THESIS FOR THE DEGREE OF DOCTOR OF TECHNOLOGY

Orchestrating the implementation of new practices in product development:
Learning through action research at the Volvo Group

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There are three principal means of acquiring knowledge... observation of nature, reflection, and experimentation. Observation collects facts; reflection combines them; experimentation verifies the result of that combination.

Denis Diderot

We now accept the fact that learning is a lifelong process of keeping abreast of change. And the most pressing task is to teach people how to learn.

Peter Drucker

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ABSTRACT

Companies in competitive markets are always dealing with responses to changes in the external environment to be able to achieve long-term survival. One such response concerns changes in product development practices. In recent years, many methodologies have been developed addressing new upstream practices within product development such as robust design, design for six sigma, or lean product development. However, companies are struggling with their application of them in practice.

Since 2004, the Volvo Group has introduced several initiatives aiming for changes in product development practices. As the Volvo Group recognized difficulties in applying changes in its practices, an action research program was designed together with Chalmers University of Technology. The purpose was to study this problematic situation and upcoming initiatives, learn from them, and improve the situation with the help of change management theories. The action research was conducted with a systematic learning approach which resulted in practical improvements as well as provided theoretical contributions. Three of the most important initiatives taken at Volvo Group during the period of 2004-2016, are the focus of this PhD thesis.

The first paper in this thesis elaborates on learning from an unsuccessful initiative for introducing *Robust Design* at Volvo 3P that was led by an external consultant. The obstacles in the organization and weaknesses in the initiative are discussed. It was found that in order to implement the new practices to their full potential, there is a need for local development or adaptation of the robust design approach through local learning processes.

Then, based on learning from this first initiative, a second initiative, the *Volvo Robust Engineering System* was launched, and paper II and III in this thesis are based on this second initiative. The first paper describes and analyses the learning processes that make product development engineers in Volvo 3P aware of what the robust design concept can contribute in practice. This awareness contributed to changes in their work practices. This paper also elaborates on how Volvo 3P utilized a 'Learning Alliance' with the Division of Quality Sciences at Chalmers University of Technology as a means of creating a learning environment in which robust design practices are locally developed and used. The third paper presents the content and structuring of these industry developed robust design practices and makes a comparison to the previous literature-based approaches.

The third initiative is *Lean Product Development*. The fourth paper in this thesis is based on this initiative and describes how the Volvo Group organized its lean product development initiative and how it has been cascaded down and adapted to the Volvo Penta. It develops and discusses a theoretical concept referred to as a 'Platform for Learning' in order to implement local lean principles and practices and put them in to continual use. This paper contributes to the knowledge of how to transform an organization to lean product development.

Based on the accumulated learning from the action research processes and the three initiatives, the Thesis 'Kappa' empirically contributes to understand how to develop and transform the people's practices in product development. It also presents and discusses the role that *action research* can have in supporting organizations orchestrating such transformation. The cyclical process of reflection and learning, being an integral part of action research, was found to be

important for building knowledge while driving change. It was additionally found that employees can participate as 'insider action researchers', being involved in the research process and functioning as catalysers of reflection inside the company.

Keywords: learning processes, learning alliance, platform for learning, product development practices, action research, change, transformation

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APPENDED PAPERS

Paper I: Introducing robust design in product development: Learning from an initiative at Volvo

Paper II: A learning alliance for robust design in product development: the case of Volvo 3P and Chalmers University of Technology

Paper III: The Volvo Robust Engineering System: how to make robust design work in an industrial context

Paper IV: Implementing lean product development in the Volvo Group

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1. INTRODUCTION

This PhD thesis is a result of action research into several change initiatives in the Volvo Group where I have been engaged both as an internal resource as well as an insider action researcher in the form of an industrial PhD student over a period of more than nine years (January 2007-April 2016). The findings presented in this thesis are based on practice and can be of value for both industry and the research community.

The aim of this first chapter is to briefly discuss the reasoning behind this research and why this research subject was chosen by the researcher and the company researched. This chapter first introduces the researcher's background, the company researched, research projects, and then presents the research purpose, subject and finally the research questions.

1.1. THE RESEARCHER'S BACKGROUND AND INTERESTS

Every individual has been involved in different types of experiences that affect his/her opinions on everything – for example, in life, jobs, business and also research. No two people have exactly the same experiences; therefore, no two people will have exactly the same opinions. Here I will briefly describe my background, so that the readers of this thesis will get to know a bit about me, my views concerning this research field and my research process.

I was born in September 1980 in Tehran. Tehran is the capital of Iran and one of the largest cities in the Middle East. Right after finishing high school in 1998, I started my bachelor studies in industrial engineering at Iran University of Science and Technology (IUST)[1] in Tehran. During the first two years of my bachelor studies, I gained an academic insight into the field of quality management. I remember that while I was discussing with one of my lecturers at the university about statistical approaches for quality control (1920s) and Shewhart's work on the importance of reducing unwanted variation in manufacturing processes, I heard about Design of Experiments (DoE), robust design and Taguchi Methods[2] (1950s). As far as I remember, these were not standard curriculum topics at the time and were just mentioned as potential extra reading. When I reflect on it now, this was an important turning point for me.

Robust design, in other words like that found in DoE and the Taguchi Methods, became the subjects of my interest at that time. During the same period, I also read about Shewhart's cycle of learning (1939) and gained an understanding of his view on a cyclical process of improvement in reaction to non-conformances. I also gained an insight into the PDCA improvement cycle as an evolution of Shewhart's cycle. However, at that time, in my opinion the robust design subjects were so impressive in themselves, that I did not consider the possible importance of PDCA. In early 2001 I did a Taguchi Methods project at the university conversion coating

[1] http://www.iust.ac.ir/home_en.php
[2] Taguchi Methods are a tool for robust design.

laboratory together with my teacher, to increase the life cycle of a specific type of coating through 'parameter design'. I was sure then that this subject was what I wanted to work with. Later on in 2001, I started to work part-time at a consultancy company and had assignments to apply DoE and Taguchi Methods with several automotive suppliers.

During this period, I experienced a lot of difficulties concerning the practical aspects in the implementation of robust design methods in the industry. In my opinion, the automotive industry in my country was not mature enough to adopt such advanced methods. The existence of other problems made it difficult to motivate the management of these organizations to utilize the methods. Yet I did not think and reflect more about the possible root causes for this.

After my graduation in 2003, my career continued in the oil and gas industry. In February 2003, I started to participate in a project concerning exploitation of gas fields in the southern part of Iran with Statoil Iran Company. In that project, I was working with health, safety, environment and quality, commonly known as HSEQ in the oil and gas industry. My responsibility was to support the adoption of systems for HSEQ assurance, including proactive actions as well as corrective actions when problems occurred. Through this job, I learnt more about problem-solving and process improvement methods in application. Later on when I thought about my experience in this job, I noticed that we unknowingly partly exploited the PDCA improvement cycle, which I prefer to call the PDCA learning cycle. Through this job, I also got to know a little more about the Scandinavian countries and culture.

In 2004, I decided to continue my education outside Iran. Due to my personal experiences, a Scandinavian country was a natural choice for me. In the summer 2004, I was admitted to Chalmers University of Technology[3] and therefore moved to Gothenburg, Sweden. I continued with my Master's degree in the Division of Operations Management for a period of a year and a half. Operations management was a field in which I could learn more in general about all kinds of operations and therefore find applications in my field of interest, quality management. During this period I also put a lot of effort into learning more about Taguchi Methods and their underlying principles. Moreover, I gained an understanding of other views on robust design as a broader concept as in, for example, Robust Design Methodology (RDM) (Arvidsson et al. 2006).

Aligned with my interest, in February 2005 I got in touch with Volvo 3P[4] through my proposal concerning a possible collaboration for application of robust design in product development. Volvo was interested to apply robust design methods in order to increase the products' uptime as perceived by the customers. Volvo had learnt that in order to do this, there is also need to avoid less frequent product failures. In June 2005, prior to my master's thesis, I joined Volvo 3P as a 'robust design facilitator'. In this job my first assignment was the application of robust design, more specifically Taguchi Methods, to Volvo trucks' side mirrors, which was later used as a case for my master's thesis in 2006 (Fazl Mashhadi 2006).

My pre-assumption when I worked with robust design in my home country of Iran was that the difficulties I faced had been due to immature industry, in which management could not see the benefits of robust design. Surprisingly, I also faced difficulties in applying robust design, more or less of the same kinds, when I worked in my first job at Volvo 3P. That was an eye-opener and turning point for me. I started to be more observant and keen on understanding the reasons for

[3] www.chalmers.se

[4] Until the end of 2011, Volvo 3P was the name of the organization which was responsible for product planning, product development, and purchasing concerning all truck brands within the Volvo Group. 2011 this unit was modified and changed name to Group Trucks Technology (GTT)

this, and began testing new approaches to using robust design while on this first job. When my manager noticed my curiosity, he planned a meeting with Volvo 3P's human resources manager, with whom we decided that I could potentially do part-time industrial PhD work. This was to help Volvo to learn how to develop more robust products in forthcoming projects. This initiation from my manager was partly due to having himself been a former industrial PhD student at Volvo. He was aware of the potential in defining such a collaboration with academia, and its benefits for both Volvo and employee development. I was interested in this offer, as I was eager to get the engineers at Volvo 3P to utilize the robust design methods in a more routine way. I saw this offer as a big opportunity to get help from academia in understanding why I faced resistance in applying robust design, and how I might eliminate this and succeed in applying the methods.

I started my industrial PhD work together with Chalmers University of Technology in early 2007 to support myself and Volvo in learning, testing and developing new approaches to using robust design methods. During this journey I began to learn that many of the difficulties I faced were not only due to the content of robust design, but also to the process of implementation and the context of application. Another turning point for me was when I got curious about the difficulties due to the context and process of change. I was not only eager to learn how to implement robust design, but also eager to learn how to implement any new changes in practices of developing products. Aligned with this evolved interest and in order to broaden my understanding, I have taken up the challenge of working with different operational development projects at different product development units in different companies within the Volvo Group. These works and companies are Volvo 3P (2005-2008) working on robust design, Volvo Technology (2008-2011) working on robust design and lean product development, and Volvo Penta (2011-2016) working on lean product development and other operational development projects. I also continued my research work during these years together with these companies. These projects and companies are the main context of the research in this thesis, and are described more in the next section.

1.2. THE COMPANIES RESEARCHED AND THE RESEARCH PROJECTS

The company those are mainly mentioned in this inquiry are: Volvo Group, Volvo 3P, Volvo Technology, and Volvo Penta. Among these companies the main research context has been: the Volvo Group, Volvo 3P and Volvo Penta.

The Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. It consists of several Business Areas (BA) e.g. Volvo Penta (see Figure 1 and Figure 2). The Group also provides complete solutions for financing and service. The Volvo Group, with its headquarters in Gothenburg, employs about 100,000 people, has production facilities in 18 countries and sells its products in more than 190 markets. AB Volvo[5] is the legal name of the mother company for the Volvo Group.

Volvo 3P was a Business Unit within the Volvo Group (Figure 1) that was responsible for product planning, product development and purchasing for all truck brands under the group. After reorganization in 2011, Group Trucks Technology (GTT) took on this role. Since 2011 there have been several more reorganizations within the group. Figure 2 illustrates the organization as of March 2016.

[5] AB Volvo stands for "AktieBolaget" Volvo, which is a Swedish term for the Volvo Limited Company. AB Volvo is referred to as the Volvo Group in this thesis.

Volvo Technology, within the Volvo Group, was mainly responsible for technology development as well as the host for several support functions such as Lean Production and Lean Product Development, for example. After the reorganization, Volvo Technology was mainly integrated within GTT, and some of the support functions were moved to be hosted by Group Trucks Operation (GTO).

Volvo Penta is a Business Area (BA) within the Volvo Group. Each BA in the group is a daughter company to AB Volvo. Volvo Penta develops, manufactures and markets world-leading engines and complete power systems for boats and industrial applications. It has a cross-functional, matrix adhocracy network organization.

To read more about the Volvo Group, you can visit www.volvo.com.

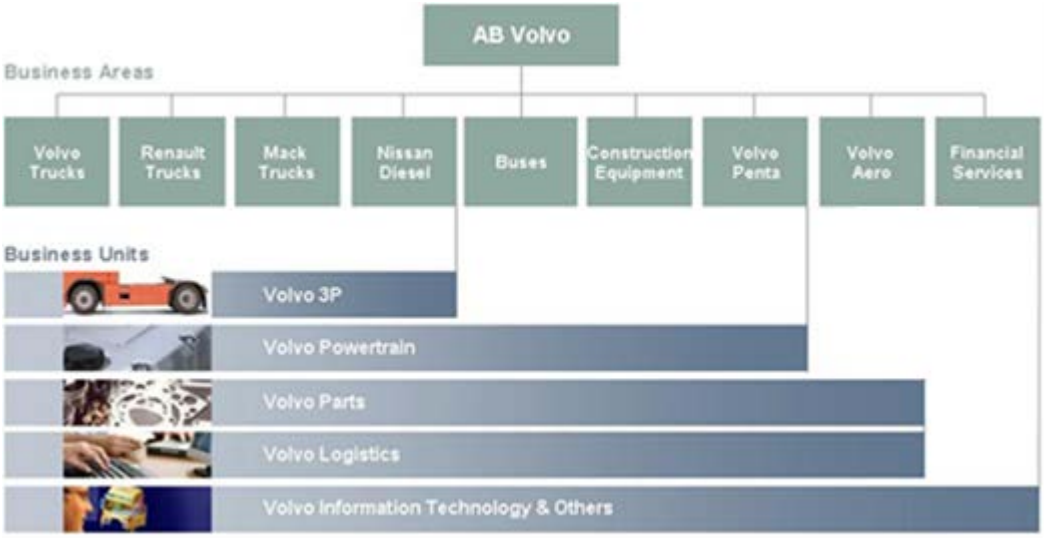


Figure 1: AB Volvo organization (until end of 2010)

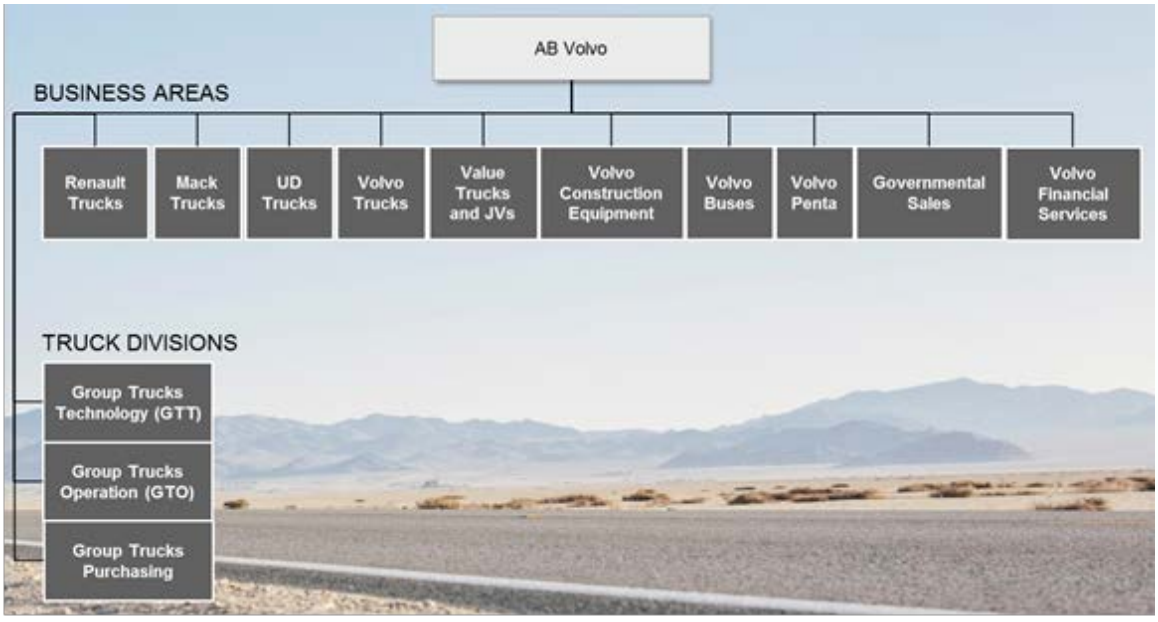


Figure 2: AB Volvo organization (March 2016)

As mentioned before, my career at the Volvo Group started in June 2005. At that time, I had the opportunity to support a department within Volvo 3P in applying Taguchi Methods, in one project for one system, side mirrors, over a 6-month period. This assignment was a continuation of a project to implement Taguchi Methods at Volvo 3P, which had already started in 2004. The Taguchi Methods implementation project (2004-2006) was not fully successful in terms of achieving continual application and stable results; however, it was a big learning both for myself and for the company (Fazl Mashhadi et al. 2012). During that short assignment, I had already started to look into potential improvements in order to achieve success. In 2006 I became a project member for a project called 'Volvo Robust Engineering System (VRES)[6]', which aimed at locally developing and utilizing robust design practices for Volvo 3P product development projects (Fazl Mashhadi et al. 2014; Fazl Mashhadi et al. 2016). It was in this job, where I had started as an industrial PhD student at Chalmers. I began to learn and test new approaches for implementing robust design methods at Volvo 3P in order to develop more robust products in forthcoming projects. This research subject was also of interest to Volvo 3P, as they had tried once before to implement robust design, and it was not fully successful. Volvo 3P wished to learn from that and then initiate new approaches in using robust design.

