL. Although there are slight deviations between projects, the roles can be divided by one key aspect. Where the GDL is responsible for the cost and time to completion for a subcomponent, the DL is only responsible for the technical aspect of the development. The DL is, therefore, often a person with great technical knowledge about the subcomponent or the development methods. Having responsibility for the technical aspects of a subcomponent also demands greater communication with the CAD-engineers for the DL and the CAD-engineers report directly to the DL. Furthermore, the DL is often present in review meetings such as DRMP, since they have the largest amount of knowledge about the product.

5.1.1.4 - Design engineer (CAD)

The design engineers are tasked with developing the product at component level. The abbreviation CAD, Computer Aided Design, is commonly used to describe this role, since a substantial amount of their work is carried out in CAD-programs. The design engineers often carry responsibility for a specific sub-part in the project, which is linked to a sub-assembly. As an example, one design engineer could have the responsibility for developing the outer part of the glove compartment, while another has the responsibility for the inside of the glove compartment. These activities are, as previously mentioned, coordinated by the design leader, which is their strongest point of communication within the project.

5.1.1.5 - system responsible (SA)

SA is a complex role, which main work task is carried out in the concept phase of the project. The work can be described as a combination of SPL, DL and GDL during the early stages of the project, which is later delegated the respective roles before the project enters the engineering phase. The SA is, therefore, responsible for setting up the projects strategic goals and funding, communicating with other departments and, testing solutions for product design and manufacturing possibilities. In the concept phase, SA is accompanied by a concept team that consists of design engineers, which is one of their most important source of communication within the section together with CAE. Furthermore, the SA is tasked with the handover to GDL, SPL and DL at the end of the concept phase.

5.1.1.6 - Computer Aided Engineering (CAE)

An important part of hardware development for VCC is continuous evaluation of the product to ensure it meets demands related to safety and rigidness. This is partly done by the CAE-engineers, who tests the product in computer simulations. Although most CAE-engineers are disconnected from the product development sections they work with, this is not the case for PSS140. At PSS140, there is a group of CAE-engineers that solely works within the section. The CAE-engineers at the section is specialized in different areas, which means that they need close cooperation to ensure results.

5.1.1.7 - Analysis- and Verification (AVA)

AVA is responsible for coordinating all physical testing of components in a project. This includes communication with different lab functions and to provide them with sufficient material delivered from suppliers. Furthermore, the AVA is responsible for identifying where testing is needed and set up and manage requirements for different tests. There are two different types of AVA’s, Concept-AVA and Program-AVA. Concept-AVA works with multiple projects simultaneously in early phases where's the Program-AVA works dedicated to one project in later phases but with similar tasks.

5.1.2 - Phase Description

The development process at VCC is handled through a stage gate process, were work in a project is divided into four phases. However, the first phase (Program Strategy Phase) only includes task performed outside of PSS140 and has therefore been excluded in this study. At section level, the development process involves different roles during the different phases. This subchapter aims to explain the difference between phases, by presenting the work process for each stage at PSS140.

5.1.2.1 - Concept Phase

The concept phase is the second phase of a development project. It is initiated at the completion of the overall strategy for the project with the purpose of doing all necessary preparations for the engineering phase. Since the handover from the Strategy Creation Phase only provides limited information about intended tasks to perform, the departments are left with a lot of ambiguity that they must resolve. Based on this, a lot of research activities are carried out in this phase to find appropriate product concepts. The phase ends when the project team can deliver a synchronized system with approved project goals and budget.

The first step in the concept phase for PSS140 is to assign an SA and a concept team to the project. The concept team consists of design engineers that are solely active during the concept phase of the project. An AVA and CAE-engineers are also active in the concept with the overall objective to test the feasibility of developed concepts. The GDL, DL and SPL is assigned to the project in the end of the phase, where they work closely to the SA. Key responsibilities are later handed over to these roles by the SA at the end of the project. Some key handovers and assignments are illustrated in figure 11 below.

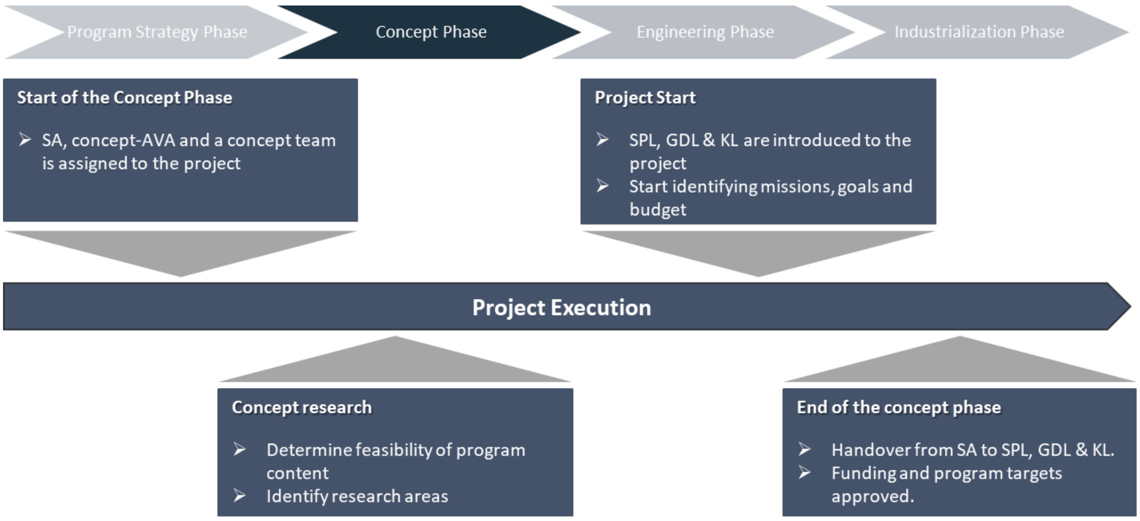

Figure 11 - Stages of the concept phase

The member with the utmost authority within the project team at PSS140 during the concept phase is the SA. In contrast to the SPL, who reports to a UPL and TPL, the SA reports to a Concept Leader (CL) in the project organization. The SA has the ultimate responsibility for key deliverances from the department during the concept phase, such as the creation of a fully synchronized system. Furthermore, the SA is tasked with the handover to the GDL, DL & SPL at the end of the concept phase.

5.1.2.2 - *ENGINEERING PHASE*

The engineering phase involves development of components that are put together in assemblies which are then compiled into a complete car. During this phase, effort is on coordination and construction in order to fit all parts together and at the same time deliver within time and budget, see figure 12 below. There are some major gates throughout the engineering phase which are performed iteratively on a twelve-week basis. In each iteration, components and blueprints are refined and after the third and last iteration the team is supposed to have buildable components ready for tool order.

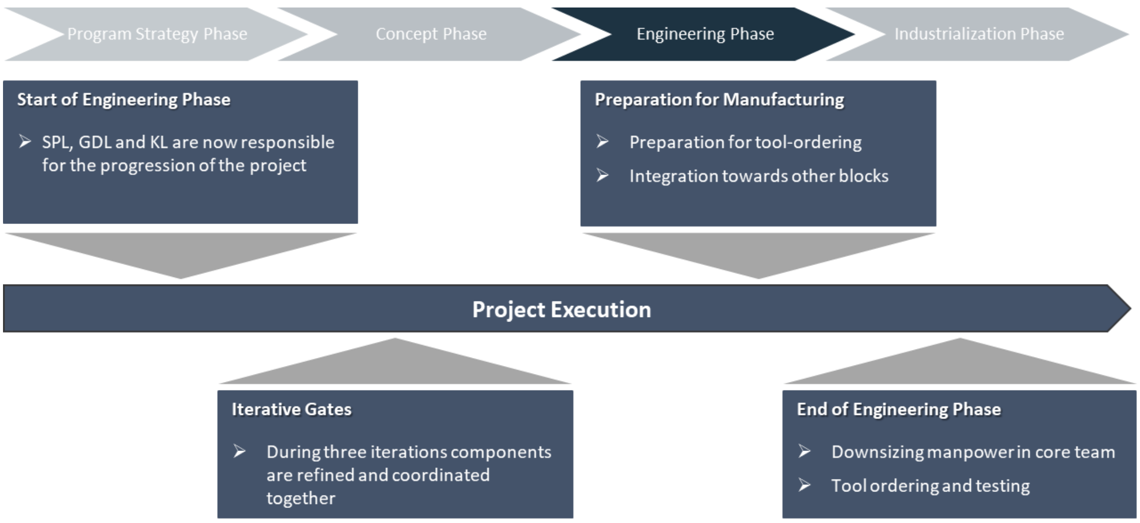

Figure 12 - Stages of the engineering phase

As previously mentioned, the SPL takes over the overall responsibility for project execution in the end of the concept phase. Main tasks for the SPL during this phase is to communicate information and issues between the project team and the overall project organization. The SPL is summoned to all meetings regarding the project with some form of decision power and speak for the project team representing their view and proposed action. The DL provides the executing team with technical and administrative support directly. DL is involved mostly in technical issues and acts as an initial link between the construction team and the suppliers in order to align technical specifications with psychical components. DL is part of the core team and communicates on daily basis with both GDL and CAD. The GDL is responsible for delivery of specific sub-assemblies of components and handles time- and cost frameworks on this level. In the same way as DL links to suppliers, the GDL communicates these aspects with suppliers to align between them and the development team.