In September 2008 I moved to Volvo Technology, together with my manager and his team, and worked as a project member to develop the 'Volvo Production System-Product Development Process (VPS-PDP)[7]' for the Volvo Group. VPS-PDP was a further development of the VRES project, focusing both on effectiveness and efficiency of the whole product development process by taking inspiration from Lean Product Development (LPD). This initiative was hosted by Volvo Technology as the internal-Volvo consultant company. It was intended to serve the whole Volvo Group with on-the-job help in assessing product development processes and supporting them with implementation of LPD practices. I was still working with Volvo 3P and the VRES project up to 40 % of my time, in parallel, until mid-2009. Moving to Volvo Technology and working with the VPS-PDP project was interesting for me academically as well. This was due to the previously mentioned turning point in my research interest that I would also get the opportunity to research on implementing other practices and changes than just robust design, as well as working with another context than Volvo 3P. When I got this opportunity to work at Volvo Technology with this new project, my manager shared my research interest with the head of the unit and elaborated on what I had so far done in the VRES project, including how this collaborative research project with Chalmers had been a core for learning and success in the VRES project. From this, I got an agreement to continue with my research on the subject of implementing new practices, which were in this case, LPD practices.

In early 2010 in order to extendedly and globally succeed with the implementation of the most important cornerstones of VPS-PDP, Volvo Group defined a program called 'Research and Development 30% more efficient (RnD30)[8]'. This helped Volvo to increase attention on LPD and create a more global engagement for implementing it in different companies under the group. The RnD30 was a program to further develop and implement LPD practices in the Volvo Group. I also attended this Volvo Group program from the start as both project member and subject matter expert.

All companies in the Volvo Group with product development operations took part in the RnD30 program, and were also required to drive a local corresponding project within their

[6] VRES was the local name for robust design at Volvo 3P.
[7] VPS-PDP is the local name for the Lean Product Development (LPD) model in the Volvo Group
[8] RnD30 was the local name for the LPD implementation program in the Volvo Group

home organizations. In March 2011, I joined Volvo Penta and became project manager for the local RnD30 project there. When I applied for this job and got the opportunity to work with Volvo Penta, before finalizing our agreement, I also took my research interest and the academic job I had done so far, and shared it with my new manager. I presented it, elaborating on how this could be of mutual interest and learning for Volvo Penta and I. Even though I was the first industrial PhD at his department, he became very interested in this and accepted my continuation of research on the subject of implementation of new practices, which in this case it was LPD practices.

> *Observation and reflection:* Later, when I started at Volvo Penta, I noticed that my new manager had proudly announced that there would be a new employee in this position and she proved to be an industrial PhD in the same field. I got comments in my first days at work like, 'Are you the PhD who's going to be helping us implement the LPD?'
> He had also informed the upper and parallel managers in product development, and most of them were open to the idea and excited. While working there, many other employees also asked me about how the progress was and if I could share my learning with them. When I reflect on it, this was one of my first observations about Volvo Penta's culture – a culture I can describe as a friendly environment where people are open to testing new ideas and learning.

This was a very interesting step in my research process, as I could get much closer to the context of application, which was similar to what I experienced in the VRES project at Volvo 3P. This time it was LPD practices at Volvo Penta while simultaneously collaborating with the Volvo Group RnD30 program, meaning that I could do research on two different system levels, both the Volvo Group and Volvo Penta. As a result of this Volvo Penta project, many LPD practices were developed and implemented in the product development processes. To support continual application of these practices as well as their improvement, in 2014 Volvo Penta formed a group within their product development that was to support all of their product development projects and managers with LPD and other quality assurance practices. From 2014 onward I worked as Group Manager for this group, called Quality, Operational Development, and project support. This was one way for me and my team to support the continual improvement and application of the LPD practices in a long-term way after the project ended.

Among all mentioned activities that I have been involved in, I can summarize three projects included in my PhD research as: 1) the Taguchi Methods project at Volvo 3P; 2) the VRES project at Volvo 3P; and 3) the RnD30 program in the Volvo Group and Volvo Penta. See Table 1 for a summary of the research projects included in my thesis.

Table 1: Research project and corresponding companies researched

Research project	Company researched	Project period	Company project main objective	Research design
Taguchi Methods	Volvo 3P	2004-2006	Implementation of Taguchi method in PD projects	Case study
VRES	Volvo 3P	2006-2009	Development and implementation of local robust design practices	Action research
RnD30	Volvo Group/ Volvo Penta	2008-2010 (Pre-project) 2010-2014 (The project) 2014-2016 (Post-project)	Development and implementation of LPD practices for the Volvo Group	Action research

I see my involvement in the VPS-PDP project (2008-2009) more as an initial concept development for the RnD30 project, which is called the 'pre-project' in the table. I have not considered this as a separate research project in the thesis. Additionally, my involvement as Group Manager at Volvo Penta (2014-2016) is considered as post RnD30 project activity. I had the opportunity to build a team to support Volvo Penta in further learning from the RnD30 project as well as making the RnD30 results more stable. This is also not considered as a separate research project.

1.3. THE PROBLEM STATEMENT

When I started my industrial PhD studies at Volvo 3P in 2007, the company had, for many years, been successful in designing products with high uptime. The main concern however, was to further increase the uptime. To succeed with this, the company recognized that it needed to increase the amount of robust design practices in product development in order to tackle the range of failures. But the question was how to do this. Volvo 3P had tried to introduce robust design and Taguchi Methods since 2004 without gaining the desired success (Fazl Mashhadi et al. 2012). This initiative was not appreciated or supported by the product development engineers. As a result, the company decided to reflect upon the experience, learn from it, and then afterwards test new approaches for implementing and using robust design methods in product development projects. This was a problem of interest to Volvo 3P as well as to me as a researcher. The continued effort resulted in the VRES concept and success for the Volvo 3P (Fazl Mashhadi et al. 2014 and 2016).

When the Volvo Group top management learnt about the VRES project at Volvo 3P, the whole team was offered to move to Volvo Technology and further develop the concept for the whole Volvo Group. I was very interested in this offer due to the evolution of my research interest concerning implementation of other practices in other contexts. This time, Volvo Group had another concern – how to increase the efficiency and output of their product development. As a result, the Volvo Group decided to learn and implement and use LPD practices in all product development units. This was another problem of interest for the Volvo Group as well as to me as a researcher. . The result became an LPD model for the Volvo Group called VPS-PDP. This was later integrated in the corporation-wide RnD30 program in order to implement the LPD practices (Fazl Mashhadi et al. 2016). Volvo Penta faced the same challenges concerning product development, and was therefore involved in the RnD30 program.

Product development is essentially about building knowledge that is represented in physical prototypes and final product specifications, while many other processes, such as production processes, for example, more closely concern the physical products. In other words, the main component to be processed in product development is knowledge, rather the physical products themselves. Product development is mainly about knowledge generation rather than product generation; therefore, people and their development are more central to this process than the documented steps of the processes. Additionally, product development processes correspond to a more innovative process in comparison to other processes. The interaction between creativity and technology is very high in this process. In product development, the challenge is to both encourage creativity as well as standardization of practices, where efficiency is essential. To be successful with the implementation of new standard methods in product development, the new practices should be integrated in the processes of knowledge generation, and best not hinder creativity. Due to these differentiations, driving changes in how managers and engineers work in product development processes has its own challenges.

These problems put together, Volvo Group like many other companies, has had a general concern about **how to drive changes in the practices of people in product development, in other words, how to implement new practices within product development**. The Volvo Group's specific challenge has been concerning robust design and LPD practices.

Volvo Group could have used the already existing experiences and theories in the field in order to approach these problems, but due to the existing knowledge gap in the field, the Volvo Group was interested in utilizing a collaborative research program together with Chalmers. The following section presents the gap in the field.

1.4. Survey of the Field and the Gap

There are many researchers addressing the difficulties of implementing changes in an organization (e.g. Shewhart 1930s, Lewin 1940s, Kolb 1985, Pettigrew 1987, Beer et al. 1990, Kotter 1995). Some of them have also introduced remedies in managing change. Some examples of these remedies are Lewin's force field model of change (Lewin 1946, Schein 1988), Pettigrew's three dimensions of change (Pettigrew 1985), Kotter's eight-step model for transformation (Kotter 1995), and Beer's six steps to effective change (Beer et al. 1990). Many of the researchers have emphasized the importance of learning and learning processes in the success of the change. Some examples of these are Shewhart's learning and improvement cycle (1930s), the PDCA cycle (Ishikawa 1985), and the theory of learning for change management by Argyris and Schön (Argyris et al. 1985). Some researchers have discussed change difficulties due to the nature of change and the natural reaction and resistance of individuals. Many of them have dug further into resistance to change, providing remedies on how to deal with it (Coach & French 1948, Lawrence 1954, Nevis 1987, Pardo del Val & Matrinez Fuentes 2003, Ford & Ford 2008, Kotter & Schlesinger 2008). Some of these researchers have treated the resistance as a hindrance which should be removed (Kotter & Schlesinger 2008), and some have treated it as an energy that can be transferred to positive energy utilized for change (Nevis 1987). This resistance is a part of the social behaviour of human kind, and companies are always going to face this. In spite of all existing theories, companies still fail at transformation. There is no doubt that change management, the resistance to change, and how to overcome it are relevant topics for academia.

Among the researchers in the field of product development methods and tools, there are many who have pinpointed the difficulties in applying new methodologies like robust design and lean product development in practice (Gremyr et al. 2003, Martinez León & Farris 2011). When it comes to robust design, despite there being a Quality Engineering Society and other attempts at standardization of the method, it has failed to be extensively applied (Gremyr et al. 2003, Hino 2006, Bergquist & Albing 2006, Tanco et al. 2008). Aligned with this gap, some researchers have elaborated on the reasons of why this method is seldom used by practitioners (Tanco et al. 2009 and 2010, Bergquist 2015). These are mostly elaborated on as hindrances in the content of the method. Some of these researchers have further elaborated on how to get the method used more often by practitioners through introducing new content as practices of robust design (Gremyr 2005, Arvidsson et al. 2006, Hasenkamp et al. 2008, Fazl Mashhadi et al. 2016, Krogstie et al. 2015). There are a few researchers who have elaborated on hindrances due to process of change as well as remedies to overcome these hindrances. Further, change and learning theories are seldom used in this context by researchers (Fazl Mashhadi et al. 2012 and 2016). We can see the lack of usage of change management references in robust design related publications. There is also lack of action research approach in this field. There are a few cases by insiders who practice the implementation of the method in the context of application (Johansson et al. 2006, Lönnqvist in Bergman et al. 2009). Other cases are mostly literature-based or case studies by outsiders.

Lean Product Development (LPD) is another example of recent methodologies in product development. Some researchers have pointed to how Toyota manages product development (Sobek et al. 1998 and 1999, Ballé & Ballé 2005, Morgan & Liker 2006, Ward 2007, Ward & Sobek Sobek2014). Other researchers have also suggested more approaches, frameworks, principles and practices (e.g. Kennedy 2003, Haque & James-Moore 2004, Letens et al. 2011, Mascitelli 2011, Ballé et al. 2016) of lean in product development. There are also cases presented from the application of the lean practices (Kennedy et al. 2008, Oosterwal 2010, Liker & Morgan 2011, Al-Ashaab et al. 2013). Some other researchers have elaborated on difficulties in implementing lean product development in practice (Karlsson & Ahlström 1996), as well as some having discussed remedies as the future of LPD (Martinez León & Farris 2011). In spite of the work done by these researchers, there are a few empirical studies on how organizations can overcome hindrances and how they can be transformed to LPD (Liker & Morgan 2011). Choothian (2014) has elaborated on this gap as well. There are a few researchers who have elaborated on the importance of learning in becoming lean in product development (Shook 2008, Ballé et al. 2016).

Put briefly, product development is mainly about knowledge generation rather than product generation; it corresponds to a more innovative process in comparison to other processes (Ballé et al. 2016). Driving changes in how people work in product development processes has its own challenges. In the field of product development methods and tools, specifically robust design and lean product development, there are many researchers who have pinpointed the difficulties in applying them in practice (Karlsson & Ahlström 1996, Bergquist & Albing 2006); however, **there is lack of empirical studies providing knowledge on how organizations can overcome hindrances and transform people's practices in product development** (Choothian 2014, Liker & Morgan 2011). Learning and change management theories are seldom used and often not further developed in the product development methods and tools' context (Fazl Mashhadi et al. 2012 and 2016, Ballé et al. 2016). Action research is also seldom used for local development and implementation of the practices in the context of application in product development (Johansson et al. 2006), even though it is proposed as the most suitable methodology by some researchers (Liker & Morgan 2011).

1.5. THE RESEARCH PURPOSE AND SUBJECT

As stated in section 1.3, the Volvo Group like many other companies, has had a general concern in how to drive changes in the practices of product development, in other words, how to implement new practices within product development. In the previous section I elaborated on the theoretical gap in the field, as there is a lack of empirical studies providing how organizations can overcome hindrances and transform people's practices in product development. Driving changes in how people work in product development has its own challenges. Learning and change management theories are seldom used and further developed in the context of product development methods and tools.

The *purpose* of this research is to **understand how to develop and transform people's practices in product development.** Aligned with the concern for the Volvo Group and the theoretical gap in the field, this purpose could be expressed as a desire to study and learn from the implementation of new practices in product development at the Volvo Group, facilitate and improve the situation with the help of the existing theories in the field, and again learn from the application of the theories in practice, thus generating further knowledge. By doing these steps in a cyclical manner, this enquiry contributes to further development of the theories in how organizations can overcome hindrances and transform people's practices in product

development. This *action research* (or action learning) approach is described in section 3.2 in more details.

Through this enquiry, the theories are further developed by action of implementing robust design and lean product development practices at the Volvo Group. The audiences concerned with this thesis are researchers within quality engineering, quality tools, quality management, change management and product development, as well as the action research community.

The research subject of the research area is *orchestrating the implementation of new practices in product development*. To orchestrate means to arrange and control the elements and infrastructure of, for example, music, a political campaign, or in this case a process of transformation in order to achieve a coordinated effect. Practice means ways of working by individuals which are also embedded in the individuals' assumptions, values and behaviours. A practice is followed by most of the individuals in an organization and is not always the same as written procedures.

Therefore, the title of this thesis is 'Orchestrating the implementation of new practices in product development - action research at the Volvo Group'.

> *Observation and reflection:* Besides use of the word 'implementation' while writing this thesis, I have also tested other alternatives such as development and implementation, localization and implementation, or even deployment. Finally, together with my research committee, we have agreed to use 'implementation' to make it simple for people to understand, and instead describe implementation as a process of local development and usage of the practices within a context. Here, the development and usage of the practices are in parallel and grow together. Some of these alternative words are used in the appended papers.

In order to fulfil the purpose of the research and bridge the gap in the field, the research questions are developed as shown in the coming section.

1.6. THE RESEARCH QUESTIONS

Any inquiry aims to answer one or more questions in some defined context(s). The research questions are not only in writing but are the main questions that a researcher carries with her/him all the way through the research process. In social research, questions cannot be rigid, and as the researcher and the researched context learn-in-inquiry more and more, the research questions change in an evolutionary manner.

At the beginning of this journey, some research questions were developed on the basis of both my interests and the company's interests. However, through the learning-in-inquiry, the initial questions changed direction. As the research went further and evolved, more changes were introduced based on what was learned through the research and the company's interest, my interest, and supporting university's interest. By this, the research questions were refined, twisted and narrowed down along the way.

Based on the research area and subject, Volvo Group needs and the gap in the field, the final research questions could be formulated as below. The effort has been to formulate research questions which are clear, researchable, and can lead to answers that are contributing to knowledge development.

As previously mentioned, the first case study (on the Taguchi Methods project) aimed at understanding the mechanism of change through learning from a previous initiative at Volvo 3P that was not successful. Additionally, throughout the research journey, the intention has been to learn from every single project success or failure, and use them as inputs in the next project. Even within each project, I have reflected and learnt from every single action for the improvement of the next action. This is the necessity in a cyclical action learning process. Along with this aim, the first research question is formulated as:

> RQ1: What hinders or facilitates implementation of new practices to be used by product development organizations?

In both action research projects (VRES and RnD30 projects), we first utilized the learning from previous projects. Based on that, with the help of academia, I selected more theories[9] to test in dealing with the learning. Along with this intention, the second research question is defined as:

> RQ2: How can new practices be cultivated for continual use by product development organizations?

In RnD30 project, I further developed and evolved the selected theories towards a new problematic area when applying a bigger change initiative (a more complex content) that requires many people in different parts of the organization and at different system levels of a company group to change their way of working. In spite of difficulty, such as with its size, for example, working at a company group also has advantages for driving change. There are synergies to use. Thereby, the third research question is:

> RQ3: How can change of practices in product development be orchestrated in company groups[10]?

One reflection I have had from this journey and mentioned previously in section 1.1, is the role of the action research process and the action researcher in driving change in any organization. Along with this, the fourth research question is defined as:

> RQ4: How can action research support orchestrating the implementation of new practices in product development?

Here there are some new terminologies and vocabulary that I would like to clarify, although there might be some repetition.

P*ractice* means the way of working by individuals which is also embedded in the individuals' assumptions, values and behaviours. A practice is followed by most of the individuals in an organization. The practices are typically not the same as written procedures or tools.