5.1.2.3 - Industrialization Phase

The industrialization phase centers around verification and testing to make everything ready for full scale production. During this period, parts and functions are being trimmed together in order to optimize functionality and manufacturing processes. The core team is still responsible for the project. However, in the end of the industrialization phase the team is downsized to only a few people that handles incremental changes and updates for later model updates. See figure 13 blow for a phase overview.

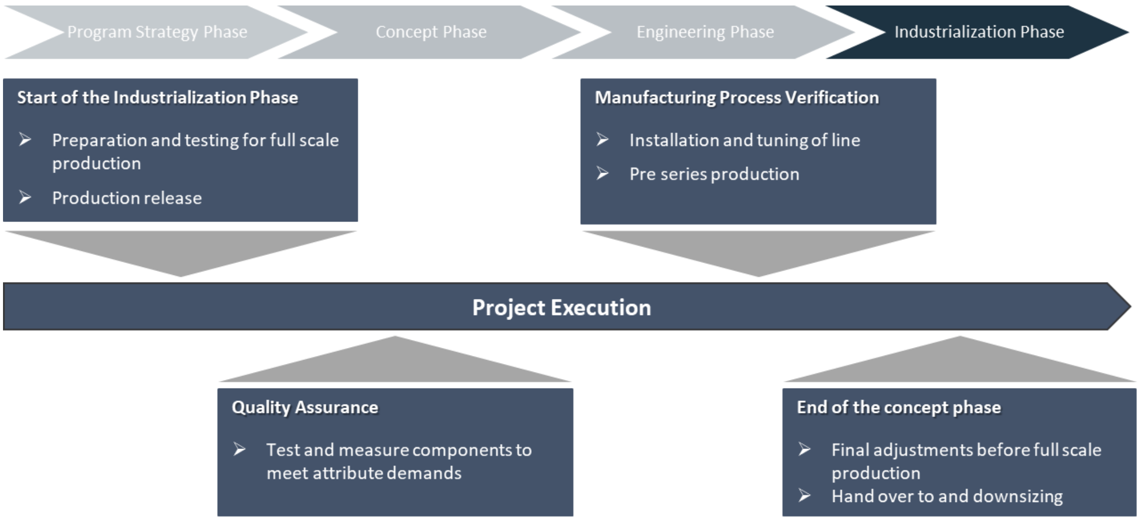

Figure 13 - Stages of the industrialization phase

During the industrialization phase the pure development of the car ends and most specifications on tools and parts are locked. This results in that it becomes difficult to make changes in the specification and rigorous processes needs to be applied to make changes at this stage. All tools are being set-up in the factory and a pre-series of cars are built and tested to make sure quality and performance measures are in line with the objectives. During this phase, the product GDL and GDL-integration work intensively to meet all requirements form the factory. All minor issues that arises during this phase are addressed by task force teams to find a suitable and efficient solution to the problem. Major issues which affects a larger part of the product or production line however must be addressed in more formal channels, *e.g.* DRM-P. During the industrialization phase the external communication, outside of PSS140, is intensified and the SPL acts as coordinating role between *e.g.* the team and concept leader.

5.1.3 - VISUALIZATION OF ORGANIZATION MAP

The result of the empirical study for the communication and information patterns for employees within PSS140 resulted in an organizational map. The map shows all direct connections from PSS140, including meetings where roles from external departments are present. Among all meetings, CIM has the most external roles present with a total of 14 roles attending the meeting. The external department with the most connections is ME, who has a total of 8 connections. Further investigations of the map enable the identification of internal roles with the most communication channels. The most connections are held by the GDL, who has 32 edges connected to its node. This is followed by the SA, who has 28, and the SPL, who has 21. However, as some of the roles are in charge of meetings, their connections might not show up as a direct link to the node. For example, the GDL CI is in charge of the CIM meeting, which was earlier shown to have 14 attending roles.

5.2 - DEVELOPMENT OF PRODUCT

This subchapter describes how the product is structured and developed through the previously presented phases. Understanding the product structure becomes crucial for the assessment and analysis of the change process. A great focus is put on product modularity in different levels of the organization to be able to find product attributes and corresponding capabilities of self-organization.

5.2.1 PRODUCT MAP

Work tasks at PSS140 are centered around the development of products and the products are, therefore, an important aspect to acknowledge. The product map aims to provide a understanding of the relationship between the product and the organization creating it and how the interface between products affect communication patterns in the organization. The product development at PSS140 starts in the concept phase, where a first draft of the finished product is created. This draft product is created by the concept team, who does necessary calculations based on the demands received from the design department in order to confirm or reject their proposal. As the project transitions into the engineering phase, the product draft is realized into more accurate models. The remainder of the development efforts for the project is, thereby, based on this first draft. The delivery from PSS140 is divided into four product areas; Instrument Panel (IP), Decor, Air vent and Cross Car Beam (CCB). Each area has their own development team, consisting of CAD-engineers who report to a DL. The CAD-engineers are responsible for sub-components for a product, which is gathered by the DL to create a sub-assembly. For example, a CAD-engineer could be responsible for the inside of a glove compartment while another CAD-engineer from the same development team is responsible for the outside of the glove compartment. The DL would in turn be responsible for the complete technical delivery of the glove compartment and distributing work tasks among the development team

Input from other departments, product areas and, attribute leaders are handled through the CIM meeting. The meeting is controlled by an Integration GDL and the DL represents the development team at these meetings. The DL is therefore responsible for transmitting the decisions from the CIM meeting to the CAD-engineers. Integration of interfaces towards other blocks in the car is handled through a Mechanical Integration Meeting (MIM), which is attended by the Integration GDL. The Integration GDL brings this information back to the CIM meetings, where it is transferred to the rest of the group. In the case of a glove box, the CIM meeting would be used to ensure its interfaces are acceptable towards the remainder of the instrument panel and that it upholds demands from all attribute leaders. In turn, the MIM meeting would ensure that the IP has acceptable interfaces towards the remainder of the cockpit as well as the other blocks of the car.

5.2.2- Product Integration at PSS140

Similarly, to the division into blocks for the whole car, the blocks are also partitioned into sub-areas. The most apparent of these at PSS140 is the division between the development of the tunnel console and the instrument panel both associated to the same block. The development activities for these areas are carried out separately and are coordinated by managing the interface they share. This is often managed through a block integration meeting called MIM, where all sub-areas of the block coordinate their interfaces to assure the functionality of the block.

However, sub-components within tunnel console and cockpit also needs coordination if they share a interface. This is managed through two coordination meetings, CIM and TIM. CIM is the Cockpit Integration Meeting, while TIM is the Tunnel Integration Meeting. Although the primary focus of these meetings are to manage the interfaces within the sub-areas, they also spread the information that is received from the MIM (Mechanical Integration Meeting) to the development team. The integration meetings enable the project team to develop their products in a modular approach, where design engineers have a lot of freedom as long as they meet the interface requirements. See figure 14 for a representation of the breakdown structure.

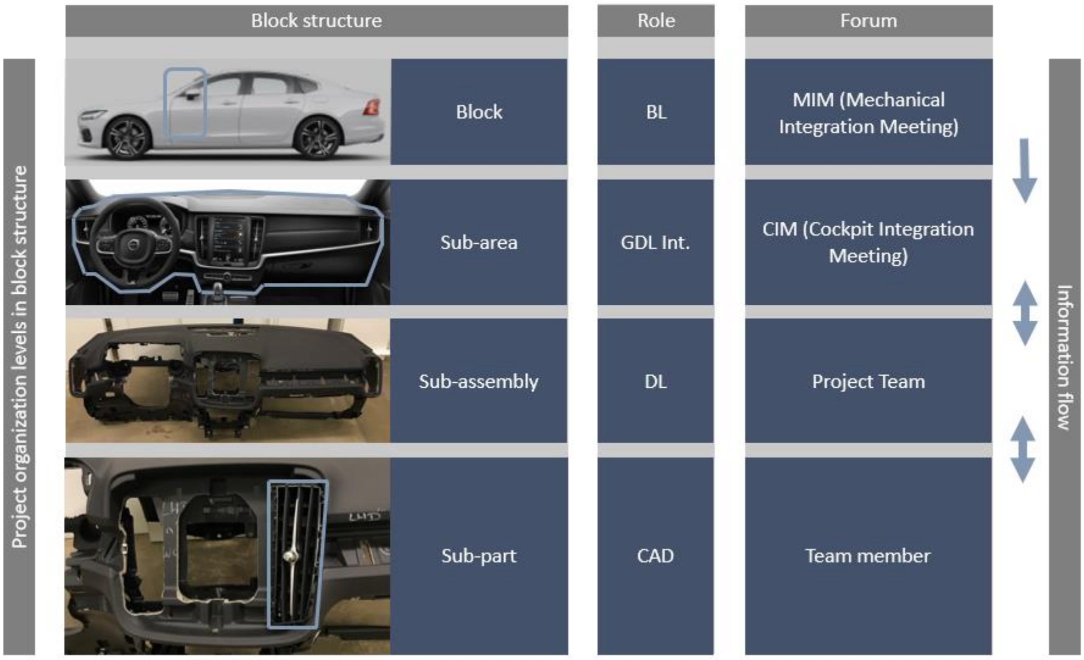

Figure 14 – Block- and meeting structure

5.2.3 - Product Structures

Similar to the block structure, there is a product structure at section level. Depending on what phase or forum, the products can be broken down in different structures. Each section in the organization is responsible for a specific part or block in the car which usually is the input structure. From the block interface the different components can be structure on different levels depending on available resources, team structure or project. Components are usually gathered in different sub-areas, organized by the physical position in the car. Each sub-area is further broken down in sub-assemblies consisting of a number of parts.

In order to handle all different parts and variants, VCC uses a component management system called KDP (Komponent Data Personvagnar). In KDP, all parts are structured on component level and each part has a position number and a function number. The position number is matched together for each part so that all parts within the sub-assembly are fitted together correctly. The position number also creates a structure for interdependencies between parts that are sharing interfaces, which is important when parts and designs are updated. In KDP, parts are given a function number which points to the functionality of the component.

However, the KDP system only handles information of administrative nature for different parts and its origin in the block structure. For handling all drawing material and 3D-models VCC uses another system called EBOM (Engineering Build Of Material). EBOM is a collaborative system which can be accessed by anyone in the design team in order to gather information about the latest updates of surrounding parts with shared interfaces. In this way, communication over interface boarders is enabled in the virtual sense.

5.2.4 - PRODUCT MODULARITY

Upon investigating the product assembly at VCC and PSS140, it quickly became apparent that the products are developed in a modular manner throughout the organization. Several respondents from the interviews claimed that modularity was necessity to the sections project team for them to develop their sub-parts independently. However, the same respondents claimed that components at the section were developed in a less modular approach.

At the start of a new car development project at VCC, the project team is responsible for setting the outer interfaces of the block. When all blocks have gathered a draft of their delivery to the final car, the exterior interfaces are formally frozen for the remainder of the project. As the exterior interfaces are frozen in the concept phase, the project team that develops the product in the engineering phase will have a highly modular block structure set at the start of their work. However, the interfaces within the block are not as rigid and can, therefore, be subject to changes throughout the engineering phase.

Interfaces within the block are set and coordinated differently depending on whether they are within a sections limits or an interface between two sections sub-assemblies. When two sections have an interface between their products it is managed through a formal MIM-meeting, where both sections are represented by their GDL-integration for the project. These meetings are held once a week with little flexibility, which means that some formal exterior interfaces are set between the sections.

Interfaces for sub-parts that are developed within the project team at PSS140 are formally managed through a CIM-meeting. However, the design engineers that share interfaces within PSS140 has daily informal communication with each other and are supported by the same DL. Furthermore, the sub-parts that are developed at this level rarely have any formal frozen interfaces. Instead, the design engineers and their DL decide upon the interfaces through constant communication.

5.2.5 - PRODUCT PROTOTYPING

The development process at PSS140 is largely done in a computer environment, where CAD-engineers use software to develop and design their product. The product is also revised and tested in computer simulations during the development project. This is accomplished by collaboration between the CAD-engineers and CAE, where the CAD-engineers can send a design they are working on to the CAE for testing. Once tested, CAE will return the design with test result and improvement suggestions, often within a few days, enabling the CAD-engineer to improve the product. Physical products and models are also put in display and are being used as communication platform when discussion technical solutions with engineers, both external and within the section.

5.3 - SELF-ORGANIZATION AT PSS140

To understand how PSS140 operates today in respect to self-organization, the interview respondents were asked a series of question about this topic during the interview phase. The questions were developed according to the previously stated definition of Self-organization provided by Takeuchi & Nonaka, (1986) which then were aligned with the operationalizations developed for this study. The interviews together with observations made during the study has provided an as-is mapping of the current operations at PSS140. The results from the mapping follows below.

5.3.1 - AUTONOMY

In a large and complex organization like VCC, there is no aligned process on team or individual level between different sections. The work processes are, therefore, often different for each team in the project. The general level of autonomy at PSS140 is deemed to be high and all the employees at PSS140 which were interviewed during the study claimed that the level of autonomy in day to day work was high or very high. The respondent's opinion regarding the high level of autonomy was generally positive and they see autonomy as a key aspect in order to complete work task in an efficient way. A few respondents could, however, see that the high level of autonomy sometimes could lead to a lack of focus on the main task. These respondents mainly had supportive roles and worked with more than one project at the same time.

The general trend indicates that, as an employee gains more seniority in their role, autonomy both becomes easier to handle and is deemed more important. In contrast, more junior employees oppositely believed their professional development and efficiency to be dependent on a more rigid and steered approach. Furthermore, some respondents argue that the importance of autonomy is highly connected to which phase the project is in. In the concept phase, for example, short iterations are a necessity in order to meet design demands that are changing at high pace. In contrast, during the industrialization phase almost all project parameters are fixed and a change request at this stage require a lot of administrative work and internal politics.

The result from all the observations provides the same picture, that there is a low alignment between aspects of autonomy and the overall development process. As one of the respondents expressed it - "*We are an autonomous piece in a rigid system*". The overall project structure and its reporting system is seen more as an obstacle than something that adds value to daily work. One respondent described it as having a clearly defined input (point A) and a clearly defined output (point B) but the route from A to B was up to the responsible employee to determine (the route being work conducted inside PSS140, see figure 15).

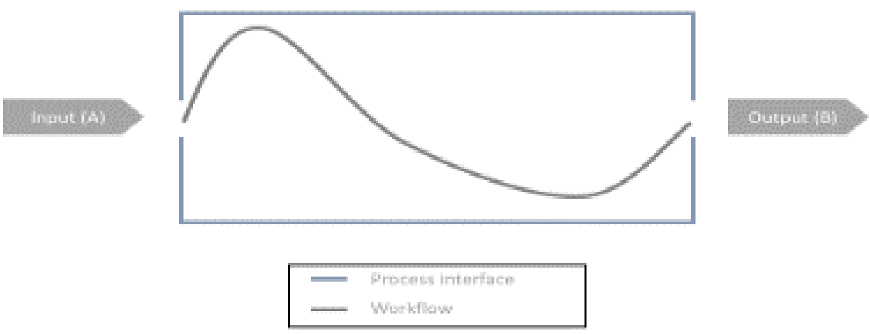

Figure 15 - Model of limited autonomous workflow

The observations further indicate two possible reasons for why PSS140 has developed into the organization it is today. First, all responding employees feel that they have mandate form their SM and GM to utilize what, in their belief, is the best way of working and drive the process forward. Employees also experience that management has faith in what they do and encourages them to take initiatives. Second, the mix of senior and more junior employees creates a mix of experience and knowledge together with energy and new initiatives which constantly challenges the status quo of the project process. The latter is, according to some senior employees, a result of well planned and executed recruitment work conducted by the senior management.

Although there is clear autonomy for the employees at PSS140, there are some present elements that are contradictory to autonomy. One of the respondents explained that the most important tasks are often handled “by the book” to reach the correct solution, while the daily work is where you can be autonomous. A similar experience is also documented by another respondent, who claims that it is hard to feel ownership of a problem, since much problem solving needs to be controlled rigorously. The employees can not affect what tasks they complete and are, instead, given assignments which they can prioritize and handle individually to some extent.

5.3.2 - SELF TRANSCENDENCE

Self-transcendence is an important aspect in order for teams to be self-organizing since it indicates the level of hierarchy and team mandate. Fully functioning self-organizing teams has a holistic perspective of the development process and deep insight in what customers desires. With focus on responsibility on team level problems should be solved and evaluated with the whole product in mind.

The general “*feeling*” of ownership of project related problems at VCC is relatively high and employees are generally committed to their team and product. However, reporting structures and hierarchical set-ups makes it hard to react fast and act as a responsible and independent team. Furthermore, methods utilized at VCC today do not allow for teams to fully own their development processes. The main finding from interviews and observations is that reporting and official forums are consuming time and energy rather than adding value to the final product. Another interesting finding is that the possibility to “own” the process varies a lot depending on which phase the project is running in.

At PSS140, the general level of independence, in terms of the possibility to make decision of design or functionality changes on team level, is low. During the interviews all respondents answered that there is, in almost all cases, not possible to take a decision regarding the project on team level. However, in most cases they felt that their opinion and input to higher forums were reviewed and evaluated in a just way.