C*ultivation* means the process of creating prerequisites to grow and develop local practices in a context. Cultivation put more emphasis on developing a local version of any concept which is adapted to the local context. Cultivation encompasses culture change aligned with the new way of working. I use the word cultivation instead of implementation here, which could be perceived

[9] Theories which, if they work well, I could use to clarify the phenomena and verify the theory.
[10] With company group we refer to a corporation with several independent subsidiaries. For example the Volvo Group consists of AB Volvo as the mother company and several subsidiaries such as AB Volvo Penta, Volvo Lastvagnar AB and etc.

as more rigid and symbolizing push from the top. Cultivation opens up for a pull from the bottom of the organization through involvement.

C*ontinual use* means repetitive use in a natural way (Book 2006) and in a dynamic manner, meaning that it is further developed when there is a need for an improvement. Alternatively, this could be called sustainable use in this context; however, I avoid this due to two potential areas for confusion: 1) 'sustainable' is broadly used in the context of environmental care with a different meaning; and 2) it could represent a more static approach, indicating that practices should be kept the same over time.

O*rchestrate* means to arrange and control the elements and infrastructure of, for example, music, a political campaign, or in this case a process of transformation, in order to achieve a coordinated effect.

In order to provide an overview of the thesis, the research questions mentioned can be cross-connected to the papers of this thesis. Table 2 illustrates how each research question will be answered through the papers. The number of crosses helps illustrate the strength of the connections; XX shows a stronger connection than X.

Table 2: Thesis research questions' connections to answers from each paper

	Kappa[11]	**Paper I**	**Paper II**	**Paper III**	**Paper IV**
RQ1	X	XX	XX	X	X
RQ2	X		XX	XX	XX
RQ3	X		X		XX
RQ4	XX		X	X	X

1.7. DELIMITATION

The context of application in this thesis is Volvo Group product development including all companies under the group that deal with product development. I have done extended scrutinizing of the Volvo 3P and Volvo Penta divisions. The scope of context is global, including people from Sweden, France, the USA, Japan and Brazil. In spite of this global representation, this thesis is not looking into the effect of the cultural differences in different countries on the research subject. It has not looked at the effect of the history of different companies within the Volvo group either.

The content of the application in this thesis is made up of robust design practices and lean product development practices. It has not looked into other practices than these two areas; however, they are extended kinds of practices that cover almost the entire process of product development. There are also some practices which are not directly covered in these two; for example, high-level HR practices like downsizing or salary setting, as well as high-level strategic decisions like when buying in new product development companies, as well as when going out from a range of product offers.

1.8. THE RESEARCH SUBJECT BACKGROUND AT THE COMPANY

Like many other companies, the Volvo Group is acting in a changing environment; therefore, there is always need for internal changes in order to keep up and enhance profitability. As

[11] *Kappa* is a Swedish term used for the first part of the PhD thesis where all papers and research questions are discussed and integrated.

product development is seen as a core process for the Volvo Group, enhancing its operational results is a key for total company profitability. This could happen partly through semi-organized continuous improvement, but sometimes there is a need for breakthrough change initiatives/projects. Through the research projects mentioned in the product development, the Volvo Group has learnt that in order to achieve operational results from the change initiatives continual action, improvement and learning are the keys to success. However, the latter requires a thoughtful orchestration. Therefore, at the Volvo Group a successful change initiative in product development is characterized by: 1)an orchestration for change to address the right issues should be in place; 2)action to improve should be taken and learning should be concluded in a cyclical process. As the result a successful change should also enhance: 1) the operational and, 2) the financial results.

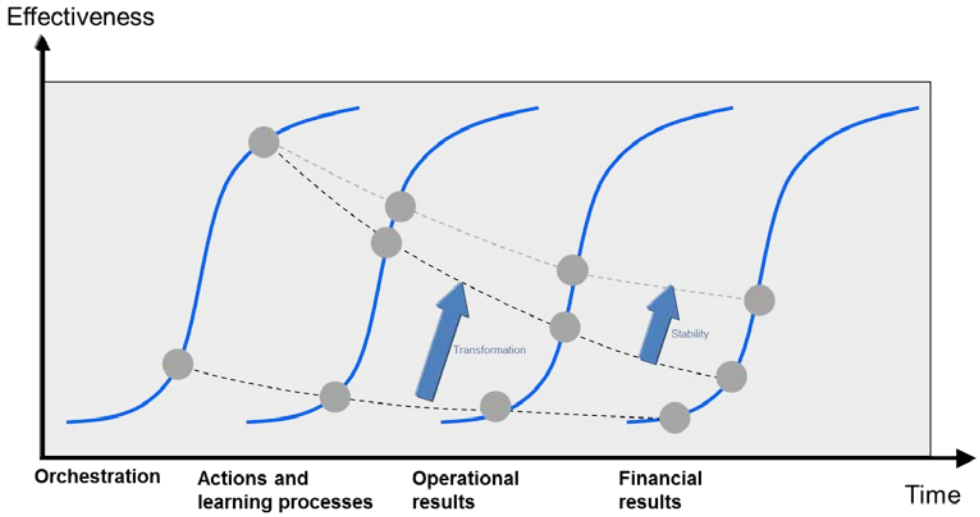


Figure 3: The effect of the change attributes on the results of change initiatives – experience from the Volvo Group (presented in the RnD30 program, 2012 by the Volvo Group)

Figure 3 presents how these attributes impact each other over time based on the Volvo Group's experience. The first dotted line at the bottom shows that in a change initiative where there is no suitable orchestration in place to arrange and steer learning processes, no big operational or financial results could be expected. The second dotted line illustrates that through more effective orchestration and more engagement in the learning processes, operational results will increase, with financial results being achieved later when things become stable. However, these two lines are not parallel, which means that achieving operations results, and even more so financial results, from change initiatives in product development are time consuming. The lighter dotted line illustrates that with the same level of orchestration, more and more operational and financial results will be achieved over time. When the organization has already experienced operational and financial results by being involved in learning processes, it will be much easier to get more engagement from people in the learning processes, and thereby get an increase in operational and financial results successively. It is also worth mentioning that if an initiative is located in the lower part of the above graph, it does not mean that the initiative is unsuccessful. It is totally dependent on required operational changes and financial results, and where in the graph an initiative aims to be[12].

[12] This part is based on the Volvo Group experience presented in the RnD30 program by the program management team. It is an subjective view and not based on research or academic consideration.

The picture above is used here to illustrate the status of the three research projects in this thesis as well. To achieve a greater understanding of the expected results from each project, Table 3 presents a summary of all required financial and operational results for the three research projects.

Table 3: Financial and operational results and measures

Evaluation	Measures in research projects
Operational results	Project Taguchi Methods: Taguchi Methods used by PD engineers for projects Project VRES: Practices used and completed at each project gate Project RnD30 Volvo Penta: Efficiency increased through improvement of GPOT and QDCF of projects
Financial results	Project Taguchi Methods: Uptime increased through Fault Frequency reduction over time Project VRES: Uptime increased through Fault Frequency reduction over time, as well as warranty cost reduction Project RnD30 Volvo Penta: RnD cost vs. Sale (%), and cost per hour reduced

As mentioned before, uptime is an important factor for truck customers. The most important part of uptime which could be affected in the product development phase is fault frequency. Through fault frequency, the failures are measured per vehicle, giving the percentage of the number of 'claimed' parts per vehicle on average. In order to assess that products are robust, the fault frequency of the products for each brand is measured over time, making sure that products have the desired performance consistently without significant variation. In the Volvo Group, fault frequency is also analysed and complaints are reported in detail.

Volvo Group evaluates the efficiency in product development by evaluating development projects through measurement of the Gate Passed On Time (GPOT) percentage with respect to the drivers of Quality, Delivery, Cost, and Feature (QDCF). GPOT is measured in three to thirteen different gates[13] to ensure the sustainability of the development processes. GPOT is also measured in all development projects.

> *Observation and reflection:* At the beginning of my work in the RnD30 project at Volvo Penta, we were keen to link the result of the initiative to the measurements (KPIs). However, during the journey the interest shifted from measurements to focusing on learning and developing better working processes.

The figure below illustrates my subjective view of the four research projects, based on my participation, when it comes to the four change attributes mentioned.

[13] The number of gates depends on the class of projects and companies. The class of a project is determined by its total estimated cost and complexity. Each company in the Volvo Group might have different numbers of gates for each of its project classes.

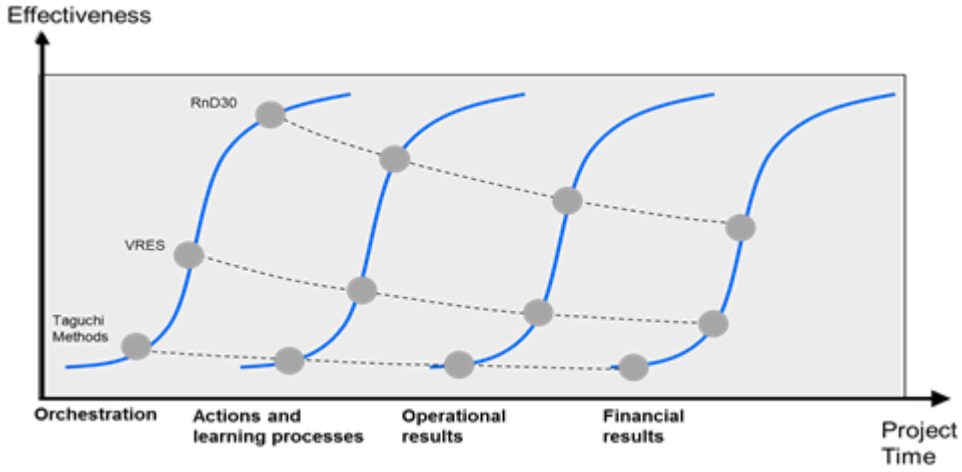


Figure 4: The status of the change attributes in the research project (my subjective view)

It is also important to mention that the learning that the Volvo Group has had in the Taguchi Methods and the VRES projects, supports making a decision to have a higher level of orchestration for the RnD30 project. The Volvo Group were aware of the complexity with such a project, as well as their high ambitions to achieve such a result.

> *Observation and reflection:* One reflection I have from being involved in these change projects is the change in the wording used by insiders. I have noticed that during these journeys, managers and people involved in the change used the word 'learning' more and more in place of the word 'change'. At the time of project initiation, only talk of change and results had persuaded them; however, later in the project, the core of what people were talking about was 'learning'.

1.8.1. THE RESEARCH SUBJECT EVOLUTION PROCESS

The research subject in this thesis had evolved throughout the research period. This evolution is the result of the development of both the company researched and of myself as a researcher. This is what I call an 'action learning' process.

In the VRES, initially robust design tools and their application were the main research interests, and the project's objective at the company was developing robust products. In this project, robust design was initially a few limited statistical tools; however, during the journey we[14] learnt that a few tools were not going to assure robust products and that we were dealing with a more complex phenomenon. We learnt that there is a need for a basic system of values with respect to variation and robustness, and a system of integrated local practices that contributes to robustness of products. We understood that local practices should be developed based on local problems. We agreed that learning processes are essential so that robust design practices become a natural part of the product development work. Therefore, the project objective was changed to development and implementation of local robust design practices to assure robust products. By that, the research subject also evolved into looking not only at the robust design practices as such, but also as to how robust design can be cultivated into local practices in product

[14] When I say 'we' here, I mean myself as researcher as well as the company researched, as my learning as a researcher was continuously shared with the project team at the company as well as with other people involved.

development and used in a natural way (Book 2006). This aimed at understanding how the process of learning and change could be facilitated.

When I became involved in the VPS-PDP development and the RnD30 program at the Volvo Group Level after that, the project team took all of the learning from the VRES project and Taguchi Methods project. More specifically, we utilized these learning points while designing the infrastructure for the RnD30 program. At that point in time, the LPD practices became the subject for my research instead of robust design. I made a small change in the research subject then also. I started to look into how the LPD program could be orchestrated in order to succeed with the learning processes and implement the new lean practices in a global company like the Volvo Group with several sub-companies or BAs like Volvo Penta. By orchestrating, I mean how to arrange or control or steer the elements and infrastructure as seen in, for example, music or a political campaign, as well as in here with a change initiative in order to achieve a maximum effect.

After moving to Volvo Penta, I got the opportunity to be closer to operations and test my theories in action closer to the implementation context. In that position, as insider action researcher, I also had the role of sharing my learning from previous research projects and helping the new team at Volvo Penta to catch up. In other words, I needed to act as facilitator for their learning concerning the process of change and how to orchestrate the project at Volvo Penta in order to succeed; I supported them in learning how to learn. As they were already involved in the RnD30 program at the Volvo Group level, they had some insight into how we had done it for the Volvo Group program. As I was an insider action researcher, the project members had more confidence and trusted that there were many theories and learning available to us in this project and from academia as well. I will come back to these projects, learning points and results through this thesis.

Presenting this background, after several changes, the research subject in this thesis is orchestrating the implementation of new practices in product development. Through this thesis, we will also reflect on the role of insider action researcher in this orchestration.

Observation and reflection: Reflecting on my journey, my turning points and my development process in these different roles, I would like to pinpoint and summarize two processes inside me that broadened my views. The first one is my view on the quality management field from rigidly looking at it as an application of quality tools in companies to a broader and dynamic view of creating a learning organization that adopts and localizes new practices in order to deal with existing quality problems. The second one is my view on the action research process, which as a researcher I prefer to call an action learning process. The process of working as an insider action researcher has pushed me into a deep reflection process, which has become my daily habit and has evolved my views in the field of my work. This evolution supports me not only in delivering a better job for my employer as prescribed in my role description, but also in developing my role as such in the right direction most effectively for the company. That is to say, besides benefits for academia, I see huge benefits for companies in employing action researchers in specific positions as a learning asset for the organization. I will use and come back to these two points in the rest of the thesis.

In the next chapter I describe the concepts and theories that I have mainly used in the rest of this thesis work.

2. CONCEPTS AND THEORIES IN USE

The theories used in this research are selected on the basis of the researcher's views about the applications of the theories in practice; however, this view has been continuously challenged by the existing paradigm at the university's division involved with this research as well as by insiders at the company, in order to be able to map the theory categories that are suitable for the features of the context (Schön 1983).

First, some views on product development processes in the organizational context are elaborated upon. Next, the key theories of change management and learning organization that are used in analysis of the data are discussed. Later, the theories concerning robust design and lean product development are briefly introduced.

2.1. PRODUCT DEVELOPMENT PROCESSES IN THE ORGANIZATIONAL CONTEXT

Every organization is a socio-technical[15] system that encompasses interlinked and interactive processes, operating in a specific environment (Flood 1997, 2004), which is in most of the cases, not very much conveyed by the organizational chart (Scott 2007). The organizational context referred to in this thesis has been defined based on Nadler and Tushman's (1984) organization framework and then adapted to the language used within the company (Figure 5).

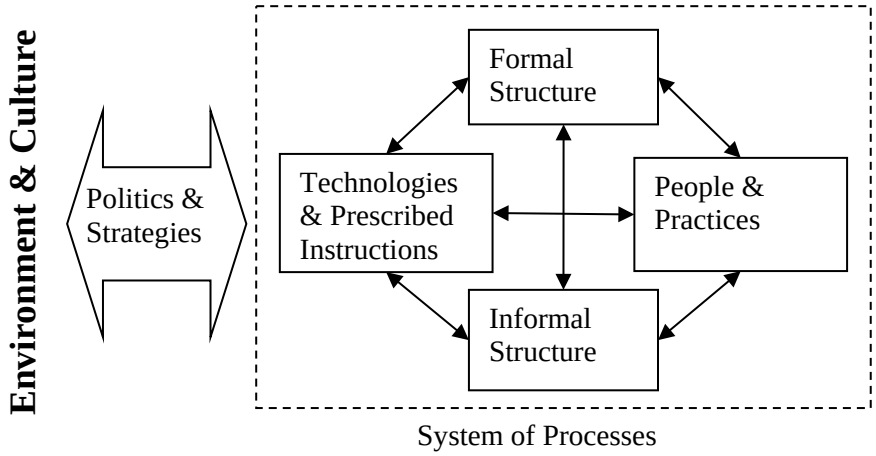


Figure 5: Attributes in the organizational context (adapted from Nadler & Tushman, 1984)

[15] A socio-technical system applies to the interaction between people and technology in workplaces.

With the latter view, the organizational context encompasses environment and culture, politics[16]and strategies, technologies and prescribed instructions, formal structure, people and practices, and informal structure (e.g. Pettigrew 1987).

Every organization carries a specific *culture*. Organization culture describes the pattern of values, beliefs, and expectations more or less shared by an organization's members (Scott 2007). Schein (1992) has defined the organization culture in terms of underlying assumptions about the organization, relationship to its environment, the nature of reality and truth, human nature, the nature of human activities and the nature of human relationships. *Strategy* describes the choice of the market segment, customer segment, and the way it seeks to provide the outcomes to the customer, defined by tactics and explicit goals. One typology that has been distinguished among different types of strategies from the product development perspective, is proposed by Miles & Snow (1994). They distinguish among three types of strategies. The first are 'prospectors' focusing on creating innovative products. The second are 'defenders' focusing on efficiency of the internal process. Finally, the third group are 'analysers' combining the two approaches by using a platform strategy for maintaining the existing product and focusing more on efficiency while also regularly updating with new products[17].

Every organization employs *technology* (software and hardware) together with working methods, so-called *prescribed instructions*, in order to pursue a particular strategy in transformation of the inputs to the outcomes. In order to do the work and utilize the technology, *people* are another type of resource; however, people in the organization do not always follow the prescribed instructions. On the contrary, they perform their own *practices*. Practices are not always the same as written procedures.

People are also working in a specific structure of formal power and job descriptions, also called *the formal organization structure*. But organizations are rarely managed through only the formal structure. Within any organization, there is an *informal organization structure*, which has a great effect on how it operates. The informal structure is embedded in the context of the organization.

Organizations encompass several interactive processes; therefore, an organization can be seen as a system of processes with a system boundary (Flood 1997, 2004). Product development processes belong to this system. In some literature, a product development process refers to a complete process of launching a new product, consisting of product engineering, manufacturing and marketing (e.g. Ulrich & Eppinger 2004, Wheelwright & Clark 1999). By this definition, a product development process is a complete process and it includes activities performed to generate a new product or modify the existing one (Wheelwright & Clark 1999). However, some companies have defined the product development process differently, where it refers only to a process of product engineering.

Generally throughout this thesis, the view that 'organizations are systems of processes with a system boundary' allowed the author to adapt many aspects of the organization theories to product development processes. Product development processes are operated in specific physical, technological, logical, cultural and social *contexts* (e.g. Scott 2007, Pettigrew 1987, Cole & Scott 2000). They include tangible aspects such as technologies (software and hardware),

[16] The politics of an enterprise relates both to the internal distribution of power and to the plurality of contenders involved (Pettigrew 1987).

[17] The Volvo 3P organization seems to be adapted to the third group. It has both new product projects as well as phase lift projects. Additionally, Volvo 3P has many platform projects which are common to all four brands. The organization is structured on the basis of standard modules as well.

prescribed instructions, formal structures as well as informal structures, daily practices and the behaviours of people. Product development is essentially about building knowledge that is represented in physical prototypes and final product specifications. It corresponds to a more innovative process in comparison to other processes (Ballé et al. 2016). Innovation and technology have a high level of interaction in this process, and people are central to this. Therefore, people and their development are central to these processes, rather than the formal steps of the process. My adapted view of product development processes is summarized and illustrated in
Figure 6, where I have illustrated the product development as input and output, with more controllable elements at the top and less controllable elements and bottom.

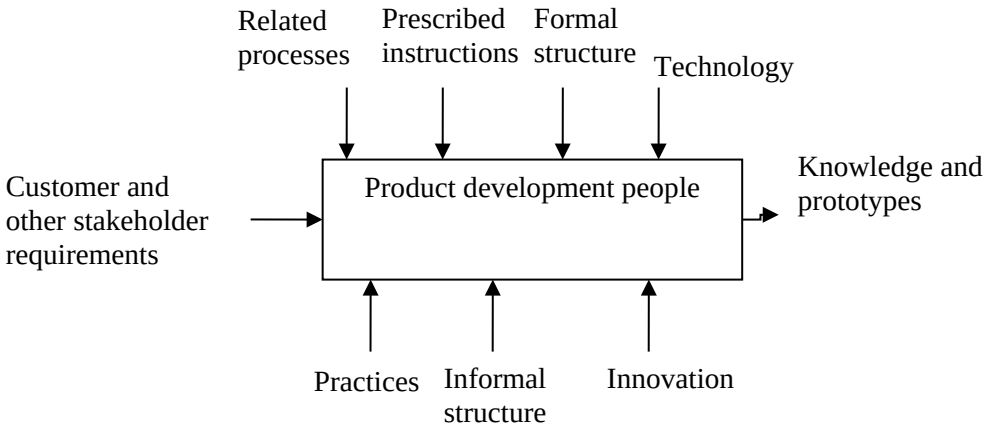


Figure 6: Product development processes as system of processes

According to Ulrich and Eppinger (2004) a successful product development process results in products that can be produced and sold profitably. There are many dimensions pinpointed by different authors to assess the performance of a product's development process. However, one commonly discussed dimension is quality (e.g. Wheelwright & Clark 1999). Quality in this sense can be evaluated by different interactive items (e.g. Ulrich & Eppinger 2004, Wheelwright & Clark 1999 and Roozenburg & Fekels 1995). One is how the product performs its specified target functions, and another is to what extent the targets are based on customer needs. These two items are the conditions for *effectiveness*. Another one is how reliable the product functions in different conditions. This is the condition for *robustness of products*. Another evaluation can be based on how well the process makes use of all available resources. This is the condition for *efficiency* (e.g. Juran & Godfrey 2000, Alänge 1992). The evaluation could also be based on how much the efficiency of the process is consistent over its lifetime and in different projects. This is the condition for *robustness of processes*.

2.2. Learning Processes and Change Theories

Organizations in competitive environments try to respond as quickly as possible to the external environment in order to be able to achieve long-term survival (Senge et al. 1999). The response to the external environment is achieved through changes of strategies, politics and systems (Beer et al. 1990), in other words, regarding the rational aspects, and through individuals changing the practices within those systems (Park Dahlgaard 2002).

According to Beer et al. (1990), successful change program follows six steps: 1) they create commitment to change through joint diagnosis of problems; 2) they develop and share visions of how to organize and work according to required change; 3) they foster consensus for the new

visions and provide competence for acting and moving forward; 4) they spread revitalization to all departments without pushing from the top; 5) they institutionalize through formal policies and systems; 6) they monitor and adjust strategies in response to problems and revitalization.

Not far from the view of Beer et al. (1990), John Kotter in his model for transforming the organization, highlighted the eight common mistakes that lead to failure of change efforts (Kotter 1995). Accordingly, he has presented the 8-step model for transformation: 1) *establishing a sense of urgency*: this creates survival anxiety so people see the urgency for change; 2) *forming a powerful guiding coalition*: there is a need to have people with power to lead the changes and make them work as a team; 3) *creating a vision*: this is to direct the change through a communicative vision and strategy; 4) c*ommunicating the vision*: is important to use all means possible to communicate the vision and teach new wanted behaviours; 5) *empowering others to act on the vision*: people should have all the mandate needed to act on the change, obstacles should be removed, and people should dare to act differently; *6) planning for and creating short-term wins*: this will illustrate the benefits and rewards of the change, generate credit for it, and motivate people to go further; 7) *consolidating improvement and producing still more change*: this is to get the use of all generated credit from the short-term success and the create more needed changes by hiring, promoting and developing people who can implement the vision; and finally 8)*institutionalizing the new approach*: this step is to articulate the connection between new behaviours and successes and develop the means to ensure leadership development.

Kotter and Schlesinger (2008) have also elaborated upon the four reasons why people resist change as: 1) parochial self-interest: losing something of value; 2) misunderstanding and lack of trust: potentially costing them much more than they will gain; 3) different assessment: the employees assess the situation differently from the change initiative; 4) low tolerance for change: fearing that they cannot develop the new skills needed for a change. They have also presented six ways that help dealing with resistance. These steps are to be selected based on the situation and case. The six steps could be summarized as:

- Education and communication: seeing the need and the logic of change
- Participation and involvement: involving resisters so they can forestall resistance
- Facilitation and support: providing training in new skills
- Negotiation and agreement: offering incentives to resisters
- Manipulation and co-optation: providing very selective partial information or giving resisters a desirable role in the change
- Explicit and implicit coercion: forcing and threatening people.

Some years before the Beer and Kotter's work, Kurt Lewin, an intellectual father of contemporary theories of planned change (Schein 1988), emphasized that the key to organizational changes was to facilitate learning and so enable the individuals to experience, understand and change their perceptions and ways of working (Burnes 2004). Learning derives from the Proto Indo-European, *leis*, a noun meaning to track or to furrow. To learn means to enhance capacity through experience and reflection gained by following a track or discipline. Learning occurs when individuals are involved in thinking and profound reflection on their fundamental assumptions and thereby improve behaviours and ways of working (Schön 1983, Argyris & Schön 1996). Learning can be viewed a cyclical process of improving actions through better awareness, understanding and 'integration' of what has been learned (Scheinberg & Alänge 1997).

Learning happens in real life contexts and not only in classrooms. It might not be fully under control, but it generated a knowledge that enhances the capacity of the learners for effective actions (Senge 1999). This has been elaborated upon in a three-step directive model of change by Lewin (1951). The first step in this model is to 'unfreeze' the existing situation and overcome the resistance to change. He argues that the existing quasi-stationary equilibrium needs to be unfrozen before individuals can unlearn the existing ways of working (see also Burnes 2004). This is typically achieved by developing awareness and understanding of the current state and its corresponding threats compared to the desired state in all individuals, in order to increase survival anxiety and therefore motivation to learn and improve. Through this awareness, all individuals reflect on their behaviours and actions in the current state in order to recognize the gap that exists between the current and the desired states.

The motivation to learn and improve does not necessarily ensure a movement towards new quasi-stationary equilibrium. In Lewin's model, the second step is to 'move' in the context towards a new competitive position and seek a new level of equilibrium. This step concerns management of the organization's transition from its current state to the desired state. It is rarely possible to plan or predict the outcome of this step; instead it is the result of decisions through testing available options and learning new ways of working. Therefore, in this step, ethics are considered through emphasis on testing, learning and decision-making with respect to the individuals' beliefs and values (e.g. Burnes 2009). The third step in Lewin's model is to 'refreeze', which refers to the need of sustaining the change in the new quasi-stationary equilibrium by developing the standards in the organization. In my view, Kotter's eight steps for change (1995) correlated to the unfreeze, move, and the refreeze steps in the Lewin model.

There have been some criticisms of Lewin's work such as concerning its simplistic view of reality and the linearity of the model, for example (e.g. Moss-Kanter et al. 1992, Weick 2002). Therefore, in opposition to Lewin's change model, emergent approaches have been offered later and started to emphasize ideas like complexity, non-linearity, continuous and open-ended processes of change, for example (e.g. Pettigrew 1987, Beer & Nohira 2000, Dunphy etal. 2007). Burnes (2004, 2009) has reflected on some of the criticisms and highlighted that there is a possible misunderstanding of Lewin's model of change. Concerning the simplicity of Lewin's view, he argues that the core of Lewin's work is his participative approach to change in ways of working. Hence, the simplicity in Lewin's view of change is more an interpretation by the people who have tried to use his model. Lewin's view seems to be linear only to some researchers. On the contrary, other researchers have argued that Lewin has emphasized the importance of cyclical activities of learning in any organizational change and improvement (see, e.g. Argyris et al. 1985, Burnes 2004, 2009). Thus, Lewin's model could also be seen as a cyclical model in which the refreeze step highlights the activity of reflection and standardization of learning.

Various researchers have used learning cycles for change management (e.g. Shewhart 1930s, Lewin 1940s, Kolb 1985). However, within the quality field, Shewhart's Specification-Production-Inspection (SPI) cycle was one of the first. Later, Shewhart's SPI cycle evolved into the Plan-Do-Check-Act (PDCA) cycle (Ishikawa 1985), which was widely used within Japanese companies (e.g. Moen & Norman 2009, Mauléon & Bergman 2009) and subsequently popularized worldwide. The main activities in each PDCA phase have been interpreted differently in the literature. Figure 7 shows one of the PDCA cycles with the main activities concerned in each phase, which has been adapted from Shiba et al. (1993) and used in this research.

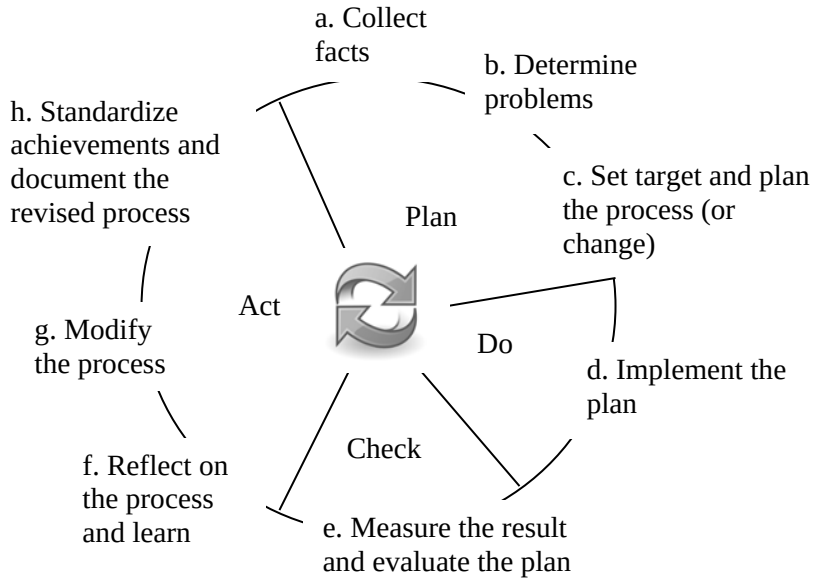


Figure 7: PDCA cycle and top-level activities corresponding to learning (adapted from Shiba et al. 1993)

Every PDCA cycle is triggered with a perceived symptom(s), a symptom that is an observation and might not be the actual problem. As the first step inside PDCA, the symptom should be transferred to a determined problem through collecting and analysing facts; accordingly, a target and countermeasures should then be planned (Plan). As the second step, actions for improvement should be taken (Do). As the third step, the results of actions should be evaluated (Check). And finally based on the result, the process of improvement should be reflected upon, the lesson learnt should be captured, and the results should be standardized (Act).

As stated before, Lewin's model could also be seen as a learning and improvement cycle. In such a cycle the 'unfreeze' step is equivalent to the 'P' phase in PDCA, the 'move' step is the same as 'D' and 'C' phases in PDCA, and the 'refreeze' step is referring to the 'A' phase.

One of the theories used in this thesis is the learning alliance. A learning alliance emphasizes establishing a joint relationship between actors due to their mutual need and interest in building knowledge and/or competence. The 'learning alliance' concept refers to the fact that most learning takes place in relationships (Alänge & Frischer 1998). According to Frischer et al. (2000), at the core of the learning alliance is the notion of mutuality in terms of developing a mutual platform for the involved learners. The mutuality indicates that learning is a mutual responsibility, and that there are opportunities for learning in the relationship for all actors. The relative balance between the actors in a learning alliance can vary considerably, and typically it also varies over time. However, it has been found that a high degree of mutuality is beneficial for learning, including mutual trust and commitment as well as an active involvement in the learning process. One example of a learning alliance is the traditional 'master-apprentice' way of learning, where the apprentice learns through instructions, by observation, by participating in work, and by enquiring (Alänge & Frischer 1998).

Relationships can be characterized as instrumental, affective and morally based (ethical) (Moss-Kanter 1967, Scheinberg 1989). Instrumental relationships focus on the task, and nothing else. Affective relationships include more dimensions, including the actors expressing what they like and dislike. The ethical dimension in a relationship includes expressions of values and views on what is good and bad, right or wrong. A relationship of a purely instrumental nature lacks the

potential for transferring more subtle and tacit components of competence. If more affective and ethical dimensions are included in the relationship, there is a greater potential for communicating more tacit aspects of competence (Alänge & Frischer 1998). Scheinberg & Frischer (2004) in their study of learning relationships between supervisors and training medical doctors, found that an initial want of being polite hindered the development of a learning relationship, although over time most pairs succeeded in developing more than an instrumental relationship.

The learning alliance concept is applicable in many different contexts, such as between teacher and student, father and son, coach and trainee, supervisor and doctoral student, as well as between team leader and team members (e.g. Scheinberg & Frischer 2004). The learning alliance concept can also be used as an analogy to analyse the learning between two organizations.

Additionally, as learning is a key factor for organizational change and action research, a learning alliance between an industrial firm and a university can be a great opportunity for both – for the firm to learn in order to make change happen, and for the university to learn in order both to generate scientific knowledge and to develop professionals in an industry setting. Through involvement in such a learning process, individuals in the organization will be engaged in the improvement activities, and therefore find it easier to make the change as a natural everyday practice. Individuals at the university can also create scientific and applicable knowledge if they are involved in the learning process in the action. The individual learning may also be transferred to the organizational learning through standardization – for the company as best-practice standardization, and for the university in the form of academic papers, or of master's theses written by students as the last step in their academic/practical education.

There could be many more theories within change management to be used in this thesis, but I have utilized PDCA as a grand base theory that I believe most of the other theories are based on.

2.3. ROBUST DESIGN

Customers appreciate a product that performs its function independently of disturbances during its life cycle; thus, unwanted variation decreases a product's value for the customers. In recent years, some methods and methodologies have been introduced in order to support companies in dealing with variation. Robust design as a general concept elaborates upon how the robustness can be insured during design activities in product development processes. According to Box and Fung (1994) and Fowlkes and Creveling (1995), a product or process is robust when it is insensitive to the sources of variation, even though the sources themselves are uncontrollable. Before describing methods and methodologies for robust design, there is a need to describe variation, which is a core concept to this subject.

Variation is a law of nature; no two people or things are exactly the same (Fazl Mashhadi 2010). As a result, no two customers use the product in exactly the same manner; no two environments in which a product is used are completely identical (Ross 1988, Watson & Watson 1994). In industry, variation is the difference between ideal and actual performance. It is the enemy of quality, as it increases unpredictability in the product performance (e.g. Juran & Godfrey 2000).

Sources of variation can be found in different phases of the product life cycle. They are the generators of the variation, wanted or unwanted. A very general categorization of sources of variation could be as follows:

- Sources of variation in the product development processes (e.g. not well defined requirements);
- Sources of variation in manufacturing (e.g. machinery capability); or
- Sources of variation in the usage period (e.g. customer behaviour).

- **Noise Factors** refers to *uncontrollable*[18] *sources of variation*, which might negatively impact the performance [19]. A product engineer cannot control noise factors, but can design in such a way that the resulting product is less sensitive to them.

When we talk about robust design in this thesis, it encompasses incorporation of product development, manufacturing and usage information concerning uncontrollable sources of variation, upstream to the product development, and designing products that are less sensitive to these sources.