Referring to the previous sub-chapter on autonomy, the interface frame around the sections is rigid and do not give support to a changing environment nor an autonomous work flow. The willingness for engaging and take responsibility is however not seen as a problem, especially not for a “well-tuned” section such as PSS140. According to one respondent it would be very beneficial to distribute decision mandate to a team level, as long as there is a strong organization behind the teams. The respondent saw this as a first step for the project organization to show their belief in the development teams and that it would enhance both flexibility and the time it takes to develop new components. Another respondent touch upon the same subject and stated that *"If there is no real ownership of the development process there will be no real commitment or engagement to the final product"*. Overall the employees at PSS140 are positive to an increased problem ownership and there is a strong belief that it would increase the overall efficiency of the development process. However, most of the respondents identified the need for a coordinating role and increased need for information spread and knowledge diversity in order for such initiative to succeed.

Depending on which phase a project runs in the possibility to make decisions varies. For example, in the concept phase the core team has more loosely defined demands form eg design which results in that they can evaluate and make decisions not depending so much on formal forums. In later stages of the process the frame of external demands becomes more fixed and the ability for the team to take initiatives or decisions on their own is more limited.

When investigating the holistic perspective of PSS140 one core theme was identified, there is a strong connection between PSS140 and their department (Interior design). This results in a sometimes-sub-optimized scope were the block is seen as the final delivery rather than the whole car. Some respondents drew the conclusion that these effects were a consequence of how the organization is built and divided into blocks. The connection to the final product (the car) would be much clearer if the teams included other competences with knowledge centered around other areas than solely cockpit or tunnel. From interviews and observations, it can be said that there generally is a high level of commitment, that employees feel involved in the process of building the products and that employees take pride in being part of the development of VCC. However, when trying to concretize how this fit in the daily work it is hard to find the connection.

5.3.3 - Cross-fertilization

The creation of project teams at PSS140 is controlled top-down, where the GM dedicates staff to projects. The GDL can, however, evaluate the employees to ensure that they will work as a group and provide this input to the GM. Several respondents claimed that the project members were mostly assigned based on availability, rather than creating a diverse set of skills and backgrounds for the project.

The consensus among the respondents was that the project teams consist of a homogeneous set of people with similar backgrounds in mechanical engineering and the car industry. Some respondents also claimed that there is little diversity in gender for the project teams, where one respondent claimed that the efficiency of projects could be increased by involving more women in the concept phase. The same respondent did, however, claim that the management team is taking active steps to hire more women. Some employees also identified experience diversity as an important aspect for a successful team. One of the respondents expressed that "The difficult thing is to find balance between newer and more experienced team members". The general age at PSS140 is, however, lower than ever before, which means that more young employees are active in the projects.

While the project teams are homogenous at the department, some key roles from external departments are still present in the development activities. Communication with these roles are managed through the CIM-meetings, where external roles, such as Attribute Leaders, are present. These meetings are generally attended by the DL and GDL, but rarely by the design engineers. This means that there is a lack of direct communication between certain members of the project teams and external roles that play an important part for the project. Furthermore, this means that the information from the CIM-meetings are spread to the group by the GDL or DL. One of the respondents has identified a problem in relation to this, stating that “There are currently some problems with the information spread, where information isn’t shared to a full extent”.

As shown above, all roles with an important input for the project team are not co-located, where most of the external roles are stationed in other buildings than the core team at PSS140. However, a recent decision was made to integrate some CAE engineers into the department. The respondents had a consensus that this move was positive for the development process, where more effective communication has been established between the project team and the CAE team. However, the project team itself is not co-located at PSS140. Even though the project team members are located in the same level of the building, they are stationed in different work areas, typically containing 40 people, within the floor. One of the respondent saw this as a problem and claimed that “All work would go much faster if all important stakeholders were located at the same physical space”.

The problem-solving activities within PSS140 is handled differently between the project teams and depending on what phase they are in. Problem solutions within VCC are stored in two databases, FU and MU, which are accessible to all employees. However, the respondent claim that these databases are rarely used, and that the information is mostly spread by the employees creating the entries by themselves. There are two main methods for problem solving within the department; Task forces and CIM-meetings. Task forces are special teams that are created with the sole purpose of solving a specific problem. These teams are mostly active in the concept phase and they are only utilized when there is a time urgency for solving the problem.

CIM-meetings are utilized for problem solving, since input can be gained from both internal and external roles that have an interest in the solution. After input has been given at the CIM-meeting, the problem-solving activities are either delegated to PSS140 or solved using a special CIM-meeting. The special CIM-meetings are arranged if there is an apparent need for cooperation between departments in order to reach a solution. Furthermore, some areas have support with technical expertise that can be utilized in problem solving activities.

5.3.4 - Workshop

The attendees of the workshop that was held at the end of the mapping phase were provided with a series of hypotheses, which they were asked to respond to. The hypotheses were created in order to provoke a reaction from the respondents regarding the implementation of self-organizing teams at PSS140. This chapter aims to describe how the employees at PSS140 reacted to the provocatively formulated hypotheses regarding change towards working with self-organizing teams. Each hypothesis is presented below together with the reaction it generated.

“The design engineers will get a larger responsibility for their delivery and will, therefore, have to steer their work more independently. In extension, the GDL and DL will have less influence over the work performed by the design engineers.”

> The attendees were split in their reaction to this hypothesis. While some of the employees believed that this described the current work environment, others claimed that this would be a welcomed change. Adding to this, one of the attendees suggested that the design engineers will have to cross-evaluate their work between projects to a larger extend in the future state.

“The high-ranking members of the project team, such as the TPL and UPL, will lose their power of the project and meetings such as DRM-P will most likely be removed”

> There was a unanimous response regarding this hypothesis, where the attendees agreed about the UPL and TPL losing power. One person even claimed that “The TPL or UPL will most likely disappear”. Furthermore, the general response towards this change was appreciative, where the attendees claimed that it would free up time. One attendee claimed that the removal of DRM-P would free up time and make the development process more efficient.

“Products will be created in the lowest level of the organization, which means that they will have the utmost responsibility for the product itself. The project organization will lose power to the product team”

> The attendees were split between two opinions regarding this hypothesis; First, some of the respondents felt that the lower parts of the organization already have responsibility for the product. Second, some arguments were made regarding the difficulty of transferring responsibility to the product team. One of the concerned attendees asked “What if two different requirements exist which cannot be combined in reality but different teams work on them separately and suddenly discover that the other team work against their own requirement?”.

“The top levels of the organization will be responsible for coordination between products and creating the overall strategy. However, after work packages has been created, they will not be able to influence how the product group prioritizes.”

> Most of the attendees believed that it would be difficult for the top management team to coordinate activities between product and recommended coordination activities to be done on team-level instead. There was, however, a unanimous agreement about the top managements loss of influence over how to the project group priorities. One of the employees expressed happiness about the hypothesis and stated “Good! Let people with

knowledge about the product keep their mandate and responsibility, while management leads and coordinates".

"Design engineers & CAE will have to broaden their knowledge in order to perform tasks that are outside their current work description"

There was a general disagreement towards this hypothesis among the attendees. Some of the attendees claimed that the work tasks will remain the same for the design engineers in the future, while the interfaces would change. One of the persons that agreed with the hypothesis said "Greater freedom and greater responsibility gives larger satisfaction. However, mentorship needs to be strengthened for new design engineers".

"The product teams will be relocated together, hence removing the current structure of the organization where people are stationed depending on their section."

Similarly to the other hypotheses, there was disagreement among the attendees regarding this statement. Some of the respondents claimed that it would be impossible to co-locate all staff of the product team, where emphasis was put on the difficulty to split supporting roles between teams. Other attendees claimed that this would be necessary in the new organization.

5.3.4.1- OTHER FINDINGS FROM THE WORKSHOP

The workshop also allowed for discussions between researchers and employees of PSS140, where the attendees were able to express general feelings towards the organizational change. One of the employees stated that the education from VCC had been poorly executed, where the top management also failed to communicate why the change is happening. A similar claim was made by another attendee, who said that the senior management has lacked in communicating how current work methods will be affected by the organizational change.

6- ANALYSIS

In the following chapter the previously presented result will be analyzed in accordance with existing theoretical knowledge on the subjects of this study. The analysis is intended to act as foundation for answering the research questions in the following chapter. The first section of this chapter presents present capabilities and product structures at PSS140. Further, the relationship between the products and the organization is analyzed and the organizational changes related to implementing self-organization are elaborated upon. Finally, some general expected outcomes from implementing self-organization are presented and discussed.

6.1 PRESENT CAPABILITIES FOR SELF-ORGANIZATION

The line management at PSS140 has developed the section and its members into a well-tuned and strong organization. A strong will from the section management to empower employees together with successful recruitment work has developed the section into a confident and productive organization. Hoda et al. (2010) and Moe et al. (2008) give examples of outcomes to expect from increased self-organization, *e.g.* improved workflow, more engaged employees, more effective problem solving and increased knowledge. The first acknowledgment that can be made from the study is that PSS140, already today gains efficiency by utilizing capabilities of self-organization to some extent. Second, there is a clear misalignment between processes and work methods used in practice inside of PSS140 and the ones used in the rest of the organization. This hampers the section from utilizing full efficiency since they have to work around the boundaries of the overall product development system, hence not focusing on producing value to the final delivery.