The Taguchi Methods are one of the development methods for robust design. It is a pragmatic statistical method for designing products and processes that are insensitive to sources/uncontrollable sources of variation under actual, real-life conditions. It was pioneered by Dr. Genichi Taguchi after the Second World War (Phadke 1989). It was initially established as a Japanese statistical method in the 1970s; however, Japanese companies shied away from using the method due to its complex theories and typical terminologies. The method was first deployed in the United States successfully in the 1980s and re-imported to Japan in the 1990s as Quality Engineering (QE), but it failed to be extensively applied (Hino 2006). Still, there exists a Quality Engineering Society and there are attempts at standardization of QE.

Taguchi's focus was mainly on *robust parameter design and tolerance design*. Robust design in this sense refers to how to set controllable parameters in the design in order to make products or processes robust and minimize the quality costs (see, e.g. Phadke 1989; Taguchi 1986, Hino 2006). This is done with the help of statistical Design of Experiment (DoE), in a more simplified manner, to create an experimental test plan, analyse the results of the tests, and improve the performance of products. This step may be mainly utilized during development phases of any new design (Ulrich & Eppinger 2004). The conceptual phase has an important role in reducing the sensitivity as well. This is referred to as *system design*, which encompasses the process of robust concept generation and selection based on customers' true requirements (Bergman & Klefsjö 2004; Wang 2005; Andersson 1997). System design was not emphasized by Taguchi as much.

Robust design, as a general concept of 'decreasing the variation' of product performance, has gradually become popular in product development literature (see, e.g. Barkan & Hinckley (1993), Araujo et al. (1996), Esterman & Ishii (1999), Araujo (2000), Araujo (2001), Ulrich & Eppinger (2004), and Swan et al. (2005)). Despite the popularity of the robust design concept in product development literature, the diffusion of the Taguchi Methods in application does not seem to be very widespread [20] (see, e.g., Thornton et al. (2000), Antony (2002), Gremyr et al. (2003),

[18] They may be either essentially uncontrollable or too expensive to control.
[19] According to Clausing (1994), noise factors can be divided into three groups: uncontrollable variation in usage condition, e.g. uncontrollable variation in behaviour of customers in using products; uncontrollable variation in manufacturing, e.g. uncontrollable changes in manufacturing environment; and uncontrollable variation in deterioration, e.g. uncontrollable changes in material performance during the wear-out phase. There are also other ways of making this categorization (e.g. Taguchi 1986, Phadke 1989, Davis 2006).
[20] The gap basically concerns the disagreement between statisticians who have been critical of Taguchi's simplification of the concept, which might result in wrong solutions.

Arvidsson et al. (2003) and Saitoh et al. (2003)). This gap has led some academic and industrial researchers to search for ways of increasing the acceptance of the method in industry through development of broader methodologies focusing more on the primary principles behind the Robust Design Method by Taguchi and developing practical linkage to product development processes (e.g. Gremyr et al. 2003, Arvidsson et al. 2006, Arvidsson & Gremyr 2007, Hasenkamp et al. 2008).

One such example is Robust Design Methodology (RDM) proposed by Arvidsson et al. (2006). In order to avoid robust design being rejected by organizations, RDM has supported a set of principles that support the emergence of a culture that is characterized by the values and usage of tools appropriate for robust design concepts (e.g. Mellby 2006). In RDM, a robust design concept is referred to as any effort (statistical or non-statistical) to achieve insensitivity (Gremyr 2005, Arvidsson & Gremyr 2007). This perspective is what makes RDM different from the concept that Taguchi pioneered. Arvidsson et al. (2006) have elaborated on three different principles for robust design in their RDM. One is *variation awareness,* and conscious consideration of variation in decision-making during the development process.

Insensitivity to noise factors is the second RDM principle, which means that RDM focuses on eliminating sensitivity to noise factors rather than eliminating the factors or controlling them (see Hasenkamp 2009). These two principles of RDM work hand-in-hand. Deploying RDM as such supports the development processes in designing products that carry out their required functions regardless of the sources of variation. However, the *continuous applicability* of the concept in the context of the organization is the third important principle of RDM. This principle emphasizes the importance of RDM in all phases of product development processes every time.

Besides the RDM, there have also been other efforts in development of methodologies around the mindset of variation, e.g. Design for Six Sigma (DFSS) (see Chowdhury 2002, Mader 2002, Antony 2002).

2.4. LEAN PRODUCT DEVELOPMENT

In academic literature, 'lean' started to be used by introducing 'Lean Production', basically referring to the 'Toyota Production System (TPS)' as the first reference example by Krafcik (1988), Womack et al. (1990), and Clark & Fujimoto (1991). Even though these first references do not provide the details of the product development system at Toyota, due to limited access to Toyota product development, the ideas behind Lean Product Development (LPD) or lean design started to take form (Clark & Fujimoto 1989, Womack et al. 1990, Clark & Fujimoto 1991). Womack et al. (1990), in their book 'The machine that changed the world.' used the concept of LPD, illustrating this with the example of Honda developing its Accord model. In this context, they elaborated briefly on the characteristics of LPD. Thereafter, many researchers started to elaborate upon the meaning and function of LPD or lean design (e.g. Ward et al. 1995, Liker et al. 1996, Reinertsen 1997, Cusumano and Nobeoka 1998, Sobek et al. 1998, Kennedy 2003, Fiore 2003, Mascitelli 2004, Morgan & Liker 2006, Reinertsen 2009, and Ward & Sobek 2014).

While reviewing the above literature, discussing with university people and having dialogues with people in industry, I found out that there is some commonality for LPD definition and purpose between different sources, but that there is still a wide range of interpretation of the concept.

In 2006, James Morgan and Jeffrey Liker in their book 'The Toyota Product Development System-Integrating people, process and technology' introduced the title of Lean Product Development (LPD) based on the Toyota Product Development System. The first element, people, emphasizes the role of chief engineers and claims that a true lean system focuses on people development and continuous improvement. By processes, they mean flows in the product development operations through cross-functional and simultaneous engineering, which also is further elaborated in some other references as set-based concurrent engineering (Sobek et al. 1999, Ward 2007). Finally, tools and technology refers to standardization and visualization as two main enablers of LPD. Other authors, e.g. Reinertsen (1997), Sobek et al. (1998, 1999), Kennedy (2003) and Fiore (2003), wrote about the idea of Lean in product development without referring to the name LPD.

In some literature, LPD is presented as continuously reducing waste in the form of Design-In-Process (DIP), cycle time and cost associated with development processes (e.g. Morgan & Liker 2006, Ward 2007, Ward & Sobek 2014). Other literature addresses Lean design focusing on reducing waste in the form of product cost and cost of poor quality (e.g. Mascitelli 2004). Considering the above goals, many initiatives and methodologies in product development, e.g. Robust Design Methodology (Gremyr 2005) and Design For Six Sigma (Chowdhury 2002) can also be considered to belong to LPD.

LPD is defined typically by a set of principles, practices and techniques (Liker et al. 1996, Reinertsen 1997, Liker 2004, Haque & James-Moore 2004, Morgan & Liker 2006, Hino 2006, Ward & Sobek 2014). Principles describe the required objectives and practices to put them into action. The practices are mostly supported by techniques and tools. Based on my literature review the most important principles and practices of LPD could be summarized as below (Liker et al. 1996, Reinertsen 1997, Sobek et al. 1999, Liker 2004, Haque & James-Moore 2004, Morgan & Liker 2005, Hino 2006, Ward 2007, Ward and Sobek 2014).

> *To create value for the customer in all operations*: This emphasizes the need to identify which operations bring value for the customer and which do not, and to eliminate the non-value adding activities – or waste – in the development process. Value Stream Mapping and Value Engineering are alternative practices for this principle.
>
> *To work in goal-oriented and cross-functional team*: This is about creating empowered cross-functional teams with high average skill level, instead of focusing on individuals with extraordinary technical skills. Such cross-functional teams will reinforce the relationship between functional management and project management and create an organization in which all employees are engaged and committed to the goals. A practice for this is Visualization.
>
> *To involve everybody in continuous learning and sustainable improvement*: Learning and continuous improvement is fundamental components of every job. Toyota's main practice to accomplish continuous learning and improvement is 'Hansei', or reflection. Reflection and learning are key elements of every improvement cycle. Standardization of procedures is used to make the improvements sustainable. The standard is the best method known at a given time and hence not a rigid method. A3 thinking is another technique of LPD, which supports continuous learning (Sobek & Smalley 2008).
>
> *To build a culture of Lean*: An important point in lean is the paradigm and culture of the infrastructure of a company. Concrete points are:

1) Deliver right from me: Failures in product development processes are a source for extraordinary information and could bring about learning. Yet we must distinguish between failures that we can learn from such as a failure in testing a new technology, for example, and those that don't generate any information such as when, for example, we encounter problems because we neglect design review or communication. The 'right from me' culture does not mean that we must never fail, but we need to follow the standards and lessons learned and not apply the 'we can correct it later' routine.

2) Make decisions based on knowledge and facts: Decisions should be made by people who have the required knowledge to do so. It is the responsibility of the management to push down decision-making to the right organizational level. This will force knowledge-based decisions and avoid unnecessary escalation.

3) 'Go-to-source' engineering: This is about being close to the source of information, and going and seeing instead of acting on the basis of second-hand information. As Kelly Johnson, the famous head of Lockheed's Skunk Works said, 'an engineer should never be more than a stone's throw away from the physical product' (Merholz et al. 2008). At Toyota, this philosophy is referred to as 'Genchi Genbutsu', the 'go and see' approach.

To build a creative environment yet controlling the variation: Standardization is a key instrument for efficiency through controlling variation in how people work. But it could also lead to rigidity and loss of creativity. This means that efficiency and creativity have a reciprocal relationship. In a lean company, a standard is a documented best method at a given time; it is used until a better one appears. In an organization with a creative environment, everybody strives to continually change and improve the standards though creativity.

To create a pull system with less Design-In-Process[21] *(DIP) within the development processes*: Just-In-Time is applied to cross-functional teams in product development. Each process/cell should express what they need from the previous step. This will reduce the rate of unnecessary information and data flow and make it easier to visualize the problems and design issues. The consequence is less DIP. DIP inventory is larger and more costly to hold compared to the Work-In-Process (WIP) in manufacturing processes.

To work front-loaded in product development through set-based concurrent engineering: A true cross-functional early participation is a key to maximizing the efficiency of product development (Morgan & Liker 2006). The cost of change increases exponentially throughout the process. On the other hand, information about the requirements and information gained through execution becomes available later in the process (Reinertsen 1997). Front-loaded development means that the development teams must maximize their utilization of the information available at every instance. It is necessary to thoroughly explore alternative solutions while there is maximum design flexibility and it is inexpensive to make changes. Set-based concurrent engineering is a practice to make product development more front-loaded. It is a Toyota practice for considering a broad range of possible design alternatives and delay certain decisions (Sobek et al. 1998, 1999). In set-based engineering, sets of possible solutions are gradually narrowed in order to reach the final solution. It means less reworking as well as increasing the flexibility, which is also an important characteristic in product development due to rapidly changing

[21] DIP is partially finished work still inside the process. It is like block inventory in the process.

customer requirements, as well as market and environment changes. It will also create a design shelf to be used in future projects. A3 thinking, trade-off curves and chief engineering are core methods in set-based concurrent engineering (Morgan & Liker 2006; Sobek et al. 1998, 1999; Sobek & Smalley 2008).

Michael Kennedy, author of Product Development for the Lean Enterprise in 2003, discusses the cornerstones of lean in product development. According to him, the key is a process that emphasizes knowledge building and learning first (Ward 2007, Ward and Sobek 2014). The problem is that there are many decisions to be made in the early phases (i.e., the 'Fuzzy Front End'), which due to knowledge gaps cause loopbacks. Kennedy also underlines the importance of visualization and the reusing of knowledge. From the early phases onward, Toyota utilizes set-based engineering to build knowledge about the limits of different technologies and concepts and visualizes this knowledge. This facilitates knowledge-based decision-making. Ballé et al. (2016) in 'Why learning is central to sustainable innovation' have elaborated upon an approach emphasising people and their development as the centre issue for LPD. According to them, it is skilled people not a process that creates great products. They have presented the LPD as a process involving three questions: 1) What do we need to learn about the customers, products and production processes to design better products? 2) How do we learn what we need to know? 3) What organizational structure and routine will support the learning? Therefore, in this research they have presented the learning and continuous improvement as the core of operational excellence.

Liker & Morgan (2011) present a case based on an experience of introducing LPD in Ford while learning from Mazda. In that study, they elaborate that Ford, in its LPD journey, matured from application of tools in specific areas to integration of people, processes and technology towards lean thinking. For Ford, people transformation is about attitude change among leaders and engineers, including increasingly taking into consideration factors such as customer value, cross-functional work and pride and confidence in group work, technical competence development, communication and shortening the distance between the top level and bottom level of the organisation, as well as the role of leaders in driving change. Process transformation is most importantly about building continuous improvement and learning mechanisms. It is about awareness of process current state and ideal state and the gap between them, and planning to prioritize and close that gap. Front-loading and set-based engineering are main practices of process transformation. Reflection event at critical stages of product development is another practice in order to learn and improve by reflection on performance. Technology transformation in the Ford journey has been about keeping information and knowledge current, valid and accessible. Standardization and visualization through Obeya has been two of the important tools in this regard. This study also points out that the Ford attempt had not been to copy Toyota or Mazda, as Ford had a unique culture and point of origin. Instead, the attempt had been to learn from the LPD principles that Toyota and Mazda had concerning people, processes and technology. By doing gap analysis relating to these three principles, Ford derived a detailed picture of the problems and opportunities for improvement.

Even though the above-mentioned literature attempts to present empirical studies of LPD transformations, they are still mostly case studies, primarily elaborating on the content of the LPD practices on a more detailed level. How to put these practices into action and how to lead such transformations are still areas in need of further academic enquiry.

3. RESEARCH STRATEGY AND DESIGN

This inquiry is a qualitative study[22] in a social science (e.g. Bryman 2004, Flick 2006, Bryman & Bell 2015)[23]. I have chosen to make a qualitative study since I believe the research subject in this thesis (orchestrating the implementation of new practices in product development) gets affected by individuals' mental model and behaviours. These may not be written anywhere, but still be accepted as the norm at a company. Such a model cannot be captured only through quantitative and explicit data; the qualitative and tacit data must also be gathered.

The aim of this chapter is to describe the research design of this thesis. Here I firstly present my ontological, epistemological and methodological assumptions in order to clarify the general orientation of this inquiry. By this, the readers of this thesis will get an insight as to why I have designed my research in the way I have, and thereby be able to see more academic value from it. After that the research design, action research, and the reasoning behind this research design selection are elaborated upon. Furthermore, the research set-up, process, methods of data collection and analysis are presented. At the end, the methodological requirements of this thesis are discussed.

3.1. ONTOLOGY, EPISTEMOLOGY AND METHODOLOGY

The ontological, epistemological and methodological assumptions of the researcher often affect the research design decisions they make.

Ontological assumptions in an inquiry are basically the view on objectivity versus subjectivity from the researcher's point of view. In this inquiry the research area is product development processes, and furthermore the research subject is orchestrating the implementation of new practices in product development. I believe that in such research, we interact not only with the explicit features of the context such as written processes, job description, or procedures, for example, but also with how people are working and behaving in reality which are tacit. This type of ontological position belongs to *constructionism*[24] (e.g. Bryman & Bell 2015, Flick 2006), and I consider myself in this position.

[22] In many research projects, the researcher is using a combination of the two approaches, concerning the method of data collection and data analysis, though some others believe this mixture is not possible due to epistemological contradiction.

[23] Generally speaking, quantitative research strategy places more emphasis on quantification in data collection as well as data analysis. Quantitative inquiries are structured in nature and therefore more predictable. By contrast, qualitative research strategy emphasizes words in collection and analysis of data. Qualitative inquiries have an unstructured nature which offers flexibility in many respects (Bryman & Bell 2015). It is important to note that it is more the degree of formalization and standardization which distinguishes the two strategies than the juxtaposition of words and numbers (Bauer & Gaskell 2000).

[24] Objectivism's position asserts that social phenomena and their meanings are independent of social actors. It maintains that reality has an objective nature in the world. Burrell and Morgan (1979) have referred to objectivism as realism. Constructionism or constructivism assert that social phenomena and their meanings are accomplished by social actors. It holds that reality has a subjective nature and is the product of the individual's mind. Burrell and Morgan (1979) have referred to constructionism as nominalism.

Epistemological assumption is the researcher's view on the knowledge generation process in the inquiry. In contrast to natural sciences inquiries, social inquiries are not done in a controllable or laboratory environment where the researcher can have many identical samples. Instead, social inquiries deal with individuals, all of whom have different opinions and mental models. An individual may think and behave differently from day to day as well as behave differently in different contexts. From my point of view, the nature of knowledge in social research should not be seen as 'hard' and capable of being transmitted only in a tangible way. Knowledge in this type of inquiry is 'soft' and more subjective, based on the experience and insights of people. I believe that since the reality in this type of research is tacit, it can be better researched through participation.

The scientific knowledge in social science is practical knowledge that is conveyed through the cyclical process of learning and solving a problematic situation. In this cyclical process, from each cycle to the next, there are new learning points that might affect the research or knowledge generation process. That is why we should remember that in many social studies, as in this case, the research process is not clear at the beginning (Schön 1983). This view of knowledge generation affiliates me with *interactionism*. In interactionism, the valid knowledge generation emphasizes the need to grasp the subjective meaning of social context through social action and learning[25]. The research on such an epistemological assumption should be judged by its own criteria and not with the criteria of natural science. These criteria will be further discussed in this chapter.

The research methodology is the logic behind the reasoning process of the inquiry on the way to generated knowledge[26]. The methodology is used by the researcher when designing the research process in connection with theories (Bryman 2004). In this inquiry, some of the existing theories of change management are tested in the Volvo Group context and the corresponding research projects in different BAs. These theories are then further developed in the context of the Volvo Group through cyclical learning processes. This is the methodological position that has been referred to as *abduction*. Abduction, or inference of the best explanation, is an iterative logic of reasoning in which one chooses the hypothesis that would, if true, best explain the relevant evidence. Abduction is the primary reasoning logic for action research.

3.2. RESEARCH DESIGN

The research design used in this inquiry is action research. Action research is 'a participative and democratic process concerned with developing practical knowledge' while creating and managing change in social worlds according to Reason & Bradbury (2001). To 'understand and change certain social practices, social scientists have to include practitioners from the real social world in all phases of inquiry' (Lewin 1951). Action science requires professionals who have the

[25] This is in contrast to positivism as an epistemological assumption. Positivism is an objective position which holds that the methods of natural science are applicable to social science (Bryman & Bell 2015). It basically seeks to explain and predict what happens in the social world by searching for regularities and causal relationships between the elements subject to research. The approach is positive in the sense of offering an objective and true account of nature and society (Smith 1998). On the other side of the continuum, anti-positivism is a subjective approach against the utility of searching for causal relationships. Based on this approach the world is realistic and can be understood from the involved individual's point of view (Bryman & Bell 2015, Burrell & Morgan 1979).

[26] Basically there are three different methodological approaches discussed in the literature (e.g. Gummesson 2000, Bryman & Bell 2015, Flick 2006): testing existing theories (so-called deduction), generating new theories from the data and observations (referred to as induction), and further development of existing theories in the context of applications based on participation (termed abduction).

insight, intervention and interpersonal skills to participate (Beer 2001); therefore action research has emerged as a research methodology to bridge the space between researchers and practitioners. As said by Donald A. Schön (1983):

'Often we cannot say what it is that we know…it seems right to say that our knowing is in our actions.'

The application of action research has often been inside organizations in the field of business and management (Flood 1997). Action research has also been applied in larger collaborative contexts including several stakeholders, such as companies, universities, governmental and non-governmental organizations (Scheinberg & Alänge 2016).

According to several European researchers, the year 1970 represented the turning point for qualitative research methodologies, with extensive introduction of action research (e.g. Gummesson 2000, Reason & Bradbury 2001, Reason 1999). However, according to some American researchers, the origin of action research actually goes back to Lewin's work in the 1940s (e.g. Argyris et al. 1985, Kemmis & McTaggert 1990). We can also relate the action research process to John Dewey's (1938) experiential learning cycle (Kolb 1984). Kolb states that John Dewey, Kurt Lewin and Jean Piaget are the founders of the approach.

Action research is applied when the researcher both takes action to create sustainable improvements and also contributes to action science by generating knowledge that improves the social world. Action science (Argyris et al. 1985) emphasizes the rigorous requirements of action research in generating fundamental knowledge. The rigour in action research is achieved through cyclical continuities between the activities of science and the activities of learning in the action context[27] (e.g. Argyris et al. 1985, Reason & Bradbury 2001). These learning activities are mutual activities between the social researcher and the people subject to the change in the social context.

Kurt Lewin in the mid-1940s advocated three steps for action research: Planning, Taking action, and Evaluating action. Susman and Evered (1978) have elaborated on this model, arguing an iterative cyclical process for action research in five main steps: Diagnosing, Planning action, Taking action, Evaluating action, and Specifying learning. In their model, they stressed the importance of the diagnosis step as well as the learning step.

Even though there can never be a single correct cycle of doing action research (Reason & Bradbury 2001), the basis of the action research cycle is similar to the PDCA learning and improvement cycle. From my point of view, this similarity makes sense, since the basis of all these is the necessity of the activities of 'learning' in a cyclical manner. Learning is a key component for the validity of the knowledge generated through action research as well as for improvement in a social context. This is why I prefer to call this research design an action learning process. Figure 8 shows the action research cycle as the research design in this inquiry, which follows the PDCA cycle for change.

[27] Thereby, action science aims to unfold the features of applicable knowledge, while action research proposes a research process for generating such knowledge.

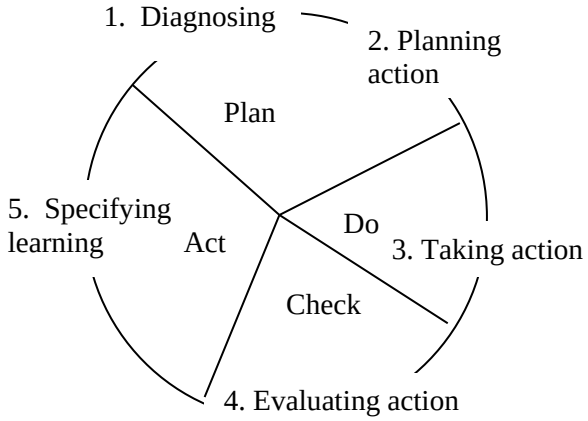


Figure 8: Action research cycle compared to PDCA cycle

Action research can potentially be utilized when an inquiry follows these simultaneous aims: 1) studying a problematic situation and problem-setting[28]; 2) improving the situation; and 3) having the cyclical learning and change carried out by the people facing the problem through involvement in the action. More explicitly, when a research question relates to understanding a series of actions, understanding why action creates change and improvement, and also understanding the process of learning and change, action research is an appropriate research design [29] (Aguinis 1993, Coghlan 2001, Coghlan & Brannick 2001, Coughlan et al. 2001, Coughlan & Coghlan 2002, de Guerre 2002, Coghlan et al. 2003, Adler et al. 2004, Bryman & Bell 2015).

The existence of the researcher inside the organization makes it natural to select action research as a method of the inquiry. Additionally, the research questions[30] of this inquiry are obviously among the potential applications of action research. The first question, RQ1, basically concerns the understanding of a series of actions and their effect on change implementation, either failure or success. The second and third questions, RQ2 and RQ3, are mainly about understanding the process of learning and change. And the RQ4 is concerning the potential mutual interest of academia and industry in using action research. These four research questions are aligned with suitable research questions for action research.

3.2.1. THE RESEARCH PROCESS

This inquiry included several research projects in different BAs within the Volvo Group.
Table 4 summarizes the research projects in this inquiry and research design used in each of them.

[28] According to Schön (1983), "problem-setting is a process in which, interactively, we name the things to which we will attend and frame the context in which we will attend to them".

[29] Research Design reflects on decisions about the priority being given to a range of dimensions of the research process (Bryman & Bell 2015).

[30] In order to illustrate the suitability of action research in this inquiry, the research questions are repeated here:

RQ1: What hinders or facilitates implementation of new practices to be used by product development organizations?

RQ2: How can new practices be cultivated for continual use by product development organizations?

RQ3: How can change of practices in product development be orchestrated in company groups?

RQ4: How can action research support orchestrating the implementation of new practices in product development?

Table 4: Research projects and corresponding research methods

Research project	Company researched	Research design
Taguchi Methods	Volvo 3P	Case study
VRES	Volvo 3P	Action Research
RnD30	Volvo Group/ Volvo Penta	Action Research

Here, I would like to distinguish between two levels of the research process. One is the high-level research process, which is followed by this inquiry as a whole and the other, which is the one used within each researched project. If we symbolize the action research cycle for the first one as 'PDCA', I use 'pdca' for the action research processes within each research project.

Most action research projects are divergent, start with particular problems and are open to a broad process throughout the research. This is mainly due to the dynamic complexity of the action context. In each research project there might be a lower level of learning process than 'pdca', meaning that the learning cycle could be at several different levels. Thus, it is sometimes difficult to put exact borders around and predict, or sharply distinguish between, the activities in each of the phases in these levels. Still, I believe that following such a process provides a holistic understanding of the activities to be done in order to fulfil the required steps for learning. Here, I roughly elaborate on the research process within the 'PDCA' and 'pdca' cycles. Table 5 summarizes the research projects and different PDCA or pdca steps in each of them.

Table 5: PDCA and pdca cycles in the research

Research projects	PDCA research cycles of the thesis	pdca phases in each research project	Research design
Taguchi Methods	C, A, P		Case study
VRES	P, D, C, A, P	Several pdca	Action Research
RnD30	P, D, C, A, P	Several pdca	Action Research

The case study at the beginning of the research on the Taguchi Methods initiative followed the 'C', 'A' steps of the first learning cycle. This first cycle was aiming at exploration of the existing situation based on the past projects. As John Dewey says (1938), the past and future does matter to the present. To better understand the past, I looked at the results of the initiative and checked its effectiveness; afterwards, the reasons behind the failure were collected. Volvo 3P also reached some conclusions about what to consider in the next initiative, the 'P' step (Fazl Mashhadi et al. 2012; Paper I); this then became more detailed in the next initiative cycle.

The learning points from the first cycle steered the new initiative set-up in VRES. We[31] continued further planning, 'P', in the second cycle when starting with activities concerning diagnosis of the situation. This 'P' was not completely separated from the previous cycle, but rather was embedded in action and reflection on the previous cycle (Dick et al. 1995). Within the VRES initiative we have had research collaboration with several master's students. Each master's thesis by these students was formed as a pilot case in a learning alliance with PD engineers (Fazl Mashhadi et al. 2014 and 2016; Papers II and III). We followed several small 'pdca' cycles by students around the 'D' phase of this research cycle. We had a plan for each pilot (p), actions were taken (d), the results of the case were checked (c), and learning points were collected and

[31] When I say 'we' here, I mean both myself as researcher and the company researched, as my learning as a researcher was continuously shared with the project team at the company as well as with other people involved.

shared with other master's students and people involved in the pilot cases (a). As long as the number of master's theses increased in the organization, the big 'C' and 'A' phases happened after several 'pdca' (Fazl Mashhadi et al. 2015; Paper III). Afterwards the effectiveness of the VRES set-up and results were checked, and reflection and learning were gathered as input to the coming next initiatives. We finally concluded with what to consider in the next coming initiative for the 'P' step.

The learning from the VRES initiative was input to form and orchestrate the RnD30 and the platform for learning in this initiative. This was the content of the 'P' step of this cycle when we tried to further understand the current situation at the start of the initiative and did the planning. Within RnD30 and the 'D' step, we also had several 'pdca' cycles both on the Volvo Group level as well as the Volvo Penta level. We had several learning alliances that worked together in the RnD30 platform, and their agendas had been based according to 'pdca'. Some of the learning alliances were shared between the Volvo Group and its BAs as, for example, with Volvo Penta. As a result of all the 'pdca' and the results of the application at Volvo Penta, we also continuously checked the effectiveness of the initiative as total, 'C', and learnt from it, 'A' (Fazl Mashhadi 2016; Paper IV). Finally, all the learning points were concluded to be potential input for the future, as well as being an input for this PhD thesis. Figure 9 illustrates the three research cycles in this PhD thesis.

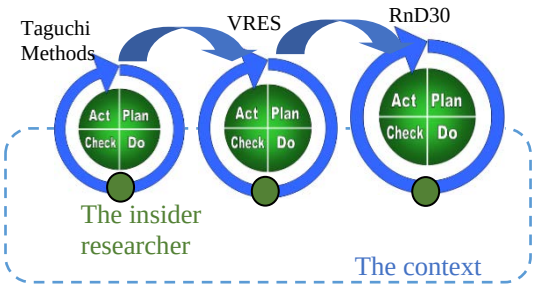


Figure 9: The three PDCA cycles in this research

The role of insider researcher illustrated in this picture is elaborated upon further in section 3.3.1.

3.3. Research Set-up

This research program has utilized an iterative process for testing, learning and developing new ways of managing change of practices within product development. In this thesis I sometimes speak of 'initiative' and sometimes of 'research project'. 'Initiative' is the term used from an inside-out point of view. 'Research project' is the term used from an outside-in point of view, and I use it when I am considering myself as a researcher who is reflecting on the process. In practice at the company, the first term is more commonly used.

There have been several actors in this research program with different roles. These actors had several informal and formal meetings together in order to manage the research program so it would deliver results for the company as well as make an academic contribution for the research community. Here the role of different actors and different meetings are described.

3.3.1. The role of the different actors in this research

In addition to the company researched and the research project that have already been described in the previous chapters, there have been other actors in this research. In this chapter these

actors and their roles in the research program are elaborated upon. These roles are also described in the papers.

Researchers

As the researcher in this thesis, I have been an industrial PhD student since 2007. During this period when I took on different roles, I had support from other people both at the company and at the university as well. While I worked at Volvo 3P and Volvo Technology on the research program (2007-2011), in addition to all of those who were involved in the initiatives at the company, there was one other company member working closely with me in my Volvo role as well as being a member of my research committee. He was a part of the initiatives at the company; however, he also had specific engagement in the knowledge generation process. He was involved in the reflection process, supporting me with reading proposals, challenging me in my pre-understanding and thinking, and we also had many unstructured discussions around the academic criteria of my research work. He was also involved in my structured research meetings, from the start until the end. He had more than 25 years of experience working at Volvo in different organizational leadership roles and was a former industrial PhD student and researcher at Volvo. When I was working for Volvo Penta (2011-2016), I was mainly alone as an insider researcher; however, I also had this same colleague in my research committee and in many of the reflection meetings. He was still involved in the action research process with his insight from the Volvo Group.

In the last two research projects I was involved in starting, designing, implementing and evaluating the results. In the robust design related projects I started at the bottom of the product development organization working closely to the PD engineers and after a while moved to a central department for quality. In the RnD30 project, it was the other way; I started at Volvo Technology, in a specialist group on corporate level and after a while I moved to Volvo Penta product development and worked closely to the PD managers and the engineers. So by being involved in all stages of the projects and working on different distances to the context of application I have had good access to empirical data through participation on different system levels.

Insider researchers often have problems of role duality as they have both organizational roles and researcher roles. As a part of the organizational role, insider researchers are integrated in the organizational context; however, as a part of the researcher role, they need to have separation from that context. They need to keep themselves as **outside-insider researchers** (de Guerre 2002; Herr & Anderson 2014), detached from the context, close to the boundary, but still engaged in the initiative.

I, as an insider action researcher in this process have been aware of my subjectivity. I knew that I could never be fully objective due to my dual role and my closeness to the context; however, I tried to reflect and consider this issue throughout my research process. To keep me somehow detached from the context, I utilized reflection meetings together with university supervisors. I sat a minimum of one day per week at the university to have discussions with my supervisors and other colleagues at the university, as well as to keep myself dedicated to reflection independently and even see myself physically outside of the company.

In addition, on three occasions during the course of this research process, I sat at university for longer periods of time, i.e., two months in 2010, one month in the summer 2011, and finally five and a half months in 2016.

International master's students

This research has also included floating members from Chalmers University of Technology. While I was working at Volvo 3P and Volvo Technology on this research program (2007-2011), every year between four to eight master's students with different nationalities had been selected to do their master's theses at Volvo 3P and Volvo Technology in relation to this research program. They worked in groups of two. They were mostly involved in the VRES initiative since then (2006-2008), as well as in the RnD30 pre-project phase (2008-2010). In total, 28 master's students with 17 different nationalities have been involved. Besides all the help they were provided with by the company from different actors, they were given dedicated supervision time from the university. In most of the cases, their Volvo supervisors were my researcher colleague, as mentioned above, or even myself. During the period when I worked at Volvo Penta (2011-2016), we lacked utilization of the master's students, and this was mainly due to the lack of time I had at the company to be able to provide suitable and fair company supervision, even though I later came to regret this.

Master's students supported the initiative by working as **inside-outsider researchers** (de Guerre 2002)**,** close to the action but coming from outside the company. They had good access to data without any pre-understanding of the organizational context. As they did not have any previous experience from the context, they were less biased by the context, and were more curious and provided different perspectives. They were not native, therefore they could better question our ways of working. However they had other biases due to their knowledge and limited experiences from the company.

In the selection process of Master's students, through the interviews, we selected students who dared to talk and question their observations. We also selected multi-cultural students as a means to create more diversity and therefore more perspective for observations and analysis. Each one or two of the pilot cases, identified by the middle management at the VRES initiative, enabled a master's thesis to be assigned to a group of master's students. There were a few master's theses in which master's students were not involved in a specific pilot case. Instead, they looked at the whole initiative from a change-management point of view and reflected on the implementation process. In the RnD30 pre-project phase, master's students worked to gather best available practices at that time to create the VPS-PDP model for the Volvo Group.

> *Observation and reflection:* Each team of master's students was involved for only five months, but still they became more native at the end of their work. This could have resulted in the disadvantage of their becoming more biased in their data analysis work. In order to minimize this risk, in some cases close to the end of their thesis work, we moved master's students physically to another floor or another building in order to have them far from the context of their research.

Chalmers' professors

Chalmers University of Technology[32], specifically the Division of Quality Sciences[33] and the Division of Product Development, has been the **outsider supervisor** (e.g. de Guerre 2002) for the entire research project as well as with the individual master's theses.

[32] Chalmers University of Technology is located in Gothenburg, Sweden.

[33] The department was reorganized in March 2016; the previous division of Quality Sciences no longer exists.

There have been two main supervisors for this research program the entire time, as well as other supporting professors and PhD candidates who have been involved in supervision, especially in supervision of the master's theses. Due to the history of the collaboration between this division and Volvo, the professors have had a good understanding of the Volvo context, something that has supported them in being practical supervisors for the research.