6.1.1 - MATURITY LEVEL AND PRESENT CAPABILITIES OF SELF-ORGANIZATION

By reviewing each criteria of self-organization in the current operations of PSS140, it is possible to draw conclusions regarding existing capabilities of self-organization. It becomes apparent that PSS140 has some existing capabilities of self-organization in *e.g.* autonomy. However, the general level of accomplished self-organization is still low for the other criteria

Factors affecting criterias of autonomy is mainly situated within the section where the section management has the possibility to promote and steer the development to a larger extent. Employees at PSS140 has, therefore, embraced and developed in accordance with a somewhat autonomous environment. After the concept phase has passed, the ability to adjust how tasks are executed is limited to incremental changes at team level. However, during all phases, the teams provide input to decision forums with the objective to improve the final product. At PSS140, all employees can prioritize their individual task as long as they deliver on gate and forum deadlines. As previously mentioned, management at PSS140 has great trust in individuals in the section and employees are empowered to find new and efficient ways to execute their work. The utmost responsibility for delivery is, however, still dedicated to GM and SM and not to the teams. On the other hand, reporting structures and formal follow ups are more frequent outside of PSS140. Even if a trusting culture is present at PSS140, the external way of working affects the daily work at PSS140 so that reporting and follow ups becomes an obstacle in daily work. One employees, working as DL, argued that formal forums such as

DRM-P were time consuming and that it would be more efficient to debate and solve problems on a team level if the mandate was increased. This hampers one of the key effects of working autonomously, namely the advantage of fast responses without bureaucratic decisions (Patanakul et.al, 2012).

The assessment of existing capabilities for self-transcendence are somewhat ambiguous, where employees feel responsible and relate to the product but are at the same time not able to challenge the main objective of projects. Takeuchi & Nonaka (1986) argues that the level of self-transcendence has great impact on innovation abilities for organizations. Furthermore, increased self-transcendence and team responsibility can promote employee's willingness to act on new initiatives and to learn new things (Moe et al., 2008). By empowering employees to be part of the development of the organization as well as the product, a higher level of commitment and inherency can be accomplished. At PSS140 the level of commitment and inherency to the product is high, however, the current decision hierarchy creates a barrier for full problem ownership which, if improved, would increase the holistic perspective on team level. The organizational hierarchy in combination with the current product structure makes it problematic to see the effects of team efforts in the final product. The high level of commitment to the final product at PSS140 resides in that team members are provided the opportunity to develop the product in their way, if it fulfills or exceeds requirements. This further creates a sense of responsibility, at least within block boundaries.

PSS140 is one of few sections at VCC that already today has included some level of competence diversity in their core teams. By actively bringing competence to the organization, other than design engineers *e.g.* calculation and integration, PSS140 can take responsibility for a larger scope of a project and handle product related issues directly on team level. This further enhances the development process since more competence is built into the product from the beginning. Since the team consists of a diverse set of competences more than one perspective is taken into consideration. Consequently, less external communication is needed, and the team can focus on delivering a suitable design. Cross-fertilization takes place when people with different specializations and backgrounds are co-located and information is transferred within the team (Takeuchi & Nonaka 1986). However, Hoda et al. (2012) points out the importance of balancing specialization level with the understanding of other competences to not lose the original core competence. Even though PSS140 has included some external competences and roles in their teams, further integration of key competences would increase compatibility to adjacent interfaces. For example, several roles that today is not present at PSS140 were, during the study, identified as key competences. The most frequently mentioned competence was Manufacturing Engineering (ME). When asked, ME responded positively to be more integrated in the development process to ensure that their perspective were taken in to consideration in the product design.

To summarize the assessment of self-organization at PSS140, a framework for maturity level was developed based on the operationalizations of Takeuchi and Nonaka's (1986) criterias for self-organizing capabilities. A representation of the developed framework and the resulting assessment from the study can be found in figure 16 below.

Maturity level of self-organization

	Assessment criterias	1	2	3	4	Current state
Autonomy	Create and steer work tasks	Tasks are handed out by manager	Increment tasks can be added by team	Team is part of developing project content	Team members responsible for choosing work tasks	• Internal autonomy level is high and the level of external autonomy is low • Internal processes are highly affected by the corporate hierarchy and outside factors e.g. decision forums
	Self-controlled work processes	Strict processes for execution	Strict framework of deliveries and stage gates	Team members can influence how work should be executed	Team members are free to chose how to execute tasks	
	Detached senior management	Steering and controlling management, lack of trust	Frequent reporting and follow-ups	Supportive management follow-up only on specific KPI's	Trusting management, team is responsible for delivery and follow-up	
Self-transcendence	Problem ownership	Teams reject responsibility that is not ordered	Teams take responsibility for solving problems only with adjacent interfaces	Teams take responsibility for delivering solutions and solving problems appointed to team	Teams are empowered to develop and deliver a complete solution	• Full ownership of problems and products is unabled by the current organizational and product structure
	Holistic problem solving	Focus on main task only (sub-optimization)	Problem solving on team level	Awareness and responsibility of change impact on adjacent interfaces	Team actively contributes to final product quality and customer value	
Cross-fertilization	Un-homogenous groups	Teams are put together with people of similar background and experiences	Management tries to form teams that have fitting competences and personalities	Teams are formed to involve people of mixed gender, personalities and background	Team members have different specializations, -thought and behavior patterns	• Teams are today composed based on competence access and expertise • Co-location of other competences and functions is not part of todays resource allocation • Problems are solved in homogenous teams
	Accessibility	Each competence is separately located	Team of core competence is co-located	Team of core and support competence is collocated	All collaborating teams are co-located and share support functions	
	Team member involvement	Responsibility for problem solving only when ordered	"Experts" solves problem	Problem solving includes input from team members	Problem solving includes whole team and knowledge is communicated to the team	

Figure 16 - Maturity level of self-organization

6.1.2 Relation between product modularity and organizational structure

The mirroring hypothesis suggests that the organizational structure should be perfect replica of the product structure (Mac Cormack et al., 2012), which can be proven or demented by analyzing the modularity of the product (Cabigiosu & Camuffo, 2012). The organization should, according to the hypothesis, have communication patterns that correspond to a products modularity for every level of the product. Furthermore, the definition of modularity used for this research entails that a sub-systems modularity is in direct relation to the handling of its exterior interfaces (Maron, 2010). That is, if the exterior interfaces are strictly set and the rest of the sub-system can be developed independently, it can be considered as modular. However, modularity is not necessarily binary, and a sub-systems modularity can be interpreted as a point on a scale instead (see figure 17 below).

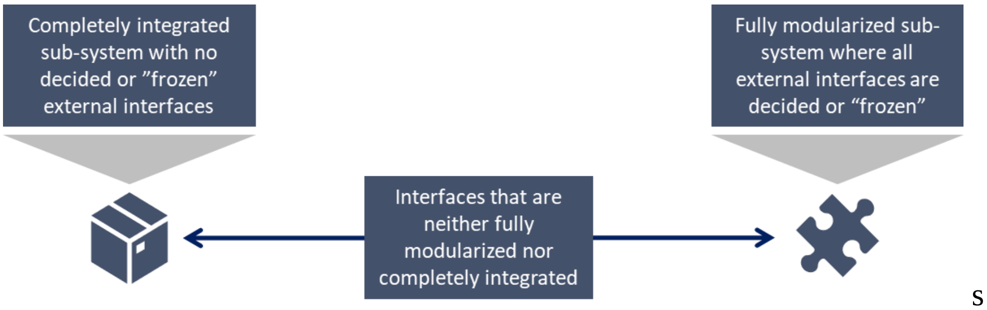

Figure 17 - Scale of integration and modularity

In extension, the product at VCC cannot be seen as either modular nor integrated. The product is simply more modular at certain levels, often higher levels of the product structure, and more integrated at others. The product can, further, be partitioned by examining it as an assembly of subsystems with exterior interfaces. The level of modularity in a subsystem can also be decided by investigating how strict its exterior interfaces are set, which makes it possible to map the product in terms of modularity.

By this reasoning, the top level of the product is the finished car, which in turn is portioned into seven blocks based on physical limitations in the car. The exterior interfaces of the blocks are decided during early stages of the concept phase, where there is little or no possibility for change during later stages of the project. Each block is then developed independently with close to no communication between the blocks. The blocks can, therefore, be considered as close to fully modularized sub-systems.

The next level of the product, following the block, is the sections sub-area, which is the cockpit or tunnel console in the case of PSS140. The exterior interfaces of these subsystems are decided during later stages of the concept phase, with the option to make smaller changes throughout the development project. Communication and synchronization between sections in the block is handled through the blocks integration meeting, MIM, which typically takes place one time per week. The sub-area is not completely modularized, but it has more similarities to a modular system than it does to a integrated system.

The second lowest system level of the product is the sub-assembly, which is a sub-system that is controlled by one GDL and one DL at the section, *e.g.* a glove compartment. These subsystems exterior interfaces are synchronized by the GDL-Integration at the department, which are commonly communicated through the CIM meetings. The exterior interfaces for a sub-assembly cannot be seen as frozen, although there are prototypes to give directions for how it should be done. Furthermore, communication between developers for sub-systems at this level is handled by the DL and not by the developers themselves. Based on this, the sub-systems at this level are deemed to be more integrated than modularized by a minor degree.