The supervisors, as outsiders, had the role of challenging the research program to employ relevant and useful theories, to make objective analyses of data and, most importantly, to continuously reflect on the research process. They helped me in finding theories, having unstructured discussions and reflections, attending conferences and so on. The supervisors have been a part of many structured meetings as well. The professors and PhD candidates had the role of supporting each master's thesis with its research process, use of relevant theories, and making objective analyses of data in coordination with other master's theses and the research program. They also conducted reflection on the master's thesis process as an input to the research program process. Moreover, they supported sharing the knowledge and experiences in each thesis with the others.

3.3.2. THE STRUCTURED RESEARCH MEETINGS

Besides many of the roles that different people had in this research program, some structured meetings were utilized. In this section the structured meetings are described.

Academic supervision for the research program

As the industrial PhD student in this research, I had many individual supervision sessions with the professors. In these sessions, we basically discussed the ongoing papers and the literature, discussed the methods of data collection, went through the empirical data, challenged the coding and analysis of the data, reviewed the text of the papers, and discussed the road map for the research process.

The research committee

The research committee, besides me as the researcher, included three fixed members, one member from the company (the mentioned former researcher colleague) and two professors supervising the research. Based on the agenda of each meeting, some other experts were invited as well. The committee met almost monthly for half a day each time, in order to challenge the methods, the research process, selected theories and methods of data coding and analysis. These are almost the same items as we did in supervision sessions but this time all together. The members also reflected on the initiatives' processes in order to highlight the learning. Every meeting had a written protocol of 'minutes' that have been used as structured transcripts to collect the key points discussed in the reflection on the research and initiative process.

Academic supervision for master's students at the university

The master's students involved in the initiative met Chalmers supervisors frequently. In some cases their supervisors were the same as mine, and in some other cases they were different. In the supervision meetings they discussed the cases, theories, methods, analysis and conclusions. They also reflected on the master's thesis process to highlight the learning and contribute to the research program. In those meetings, sometimes the company supervisors were involved for joint supervision.

Academic supervision of master's students at the company

During the period when master's students were involved in this program, they each had individual supervision sessions with their company supervisor weekly. In addition to that, the

researchers met all acting master's students in weekly meetings where their thesis processes were reflected upon. They also went through the status of each case and shared the experience between the master's students. Obstacles were also discussed, and actions to solve them were planned.

3.4. METHODS OF DATA COLLECTION AND ANALYSIS

In this inquiry different methods have been used in order to acquire empirical data. Use of more than one method in this study of social phenomena aims to collect more empirical data and also to cross-check the findings[34] (Bryman & Bell 2015).

As participatory research, the main data collection method in this inquiry was *ethnography or observation through participation* (e.g. Bryman & Bell 2015). This has been done by participation of the research core team and international master's students in pilot cases, and participation of the research core team in daily organizational roles. *Diary keeping* was the main instrument for recording data from observations. The researcher also had reflection meetings with all students to reflect on their observations and share empirical data. The other method was to review *texts and documents* in the form of presentation material, reports, archival records and minutes of meetings. Additionally, *semi-structured interviews* were used in all cases.

Table 6 summarizes all methods of data collection used in each research project and the corresponding papers.

Table 6: Methods of data collection in the papers

Papers	**Formal methods of data collection**	**Informal methods of data collection**
Paper I (Taguchi Methods project)	*9 semi-structured interviews* *Review of evaluation questionnaires from people involved in the robust design workshop for the three pilot projects*	*Texts and reports, presentation materials from the initiative* *Informal dialogues*
Paper II (VRES project)	*7 semi-structured interviews with PD engineers* *Evaluation questionnaires from all 22 master's students*	*Ethnography or documented observation* *Minutes of meetings* *Informal dialogues with all people involved* *Diary keeping*
Paper III (VRES project)	*7 semi-structured interviews with PD engineers* *Questionnaires answered by 4 knowledge managers and 12 PD engineers* *Evaluation questionnaires from all 22 master's students* *Evaluation of the tools in VRES while applying the tools in projects done by master students*	*Involvement in the focus groups at Volvo 3P designed by master students* *Quarterly presentation of knowledge managers concerning their experience in facilitating VRES* *Ethnography or documented observation* *Minutes of meetings* *Informal dialogues with all people involved* *Diary keeping*
Paper IV (RnD30 project)	*6 structured interviews with the managers at Volvo Penta* *8 semi-structured interviews with managers at Volvo Group involved in RnD30*	*Ethnography or documented observation* *Minutes of meetings from all projects meetings* *Informal dialogues with all people involved* *Focused groups and SWOT analysis at end of each pilot project* *Diary keeping*

[34] Findings are analyzed data

Papers II, III, and IV are based on the two researched projects (VRES and RnD30) in which the researcher has been involved in initiating, developing and rolling out the projects from their start to finish. Therefore ethnography, documented daily observations, documented informal daily dialogues with all people involved and minutes of meeting are the main methods of data collection. However for each paper the researcher has utilized some more formal methods of data collection as well.

In the case of Paper I, the nine semi-structured interviews were with employees involved in the initiatives' three pilot cases (see Appendix 1). The interviews were performed in early 2007. All interviews were held in Sweden, in person and conducted in English. Although they were scheduled for one hour, in some cases, they took one and a half hour. The interviews were documented during the interview session by taking notes and confirming the notes with the interviewees at the end of the session. The goal was to get a perspective from all levels inside the company. Consequently, the interviewees were two top managers who were initiators of the initiative, three quality managers in the three pilot cases, three development engineers, one from each pilot cases, and one project manager who was in charge of the project from which two of the pilot cases were selected. He was selected because of his availability. The other project manager from the third pilot case changed position and was not available for the interview.

In addition, an evaluation questionnaire was distributed during the robust design workshop and completed by participants in the pilot cases (see Appendix 2). The evaluation questionnaire was in English. Twelve answers to this questionnaire were available and used in this case study.

In the case of Paper II, the seven semi-structured interviews were with PD engineers involved in the initiative's cases with students (see Appendix 3). They were conducted in person, in Sweden and in English. The intention was to interview all PD engineers who had directly worked with the 22 master students and were responsible for them (12 PD engineers in total). However only seven of them were available during the time of interviews. Each interview was booked for one hour. All interviews were recorded, and subsequently transcribed by a third person and finally confirmed by the interviewees through email. In addition, all 22 master students involved answered an evaluation questionnaire by email right before finishing their thesis work with PD engineers (see Appendix 4). The evaluation questionnaire was in English.

Papers II and III are based on the same research project, VRES. Consequently, the data collected and used for the Paper II was also used for Paper III. Paper II utilized the data concerning the process of implementing VRES and Paper III used the data concerning the content of the VRES. Additionally, in the case of Paper III, the four knowledge managers and twelve PD engineers involved in working with VRES answered a questionnaire (see Appendix 5). The PD engineers were all located in Sweden, three knowledge managers in Sweden and one in France. This questionnaire, which was in English, was answered by email.

In the case of Paper IV, all six PD managers at Volvo Penta who were champions for the six improvement areas were interviewed. The interviews were in person. They were all conducted in Swedish, and located in and in Sweden. Each interview took almost one hour and was transcribed at the time of the respective interview. Beside this, eight managers involved in the Volvo Group level RnD30 program were interviewed. They interviews too place in Sweden and were conducted in English. The selection was to cover all eight work-streams. The summery of these interviews are shown in Table 7.

Table 7: Samples of the interviews

Samples	Paper I	Paper II	Paper III	Paper IV
Number	9 interviewees	7 interviewees 22 evaluation questionnaire	16 questionnaire	14 interviews
Sex	11% female 89% male	14% female 86% male 40% female 60% male	25% female 75% male	14% female 86% male
Role	2 top manager 3 quality manager 3 development engineers 1 project manager	7 PD engineers 22 Master's students	4 knowledge managers 12 PD engineers	14 managers
Nationality	100% Swedish	86% Swedish Multi-nationalities	82% Swedish 18% others	86% Swedish 14% others

Observation and reflection: I have a few reflections on the samples in my studies. There are more males participating in the interviews than females. This is due to the population of my research context which is predominantly male. I did my best to include female in my interviews when it was possible.

During the research processes I was always considering doing more interviews. However I realized that I was interacting with many of the people in the initiatives on a daily basis, e.g. we were working together, reflecting together, and even eating lunch together. As I kept diary of our discussions and my daily reflections, I realized that leading a formal interview, sometimes, would not give me more data and insight.

The suitability of the methods of data collection in this research was continuously discussed with the supervisors and in the research committee. Hence, there is confidence concerning the appropriateness of the methods, which means that they are suitable for the research paradigm. Appropriateness of the methods increases the **credibility** or **internal validity** of the research.

According to Dubois and Gadde (2002) systematic combining process for data analysis is a process in which the theoretical framework, empirical data collecting, and data analysis evolve simultaneously. According to my experience of this process, after data collection, the data are coded and categorized, and then checked against what it is going on in real life. This results in theories being evolved one additional step. After further data collection these steps are done again in a cyclical manner. This is continued until no more changes to coded data could be applicable. I have used this evolutionary approach in my data analysis.

Data analysis processes in this thesis included several steps (Flick 2006, Denscombe 2007).

1. Break the text down into smaller component units: The collected data through the above mentioned formal and informal methods were segmented or coded into meanings and

phrases (on post-it papers, Excel or a mind map). I have used my pre-understanding initially in this step (Gummesson 2000).

2. Develop relevant categories for analysing the data: With the help of affinity diagram/technique the coded data were categorized into groups. In this step I needed to have a clear idea of the kind of categories that I was concerned with. This was based on my pre-understanding and also I got inspiration of theories.

3. Reflect on and challenge the coding and categorization: The coded and categorised data were then discussed with my supervisors and the researcher colleague at Volvo. They challenged me in my understanding and how I had coded and categorized the data. They also recommended me more potential theories. It also resulted in additional data collection. The opportunity of having the researcher colleague from Volvo participating in the research committee provided me the unique chance of both being challenged in the interpretation of the collected data as well as collecting some previous unknown data from a different perspective.

4. Iterate the process: This process was repeated in a cyclical manner based on challenges I had got, theories I had been recommended and more data I had collected. In each cycle my pre-understanding moved closer to understanding. This iterative process, which has also been described as a hermeneutic spiral by Gummesson (2000), was performed together with my supervisors as outsider and my colleague as insider, until we reached an agreement on the evolved result (Dubois & Gadde 2002). This involvement of my supervisor and a colleague from Volvo supported the triangulation of the data analysis (Flick 2006).

Observation and reflection: One reflection I had in this regard is the evolution of my writings (the Papers) due to the evolutionary process of data analysis. In my licentiate thesis I had two drafts of papers. When I continued with data analysis the results and/or contribution of the Papers partly changed. Consequently the final published papers (which are appended to this thesis) are different with what I had in my licentiate thesis in regards to the result contributed.

3.5. METHODOLOGICAL DISCUSSION

In interactionism and its epistemological assumptions, truth is relative (Smith 1998) and embedded in the social context. Revealing the truth results is scientific knowledge. The scientific knowledge in action research is the knowledge that has been generated and tested in practice and has been applied to produce change and improvement within a context. Lewis (1929) maintained that knowledge is derived from learning caused by interaction between a 'mental model' and 'experience' (Mauléon 2003).

The rigour in action research is gained through its cyclical approach with continuous reflection through the research progress (e.g. Schön 1983, Westbrook 1995, Coghlan & Brannick 2001, Reason & Bradbury 2001, Melrose 2001, Middle et al. 2006). Important factors are: 1) variety in members and their knowledge; 2) shared understanding; 3) documentation of the approach; 4) challenging of assumptions and interpretations; and 5) triangulation, as action research is of ethno-methodological research design, formal data collection and analysis through different actors are key. These requirements have also been known while designing this research;

therefore, there have been different insiders and outsiders involved in data collection and data analysis that have been presented before. The research strategy and design of this thesis is now discussed in relation to the methodological requirements in this chapter.

3.5.1. TRUSTWORTHINESS OF THE RESEARCH

The discussion below utilizes the trustworthiness criteria especially developed for evaluating quality of qualitative research introduced by Lincoln and Guba (1985) as: Credibility, Transferability, Confirmability, and Dependability. However the traditional names for these criteria elaborated by others are referred to as in parenthesis.

In spite of the advantages of being an insider in a research process, there are challenges and difficulties. Insiders often have the problem of objectivity. The objectivity of the action researcher is partly an awareness of the researcher about her/his subjectivity and bias due to closeness to the context. While full objectivity would be difficult to achieve, there are many countermeasures that might support the researcher in being detached from the context, thus achieving less bias. The use of 28 master's students, over time, in data collection and data analysis as well as the use of professors at Chalmers in data analyses, has increased the 'expressiveness' of the data gathered and, therefore, the findings presented (Flick 2006) through external actor triangulation. Being aware of my subjectivity due to closeness to the context and my dual role both as researcher and practitioner, external actor triangulation has been used as a means to lessen my bias in the process of research. This triangulation supported my reflexivity to generally increase the **confirmability** (or objectivity) of the research (Bryman & Bell 2015). Additionally, as the master's students' involvement happened over time in different cases in the organization, it has supported the **dependability** (or reliability) of the research (Bryman & Bell 2015).

Observation and reflection: During the research committee sessions I presented my observations and quotes from the people inside the context. My Volvo colleague sometimes added to observations. We then discussed these matters together with professors from Chalmers. When I described my stories, of course they partly included my analysis and conclusions; however, the professors added a lot of questions helping me to get closer to the more pure data, and thereafter we discussed and analysed things together. I, as an insider, often left the room with new reflections, thoughts and ideas, and in most of the cases things needing to be double checked with people inside the context. Also while supervising the master's students, I gained new perspectives on our mutual observations, hearing their stories from our mutual observation.

Observation and reflection: During the days or periods I sat at Chalmers, we had daily discussions and reflections with my supervisors. Most of the time it was difficult for me to detach from the Volvo context and go to my researcher's role. It took time to get detached and reflect both with the help of my supervisors' questions as well as being physically far from the context. There was a start time for this process as well; therefore, sometimes it was better so sit two or three days in row at Chalmers instead of one day per week. For this reason, I arranged the periods which I sat at Chalmers for longer time periods instead of just a weekly sitting.

As researcher, I have documented all my informal and formal data and reflections in a diary. My assumptions in the reflection process have been challenged by the other actors involved in this research, more specifically by my colleagues, the professors at Chalmers as well as by the master's students. This is to increase the research's **credibility** (or internal validity) (Bryman & Bell 2015, Flick 2006). In addition, the openness and transparency between the research project and the professors who supervised me, has created better matching between observations and the theoretical ideas developed. This is to increase the credibility of the research as well.

As the professors have been external actors and not even involved in data collection, they have served as supportive actors to create fair analyses. The professors have supported to reflect on the research's process, specify learning, and agree upon the standardization of the learning and associated knowledge and use of them in the next step. They have also a big role in guiding me in finding relevant literature of similar cases in industry. As the professors have been collaborating with many other research projects in different contexts, their involvement increased the **transferability** (or external validity) of the research (Bryman & Bell 2015). Another contribution to the transferability is the 'thick description' in the papers (Lincoln & Guba, 1985). This means that the results presented in these papers are enriched by many quotations from people involved in the context as well as many details about the phenomenon and the context. Therefore, the results might be more meaningful to an outsider, allowing one to begin evaluating the extent to which the conclusions drawn are transferable to its special context.

In this inquiry there has been one more person inside the company researched, who has been involved in the research process so that more than one person agreed about what was seen and heard in connection with the organizational context. Since words can have different meanings in different contexts, having more than one insider actor in the research has reduced the bias through internal actor triangulation in this research. He has also supported me with data and acted as extra 'ears and eyes' for me in this research. This has supported the dependability of the research as well.

Through this research program, I as the author of this thesis, have evolved my understanding and changed the initial opinions. Comparing them with my background, the results presented in this thesis have quite a different emphasis than my initial interests. My initial interest was application of Taguchi Methods and other existing statistical tools for robust design. However, while doing this PhD work, I gained insight to the importance of local robust design or lean practices, and became interested in the process of change at companies. During the action research process, I acquired insights that could not be experienced before. This is yet another indication of the confirmability in this research.

The research subject evolution at the company is also another reason supporting the confirmability. While the final research subject in this thesis is 'orchestrating the implementation of new practices in product development' through development of local learning processes, the initial research subject at the company still focuses on the content of robust design and Taguchi methods.

Finally, the research process in this thesis has been applied to three research projects through three research cycles. This is a requirement for scientific knowledge generation in action research, and it increases the dependability of the research. The summary of this discussion is presented in Table 8.

Table 8: The methodological treatment

Methodological Requirement	**Key Question**	**Actions in the research**
Credibility or Internal Validity	Are the instruments, data, and research findings accurate and trustworthy? (Lincoln & Guba 1985)	• Triangulation of the data collection methods, several formal and informal methods for data collection • Selection of the formal methods together with supervisors at the university • Triangulation of data collection to better challenge assumptions and interpretations, master's students and one more researcher colleagues performed data collecting as well • Triangulation of the data coding and analysis, research committee members challenging the data analysis in cyclical manner • Transparency between the university and the company • Documentation of the research committee meetings • Diary keeping
Transferability or External Validity	Do findings apply to other contexts[35]? (Lincoln & Guba 1985)	• Professors' involvement in the reflection process as well as standardization of the knowledge, as external actors who are involved in other research projects in different contexts • The research committee compared the findings with existing cases in industry and academia while analysing the findings • Three research projects over time and in different companies within the Volvo Group. The essence of abductive reasoning is the cyclical process of learning • The claim is not that the results are valid everywhere without scrutinizing the process. The process itself conveys the knowledge • Thick description in the papers through quotation by people and detail description of the phenomenon and the context
Confirmability or Objectivity	How much do the personal values of the investigator intrude? (Lincoln & Guba 1985)	• Master's students' involvement for external actor triangulation, in data collection and data analysis • Involvement of the supervisors only in data analysis, not in data collection • The documented changes in the opinions of the researcher over the research time • Researcher awareness of subjectivity due to closeness to the context, and establishment of countermeasures to decrease bias in the research process • Research subject evolution at the company through the three cycles of learning in three different research projects

[35] i.e. whether the findings can be extrapolated to a larger domain of the same type or to different domains.