Finally, the lowest level of system level in the organization is a sub-part. A sub-part is developed by one design engineer and is generally gathered, together with one or two other sub-parts, into a sub-assembly. The DL is responsible for coordinating the tasks between the design engineers. However, the engineers who share interfaces are often in direct communication with each other to resolve integration issues. The exterior interfaces for a sub-part are rarely defined, but are instead developed by cooperation between the design engineers and the DL. Sub-parts are, therefore, close to being fully integrated sub-systems. A comprehensive view of all sub-systems modularity can be seen in figure 18 below.

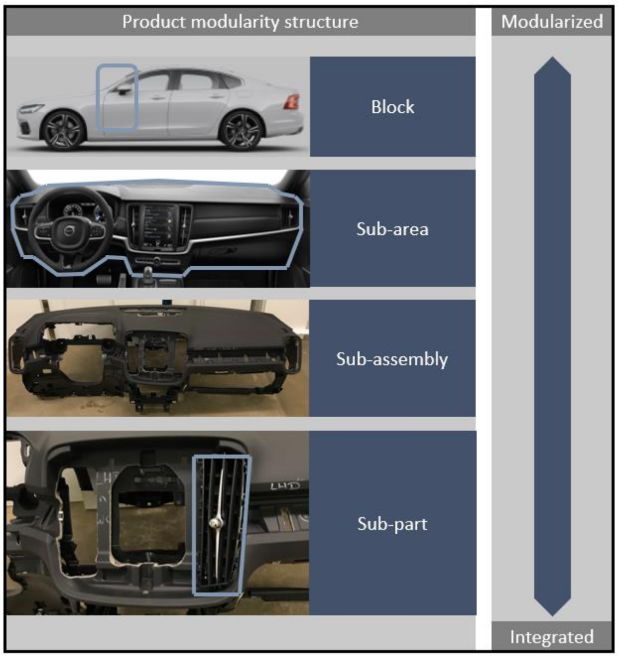

Figure 18 - Scale of product modularity

As was shown above, the organizational structure at VCC is a mirror of the product structure, where communication patterns and meeting structures follow the integration levels of the product. The more modularized parts of the product are reflected in the organizational structure by formal meetings with lower frequency, while the integrated parts are handled by informal and high frequency communication within the development team. As such, the mirroring hypothesis can be confirmed for PSS140

6.2 - ORGANIZATIONAL CHANGE & SELF-ORGANIZATION

Volvo Cars is currently undertaking an organizational transformation aiming to decentralize the organization and move decision power to the development teams. To identify potential changes in the organization setup, which are required to successfully implement self-organization, the operationalization of each criteria for self-organization has been used. Present capabilities and desired outcomes provides the basis for the analysis of each criteria.

Ability for team members to create or steer their own work tasks.
As has previously been showed, the employees at PSS140 are currently limited in their ability to choose work tasks in their current projects. An alternative to this is suggested by Cohen et al. (2004), where team members are tasked with breaking down customer demands, making them into work tasks and later choosing and prioritizing their own work tasks. Although this method could be positive for the working spirit among the development team, it would require them to have great insight about the whole product as well as customer demands. However, this would change if the breakdown of work packages and translations of customer demands were designated to management teams instead. Work packages could then be handed downwards in the organization, becoming considerably smaller by each step. When arriving at development team level, the team could choose a couple of goals together and then split them among its members. This would allow each member to have influence on the development team's overall direction while simultaneously choosing their own work tasks.

Self-controlled work processes
The current situation at PSS140 allows the employees to influence how their work tasks should be executed, indicating that self-controlled processes are currently present to a large extent. However, there are still some boundaries that steer just how independently their work can be accomplished. For the work processes to become fully self-controlled, some of the formal frameworks needs to be removed. An example of this is the DRM-P meeting, which is currently a required instance to solve specific problems. Similarly, the current integration meetings, such as CIM and MIM, is a required path for coordination of the product. The future state, as such, requires removal of all formal problem-solving forums and required paths if a truly self-controlled process is to be created. Problems that previously required the DRM-P meeting to be solved, should instead handled by problem-solving efforts where both the core and support team are present.

Detached senior management
As has previously been shown, VCC currently consists of a line organization that works alongside its project organization, where managers from both sides influences the work of team members. Some changes can be anticipated in the project organization, where clear control procedures are in place. In order to disconnect the senior management from the project teams, the organization needs to limit the need for team members to communicate upwards in the project hierarchy. This can be accomplished by assigning most of the vertical communication responsibility to one member within the team, who can spread all necessary information to the remainder of the group. An employee with this responsibility would act as a protective barrier for the team, similarly to the role of a scrum master described by Srivastava & Jain (2017).

Problem ownership & Holistic problem solving

Problem solutions at PSS140 is currently controlled in two separate entities for the project and line organization. While the project organization is responsible for the time, cost and completion for the project, the line organization managers are responsible for the technical delivery of their departments. In order to ensure that development teams are given full ownership of the product, it is, therefore, necessary to transfer the responsibility of all development related deliveries from line and project managers directly to the team. The managers would then have to adapt into the supportive leaders described by Takeuchi & Nonaka (1986), who can work in collaboration with the team and help them reach holistic problem solutions.

Un-homogeneous groups

Teams at PSS140 are created by the group managers, where input from GDL and SPL are taken into consideration regarding the team members will fit in a group. As such, the team members are evaluated based on seniority and skill alone, creating a somewhat homogenous group. To achieve the un-homogeneous groups described by Takeuchi & Nonaka (1986), members would have to be chosen based on functional specialization, thought and behavior patterns. This could partly be resolved by ensuring that all necessary specializations are included in the core or support team, which in turn would require close cooperation between group managers from different sections. Furthermore, members with different thought- and behavior patterns can be included by creating teams that have members of different ages, genders and, cultural and educational backgrounds.

Accessibility

Implementing self-organization at the section would see more external roles move geographically closer to the development team, where the most important ones would become a part of the core team. In contrast, roles that possess competence that are not fully utilized in one team would be included in a support team, which should be available for several groups. Hoda et al. (2010) show that self-organizing teams can have a great spread in size, where their study involved teams which consisted of between 4 to 15 people. The current work areas at PSS140 seats approximately 40 people, allowing more than one team to be seated in the same work area. As close cooperation with the support team is crucial, they can be positioned in the same work area as two or more core teams, thereby enabling direct communication while simultaneously utilizing resources in a sufficient way.

Team member involvement

Implementing self-organization would mean that a larger amount of problem solving activities are completed by collaboration within the team, in contrast to delegating it to experts as is currently the case. When the core team is unable to solve the problem by themselves, members from the support team should be included. Involving all team members in this situation would ensure that knowledge from solutions within the team are spread to all its members. To spread knowledge between the teams, the employees with communication responsibilities, as previously mentioned, should gather valuable information that could be communicated to the development team at the end of an iteration. Further information spread can be accomplished by having team activities, rotating team members and, rotating work tasks

6.2.1- Risks when implementing self-organization

As the main challenge for VCC is to cope with the increasing pace of technological change the organization needs to build in flexibility in the development process. Coming from a traditional stage gate development process it is complicated to adjust to increased uncertainty and shorter planning horizons (Cooper & Sommer, 2016). Increasing self-organization would imply increased flexibility, since decision can be made by the team. However, the natural effect of this is that the planning horizon is shorter and the ability to predict potential outcomes of development efforts. The risk is that top management struggles decreased ability to control and predict and still tries to estimate the outcome (Boehm & Turner, 2005). For the organizational change to be successful, top management needs to adapt to the current situation and put faith in that the development teams can deliver on both customer and portfolio requirements.

Another barrier for implementing self-organizing teams is presented by Boehm & Turner (2005), who claims that lack of education of employees and poor communication of changes is a common pitfall. If the employees receive inadequate training in new work methods, the implementation effort might fail to create change. Similarly, the top management needs to communicate what will change and why the change is necessary to its employees to lower the employee's resistance to change. VCC has initiated a training program for their employees to understand and adapt to the change, but it has not been met with good criticism. In extension, some of the employees has pointed out that the communication regarding the change has been lacking from the senior management.

When building the change, it is also important to involve the employees in developing their new environment and work methods. This is emphasized further by Moe et al. (2008), who claims that self-organizing teams can fail as a result of having to many decisions taken by people outside of the development team. The current change initiative at VCC has allowed the sections to have influence on how they can adapt, but the members in lower part of the organization has low influence about how their work tasks is developed. The organization should, therefore, aim to gather more input from the employees if they want to prevent resistance to the change.

6.3 - Potential effects on the relationship between product and organization

The mapping conducted in this study is an important step towards understanding underlying design interfaces and communication patterns within and outside the organization of PSS140. Undertaking the idea that there is a mutual relation between design interfaces and communication patterns implies that adopting self-organization would affect the product structure. Sosa et al. (2004) argues that the product does not necessarily have to be perfectly reflected in the organization, although, it is important to identify misalignment between product structures and communication patterns. Identifying these dependencies can uncover interactions in the product structures that, if addressed, can improve the development process.

The mapping of PSS140 showed that existing product structure and communication patterns aligned well within the section. However, outside of the section, several depending external roles were identified which did not have a clear corresponding communication pattern. Utilizing self-organization will require a new way of communicating and coordinating around the product rather than through separate channels in the organization. The mirroring hypothesis similarly claims that such communication patterns needs to exist if the design interface exists (Colfer & Baldwin, 2016). Although the hypothesis was found to be true in the organization, higher levels of the product structure had reduced communication across block borders.

Self-organizing organizations has a reduced need for hierarchies and reporting structures (Hoda el al., 2010). Teams are, at the same time, expected to take a greater responsibility for the product development process and formerly clear organizational entities is blurred out. Consequently, communication patterns over interfaces, throughout the whole product structure, becomes increasingly important when utilizing self-organization. Using the product as means for communication has during this study been identified as an effective way of coordinating design efforts by using models and 3D printed mockups. Increased product focus provides the organization with a natural way to organize, connect and, communicate to each other. Furthermore, this would result in that design engineers developed increased product knowledge, which consequently improves the holistic perspective in project teams since they are provided with better insight in the product as a whole. Orlikowski (1992) argues the importance of recognizing the mutual dependency between a product and its creator. By changing how products are developed and created, it will also create new demands on how the product is structured. Deliberately, putting the product in center of communication will change the communication patterns and, most likely, also the organization and the resulting product. Recognizing this, opens new possibilities for engineers to experiment with communication as a tool for product development.

Being able to show a representation of the product allows the team members to highlight issues and connect it to the larger delivery, which could lower the risk of individuals only focusing on individual goals as identified by Moe et al (2008). Expanding on this, an effect of moving towards self-organization is that the product will need to be developed in short time framed iterations, similar to that described as “sprints” by Larman & Basili (2003). This could, according to Laanti (2016), become a problem in a hardware environment, which has limitations in lead times. However, as much of the development work at PSS140 is accomplished in a computer design environment, there are clear possibilities for iterative development. An example of iterative development is presented by Punkka (2012), who suggests the use of up-front prototyping. This means that a product is built and revised continuously through the project, which enables the developers to advance on its design successively. By prototyping the object physically when possible and releasing computer designs successively, the desired iterative development is gained. Similar work methods were identified at PSS140, where the cooperation between CAD-engineers and CAE can be seen as an iterative development process. The CAD-engineers produces a computer design of a product which is transferred to the CAE for testing. When the CAE has tested the model, it is returned to the CAD-engineer who can then improve the design.

Increased self-organization is accompanied with some general challenges. For an autonomous and self-organizing team, richness of continuous communication within the team is key. Co-locating several teams that has adjacent interfaces with support teams in a limited space will increase direct communication and the emerging product can be in center of all discussions at all time. The main challenge is to allocate external communication to short time periods between each iteration. Balancing the ability to isolate the team from external interruptions during iterations, while still enabling rich communication, is important for the success of a self-organizing team. One enabling factor for this is increased modularity of the product on lower levels, which reduces the need for external communication (Sanchez & Mahoney, 1996). Further support for an increased modularization of the product on the lower level can be found in the organization structure. As the current integration path in the organization is likely to disappear, the product structure will likely follow. As such, the product will not be able to have as many levels as it previously did, highlighting the need for increased modularization of the product on team level. This change is illustrated in figure 19 below, where the yellow rectangle indicates increased modularity in a sub-system.

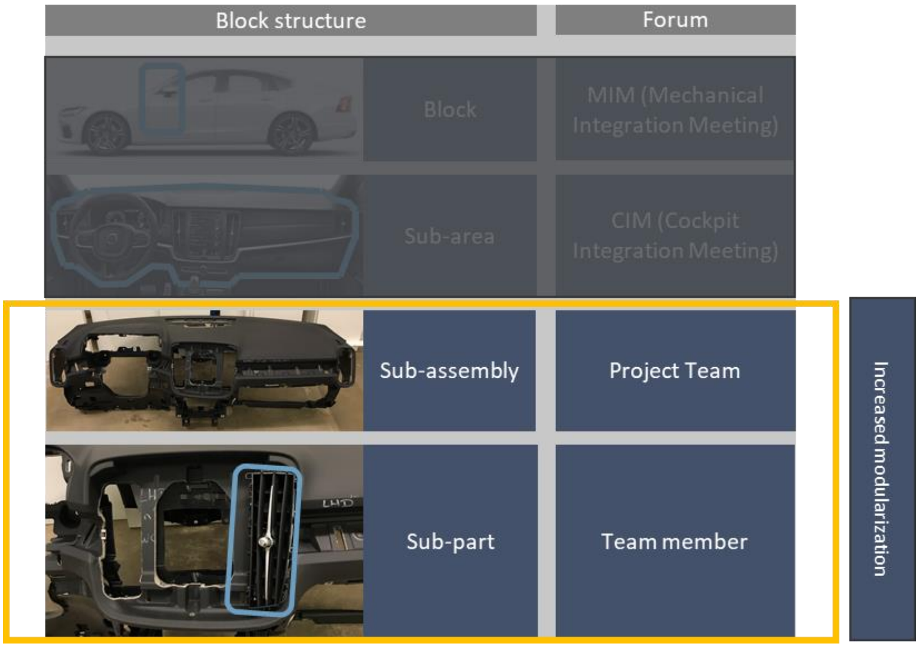

Figure 19 - Change in product structure as an effect on increased self-organization

6.4 - Expected outcomes from increased self-organization

Benefits from increased development flow

Organizations are traditionally focusing on gaining efficiency through resource utilization. By maximizing the number of task and workload for each employee the belief is that efficiency is gained. However, this often leads to diverse focus, interruptions and a person that are under too much pressure might be less effective. During the interviews frequent interpretations came up as one of the main reasons for why interviewees felt less effective. Going from a traditional, more hierarchical organization in to self-organizing operations can be difficult since resource utilization levels might be lower, especially in the transition phase. It is therefore important, from a corporate perspective, to be patient and to accept lower levels of utilization and to let the organization shift to be focused on continuously delivering results.

Benefits from increased Motivation

As has been shown in interviews with employees at PSS140 the level of employee's satisfaction is high. This was further confirmed by the employee satisfaction survey, were the result at PSS140 was significantly higher than the rest of the organization. This indicates that PSS140 already today are gaining positive effects form the highly autonomous climate at the section. Moe et al. (2008) claims that members of self-organizing teams generally are more motivated since they are provided with decision power and greater responsibilities. By further increasing the responsibility and authority to the team's greater motivation and commitment can be accomplished, which in long term will improve the general outcome of the development process.

Benefits from increased flexibility

As has previously been stated, one of the main goals for the organizational change at VCC is to increase the flexibility in their development process. Furthermore, it has been shown that organization can achieve increased flexibility by becoming self-organizing (Cohen et al., 2004), which emphasizes the need to understand how this is accomplished. When the product at the level of the development team becomes increasingly modular and the development process, as an effect of this, becomes framed into short iterations, it will open for possibilities of redesign after every iteration. As such, the product team will be able to shift focus or take in new requirements continuously throughout the development process, which would increase the flexibility of the development process. Further support for this comes from Sanchez & Mahoney (1996), who claims that modularity can lead to increased flexibility in product development.

Several of the improvements to flexibility can also be traced to improvements for autonomy, where there are mainly three reasons. First, by delegating responsibility for communication towards external parties to one team member, this employee can build enough knowledge about coming changes to be able to decide if the group needs to be influenced directly or not. This enables the group to be quickly change focus if required, while they will still be able to have focus on developing. Second, the removal of formal problem-solving forums will also lead to decreased lead times in product development (Hoda et al., 2010), enabling a faster shift of focus. Finally, by allowing the top management team to create work tasks that the development teams can later prioritize, they will be able to coordinate on top levels of the organization while the development team can still prioritize to complete the tasks with highest necessity at the moment.

Challenges from reduced governance

The current organization is centered around a generic reporting structure with formal decision forums and organizational hierarchy. By incorporating increased self-organization and, as in the case of VCC, the SAFe framework, many of the existing governance structures will no longer exist. This will, most likely, result in reduced control from a top management perspective. The objective with the transformation effort at VCC is to improve development efficiency and responsiveness to an increasingly changing environment. It will become a struggle for top management to balance between the desired flexibility and the ability to control and follow up. Reduced governance, which today is handled in the project structure, could result in that section becomes sub-optimized parts in the organization. It is therefore highly important to define what the need is for each delivery. Reducing governance and reporting will strengthen the motivation of the development team and result in that they take greater responsibility for the delivery, hence the risks with having less follow-ups is reduced.

7 - CONCLUSION

The purpose of this research was to "*identify how a change towards self-organization would change the product- and organizational structure in a hardware product development department*". This was accomplished by structuring the research based on three main questions. Each of these questions are presented below, where they are answered based conclusion from the analysis.

RQ1: *In what way would increased self-organization in product development change PSS140's organizational structure?*

The effects that increased self-organization would have on the organizational structure at PSS140 was investigated by analyzing the changes each operationalization criteria would pose for the section. The study identified four main changes to the organizational structure; First, the existing formal problem-solving forums and currently required paths in the organization will no longer be required because as a consequence of increased autonomy and authority on team level. Second, product development teams will consist of a core team and a support team, who will be co-located and include members that were previously spread among several sections. Thirdly, most communication responsibilities to employees outside of the development team will be delegated to one member. Finally, the authority formerly held by the senior management in the project organization will be transferred to the development teams.

RQ2: *What is the relationship between product structure and organization structure at PSS140?*

The relationship between product structure and organization structure at PSS140 was tested by analyzing if the mirroring hypothesis holds in said context. The mirroring hypothesis was assessed by investigating the relationship between the organizational structure and the modularity of the product. The investigation found that the mirroring hypothesis could be validated for PSS140, which means that the organizational architecture reflected the product structure. The product is increasingly modularized going upwards in the organization, where communication is handled formally and is less frequent. In the lower parts of the organization, where the product gets increasingly integrated, communication regarding the product is both daily and informal.

RQ3: *How can the current relationship between product and organization be used to understand what effects an organizational change towards self-organization would have on the product- and organizational structure?*

As was earlier shown, this study has used the mirroring hypothesis to identify and assess the product and organizational relationship. By validating the mirroring hypothesis, and thus proving that the product structure is a reflection of the organizational structure, the future product structure could be forecasted. By removing formal integration meeting, such as MIM and CIM, because of increased self-organization, the product development teams would need to work more independently. As the product structure would follow this organizational change, the level of modularity for the product developed by a development team would need to increase.

To summarize the conclusion of the present study, the assessment of present capabilities of self-organization in combination with understanding of the product and organizational relationship has provided insights to the purpose of this study. Two main findings can be concluded; First, increasing self-organization would put new demands on the organizational structure. Bringing decision power to the teams requires increased autonomy for the teams and a trusting and supportive top management that provides the teams with authority. Top management in the future organization needs to align and break down the product portfolio into development tasks that the teams are responsible for delivering. Second, understanding how the product and the organization interacts is a key enabler to understand the effects of increased self-organization. Increasing self-organization on team level requires the product to become more modularized, which will enable the team to lower their frequency of communication with external parties during the development of the product. Therefore, an iterative method needs to be applied so that external communication can be limited during the development process and be allocated in between iterations.

7.1 Further research

The aim of this study was to identify how the product and organizational structures are affected by increased self-organization. The use of operationalizations of pre-defined criteria limits the research to investigate the effects on the product structure. Utilizing another research approach to investigate the relationship between products and organizations would further contribute to the research subject of self-organization in hardware product development. To further strengthen the results of this research it is interesting to investigate how increased self-organization affects efficiency parameters in hardware product development. It would be interesting to see quantitative results from such research, both from an academic as well as an organizational perspective.

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APPENDIX I

APPENDIX 1-DETAILED SAFE DESCRIPTION

In this appendix a detailed presentation of the SAFe framework is given. First the different levels of the organization is explained and referred to the SAFe "Big Picture". Second, a description and summary of the core principles is presented.

Portfolio Level
On the *Portfolio Level* all programs are being aligned with the enterprise business strategy and all value/product streams are being coordinated in order to ensure a continuous flow. To be able to implement an agile work process where scalability is needed this instance is needed in order to govern and coordinate diverse work streams in the organization. The main task of the portfolio level is to maximize the financial value form the product portfolio and simultaneously foresee that the scope of each initiative is reasonable by appointing relevant metrics (Turetken et.al, 2017). (See picture below)

Program Level
At *Program level* the goal is to ensure that the agile teams constantly can deliver value to the portfolio requirements. The program level acts as a link between the strategic goals and work conducted at team level. The core of the workload at this level however consists of creation and distribution of the *backlog.* The program backlog is where all increments of a program are stored, these are then distributed to the agile teams. Another important part of the SAFe framework is the agile release train (ART), this is where the two day planning event for the period occurs. Furthermore, at this level a system team is created whose responsibility is to support the team effort and end-to-end testing (Turetken et.al, 2017). (See picture below)

Team Level
In SAFe the core responsibility for defining project goals, design, build and test the product are distributed collectively to the agile teams at the team level in the organization. At this level processes and roles are much influenced by Scrum and agile development eg. sprint planning, daily meetings and lessons learned are components in each iteration. The agile teams, core or support, should consist of five to ten people in order to stay effective and to work closely together and feel collectively responsible for the delivery (Turetken et.al, 2017). (See picture below)

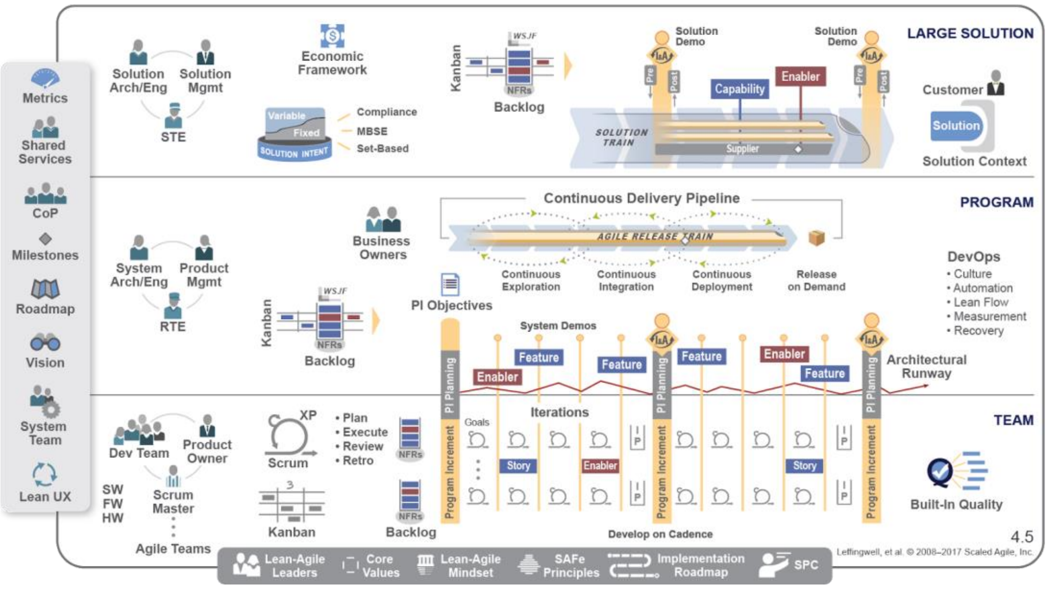

Figure 20 - The safe big picture showing the different organizational dimensions

Core principles of SAFe

As SAFe was developed from the agile and lean principles, fundamental components in the framework are common to these methods. However, in the SAFe framework, these principles are formulated in such way that they are able to be operationalized in order to fit more than one specific environment. The following are the basic principles of the SAFe framework;

1. Take an economic overview
2. Apply system thinking
3. Assume variability, preserve options
4. Build incrementally with fast, integrated learning cycles
5. Base milestones on objective evaluation of working systems
6. Visualize and limit WIP, reduce batch sizes, and manage queue lengths
7. Apply cadence, synchronize with cross-domain planning
8. Unlock the intrinsic motivation of knowledge workers
9. Decentralize decision-making

These principles are built on knowledge that can be extracted from research in Agile, Lean system thinking, product development and lean processes. The aim of the principles is to create guidance for enterprises which aim to be more successful in their professional execution. However, the independent setting and challenges for each enterprise varies, which is why the principles is meant to be adaptable to the specific needs of each enterprise.

Agile teams and trains	*Agile teams and Agile release trains (ARTs) includes all necessary resources in order for a team to deliver a solution. Working with the SAFe framework demands all teams in the organization to be self-organizing and that they can manage their own process which puts ownership of the project in the hands of the team rather than mid management.*
Cadence and synchronization	*Aims to provide the organization with a rhythmic pace throughout the development process. Synchronization regards the ability to solve more than one issue at the time by work in parallel streams with cross functional teams.*
Incremental planning (PI)	*Provides the overall planning and the ART which creates alignment and common goal for the mission throughout the whole agile team.*
DevOps and Releaseability	*In DevOps the aim is to foresee and close the gap between development and operations. Releaseability regards a corporation's ability to deliver value towards its customers by more frequent and more accurate releases to the market.*
System Demo	*SAFe aims to increase and improve communication within the organization. By iterative demos in the ART's corrections can be made to the course of the team and its deliveries and the team is provided with feedback in order to make decisions.*
Inspect and adopt	*Is another PI activity which aims to improve communication and at the same time provide time for reflection and validation.*
IP iteration	*Provides the organization with a built-in buffer in order to meet PI-objectives.*
Architectural Runway	*Is the master plan of the development process which makes it possible to develop and add on features along the way and to work on them in an independent way.*
Lean agile Leadership	*The organization needs to have ambassadors that embraces the new organization and that are willing to learn other how to interpret the new way of working.*