Dependability or reliability	Are the findings likely to apply other times? (Lincoln & Guba 1985)	• Two researchers inside the company and one with more than 25 years of experience at the company who has gained good insight over time in different areas • Master's student theses and pilot cases over time and in different areas
Academic and practical relevance	Is the topic a relevant for academia and practitioner in that field? (Hammersley 1992)	• This research area and research subject have been proposed by other researchers (e.g. Bergquist 2015) • Since the research involves working on real concerns together with those who experience them in industry, this criterion is met (e.g. Middle et al. 2006, Liker & Morgan 2011)

To strengthen the methodological argument in this thesis, the next section discusses the research strategy and design of this thesis in comparison to the criteria of action research used by the Action Research Journal.
http://arj.sagepub.com/site/author_resources/author_resources_index.xhtml (accessed date 2016-03-30)

3.5.2. ACTION RESEARCH QUALITY CRITERIA

These criteria correspond to the ones used by other researchers aiming to evaluate the design of action research articles or theses within academia (Mellby et al. 2016; Mathiessen et al. 2012). These criteria are presented and evaluated in Table 9.

Table 9: The methodological evaluation according to the Action Research Journal

Criteria	Definition	Evaluation
Articulation of the objectives	The extent to which the researcher explicitly addresses the objectives relevant to the work.	The purpose of this research is developed together with the company researched (on relevant problems), evolved over the period of the research and challenged by the professors at the university. It is justified not only from the academic perspective, but also by the practitioner's need. The research purpose and subject and its evolution are clearly described in Chapter 1 of this thesis. The research objectives of each paper are clearly mentioned in this thesis as well as the papers themselves. The evolution of the thesis objective is also visible through the comparison of objectives of each paper. This is illustrated in Chapter 4.
Partnership and participation	The extent to which the researcher reflects or enacts participative values and concern for the relational component of the research. Extent of participation refers to a continuum from consultation with stakeholders to stakeholders as full co-researchers.	The researcher is an insider and project member or project manager for the change initiatives at the company as one stakeholder. She has been involved in all steps of the research projects from the beginning. Other stakeholders of the projects at the company have been involved and contributed to the research by providing data through interviews or observation by the researcher. See Chapter 3 for the research process and set-up and researchers' role. See Papers II and IV for other stakeholder roles in the research.

Contribution to action research theory/practice	The extent to which the researcher builds on or contributes to a wider body of practice knowledge and/ or theory that contributes to the action research literature.	The researcher has built upon change management theories throughout the cyclical learning processes together with the company researched. See Chapter 5, the discussion of the research subject's evolution through the research projects and see Chapter 7 for specific contribution of this research
Methods and process	The extent to which the action research process and related methods are clearly illustrated.	The essence of abductive reasoning in action research is the cyclical process of learning. The process of action research, the three cycles of learning, is clearly illustrated according to the PDCA cycle in Chapter 3 of this thesis. This is elaborated upon more in the methods chapters for each research project in each paper. The qualitative data from the research projects are also shown and are transparent through quotation and description in the papers.
Action-ability	The extent to which the researcher provides new ideas that guide action in response to need.	The research projects are selected according to company's need for change. The research subject is described as a problematic area experienced at the company. The resulting solution in regards to the problematic area is evolved through the three cycles of research in this thesis. The learning from each cycle has strongly affected the design and content of the next cycle.
Reflexivity	The extent to which self-location as a change agent is acknowledged by the researcher. By self-location, we mean that authors take a personal, involved and self-critical stance as reflected in clarity about their role in the action research process, clarity about the context in which the research takes place, and clarity about what led to their involvement in this research.	The researcher in these studies has been an insider researcher. Of course as an insider it can be difficult to stay fully objective, but the researcher here tried to keep herself as an outsider-insider with the help of the research committee and one day per week distanced from the work, sitting at the university, discussing and reflecting together with outsider professors at the university. This helps to create a balance between the researcher's role at the company, as project member and manager for the change initiatives, and her academic role in the reflection and knowledge generation processes. This has been more discussed in Chapter 3 as well as in many of the 'blue boxes' in the entire thesis.
Significance	The extent to which the insights in the research are significant in content and process. By significant, we mean having meaning and relevance beyond their immediate context.	This research area and research subject have been proposed by other researchers as well. See section 1.4 for more information. The research involves working on real concerns together with those who experience them at the Volvo Group. In each cycle of this research, the learning from the previous cycle has been used as an input. Also the context of application was extended from each cycle to another to include more and varied Business Areas. This indicates that the findings could have broader application.

3.5.3. ETHICS AND POLITICS

The discussion about ethics and the role of values in the research process is an important subject in social science research. How we should treat the people we conduct research on is a key ethical question here (Bryman & Bell 2015). In action research we not only do research on a social context, but also do research together with the context. The degree of involvement of the context in the research process and the researcher interaction with the context is very high in action research. These increase the importance of ethical consideration in all steps of the research process for action researcher.

In this chapter some remedies for different ethical concerns in social science research are discussed. I will elaborate on whether there is informed consent, if there is an invasion of privacy, if there is harm to participants, if the confidentiality of data has been considered for the company researched, and whether there are any conflicts of interest in the research processes (Bryman & Bell 2015, Chapter 6). Finally, a reflection from politics in the publication process in journals is presented.

One of the most important ethical issues in research concerns whether the participants in the research are able to clearly see the researcher's interests, so that they can judge whether or not to become involved in the research. This is referred to as **informed consent** (Bryman & Bell 2015). A connected issue to this is to give people involved in the context of the research the right to refuse answering any questions. This could be achieved through giving individuals the opportunity to withdraw a specific answer or reject giving an answer from the beginning. This is referred to as **invasion of privacy** (Bryman & Bell 2015). Invasion of privacy also means that the researchers should not be asking questions that are irrelevant to the research. If someone shares information that is not relevant to the research by their own will, it should not be included in the results. As the researcher is an insider here, the interviewees have shared data that are not relevant to the research during the interviews. This has happened especially in the semi-structured interviews. The researcher has excluded this data from the analysis and results.

In the case of the action research in this thesis, the research interest was commonly developed together with the context and was the same as the interest in the corresponding change initiatives. In other words, the research projects and interest were the same as the change initiatives and their interests. For participants, being involved in the research projects had no more consequences than being involved in the change initiatives at the company. The change initiatives were fully transparent and communicated to all participants. The participants decided on whether to be involved in the initiatives or not through dialogues with their managers. Likewise, the managers' role in highlighting the pros and cons of each initiative, being transparent and coaching the employees in their involvement, was also influential, coming from embedded company values, codes of conduct and the managers' ethical considerations.

Another ethical issue that concerns social science research is to make sure that individuals are in no way directly **harmed** (Bryman & Bell 2015), and that the data **confidentiality** from the company researched is fulfilled, so that there is no way to harm the researched company's business. In this thesis and all of the papers, most of the data is anonymous. There are some places where the researcher was, however, concerned whether a specific participant could be traceable through the data. In those cases, the participants were asked to review the text and approve anything intended for publication.

All of the papers as well as the 'kappa' of this research have also been reviewed by the Volvo Group Research & Innovation Policy for further identification of any needed confidentiality, potential harm to any participants, and other ethical consideration for the company and the

employees. I have not experienced any hindrance from Volvo in my publication other than minor comments aimed at avoiding harm to the participants. In the last paper I have been asked to remove project numbers from my pictures only.

Affiliation and conflicts of interest is another ethical area especially important for insider action researchers. The term *conflict of interest* in research refers to situations in which financial or other personal considerations may compromise a researcher's professional judgment in conducting or reporting research. The dual role of an insider action researcher might affect this ethical issue. The researcher is loyal to both the company researched as well as to academia. The conflict between the interest of the company and the knowledge generation processes might cause a conflict of interest for the researcher. In this action research, the company researched, the Volvo Group, has the interest of studying and understanding a problematic situation in implementing new practices in product development. The Volvo Group has been open to learning from its mistakes and improving the situation through working together with academia. This interest is the same as the researcher's interest, which may reduce the risk of conflicts of interest. One clue supporting this is the first paper of this thesis, which elaborates on mistakes made by the Volvo Group in a previous initiative. The issue of confidentiality has also been discussed at the company in connection to publication of these papers. The Volvo Group decided to be open concerning the learning from its own mistakes, sharing the learning with others and publishing the paper. The paper is also referred to by some other researchers (e.g. Krogstie et al. 2015). This is evidence of openness to learn as a common interest of the researcher and the company, also in line with the essence of LPD.

As the researcher has a dual role in an action research process, there is always risk for conflict of interest. To minimise this risk of biases because of the dual role of the researcher, the findings also have to be challenged by the outsiders in this research program, the supervisors at the university. They were involved in the data analysis and reflection processes of this thesis. They continuously challenged the researcher to detach herself from the context, and take a separate path as a researcher in the knowledge generation process. The researcher was located physically at the university one day per week for this reason during the research period. The researcher was also located full-time at the university during the final 5.5 months of the research, with no contact with the company, in order to summarize the experiences from the nine and a half years of the action research, to further reflect on the findings, and to meet with the supervisors repeatedly.

This thesis and its papers are the result of qualitative research; therefore, it deals with difficulties in publication such as, for example, the contribution-to-length ratio favouring quantitative research (Bryman & Bell 2015). The initial aim of the authors in each paper has been publication in journals with audiences for whom the generated knowledge could be of value to (e.g. affecting their view).

In the publication processes of Papers I and II, the initial intention was to publish them in journals where most of the articles concern tools, statistical methods and quantitative research. My examiner suggested that 'it could be of much value to publish in a tool and method journal as it could be an eye-opener for researchers in this community who focus primarily on optimizing tools.' We believed that the audiences of such journals might have the greatest need of, and benefit from, reading an article that talks about why tools that could potentially have considerable value are still not being used and what possible ways to incorporate them exist.

However we faced resistance due to lack of relevancy of the subject as well as the length of the article. An example of the type of responses we received is:

> '…but I am afraid that these two (papers) do not quite fit in (our) journal. The papers are certainly valuable papers and certainly address relevant issues, though more in the field of quality management than in the field of quality engineering. Therefore I would certainly recommend submitting these papers to journals in the field of quality management.'

It seems that there is a general misunderstanding in evaluating the relevance of a paper subject for a journal. In most of the cases this is judged based on the journal and its audience's interest, not their need for evolution or change. It seems also that these types of journals are dealing with quantitative research and are used to receive shorter articles with higher contribution-to-length ratios (Bryman & Bell 2015). We, as the authors, tried to shorten papers without sacrificing the transparency of the data and 'thick description' that is a quality demand on qualitative research. This, however, is a known challenge in qualitative research. Finally, we secured publication in a leading quality management journal.

4. CONTRIBUTION OF THE PAPERS

This research program included three main research projects. As a result of these projects, four papers have been generated and three of them have been published in academic journals. These four papers are appended to this thesis. As the PhD student in this thesis, I have been the main author of all papers. In case of the first three papers, I have been the main person in data collection. The other two or three authors, who were among the supervisors and research committee members, supported me in the reflection and analysis of the data. The co-authors contributed in formulation of the writing in the papers as well. In the fourth paper, I am the only author of the paper and responsible for the whole process. Despite this, I have been challenged by my research committee through the whole writing process.

The paper's correlations with the research projects are summarized in Table 10. I have also added the learning cycles (PDCA) discussed in the research design chapter for each research project to this table.

Table 10: Summary of research project in each paper

Research projects	Research cycle of this thesis	Papers	Research design
Taguchi Methods	First cycle: C, A, P	Paper I	Case study
VRES	Second cycle: P, D, C, A, P	Paper II and III	Action Research
RnD30	Third cycle: P, D, C, A, P	Paper IV	Action Research

From the methodological perspective, the cyclic reflection and learning from a series of actions in different research projects is key to gaining an understanding of the subject. The evolution of the learning and, consequently, evolution of the actions from one cycle to another represent another key. So it is important to see these research projects and the corresponding papers as whole in knowledge generation processes.

For clarity of the papers' presentation, here I have provided specific research question for each paper based on its contribution, even though they are not all explicitly mentioned in the papers.

This chapter presents a summary and purpose of the papers and discusses each of them in respect to the papers' research questions. This aims to prepare a base for the next chapter when I discuss the total thesis research questions in connection to the papers.

4.1. PAPER I

Introducing robust design in product development: Learning from an initiative at Volvo

This paper is the result of a case study aimed at evaluating and reflecting upon the initial approach by Volvo 3P at introducing Taguchi Methods, which was relatively unsuccessful. The paper is concerning this first research project, and follows the first learning cycle of this research

program (C, A, P). It checked the effectiveness of the project concerning the required operational and financial results (C), reflected upon the results together with the context of application and learned (A), and finally concluded learning points as input for the next initiative plan phase (P).

From the methodological perspective, as social science is embedded within the context, the history of the research subject in the context supports gaining an understanding of it and, therefore, is an important input for generating applicable knowledge. The purpose of the paper is to evaluate and learn from an initial approach to introduce robust design (the Taguchi Methods) within Volvo 3P. It presents some learning points about obstacles and discusses possible measures for successful application. The insight from this trial has been used in design of later initiatives with the Volvo Group.

Through the first half-cycle in this research program, this paper aims to answer the following question with correlation to the holistic research questions of this thesis[36]:

> *P1-RQ1: What were the obstacles affecting the introduction of the Taguchi Methods in product development at Volvo 3P?*

Volvo 3P top management launched this initiative in 2004 in order to decrease fault frequency over time through systematic and proactive ways of working according to Taguchi Methods. The strategy of the initiative was to introduce the Taguchi Methods through the creation of success stories at this first run. For this job an experienced external consultant was hired to work directly with Product Development (PD) engineers in three different pilot projects. However, the organization was not open to change, and it was a relatively unsuccessful trial. Figure 10 shows a snapshot of the main roles and relationships in this initiative.

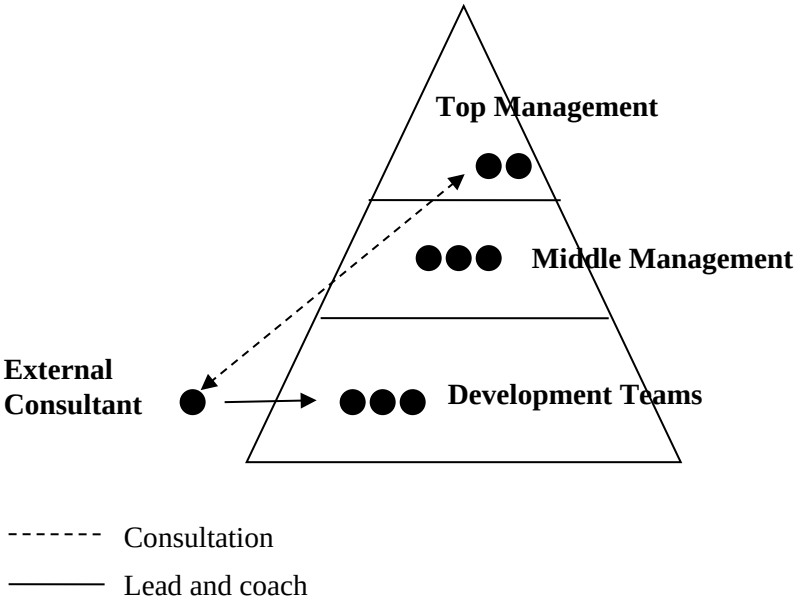


Figure 10: Taguchi Methods initiative set-up

[36] To distinguish between the papers research questions and the total thesis research questions I use P1-RQ1 as abbreviation for Paper 1 research question 1. I follow the same abbreviation for all papers research questions.

This effort was eye-opening and became a source of learning for Volvo 3P as well as the Volvo Group in the later initiatives. Here we reflect upon some highlights of the learning, which can be found in greater detail in Paper I.

The chapter on findings in this paper includes six different obstacles to the introduction of Taguchi Methods at the company as an answer to the paper's first research question. The obstacles include: *1) Set-up of the initiative* was unsuitable to affect proud engineers due to utilizing an external consultant for the introduction of new methods; *2) The initiative's narrow scope* created focus on implementation of robust design methods, and not on other areas prerequisite for robust design methods; *3) The engineers were not convinced that the tools would solve their problems,* as the pilot cases were initiated to introduce RD methods only; *d) Poor integration of the methods into the daily activities of product projects,* such that resources were not secured and prioritized according to the pilot case's plan; *e) Lack of prerequisite statistical knowledge* made it difficult to fully grasp the benefits of the tools and caused lack of commitment; *f) A culture of fire-fighting* caused lack of focus on preventive methods like robust design.

Later on in the discussion chapter, five different learning points are discussed with help of theories as weaknesses in the initiative. These five learning points are summarized below:

Improving a successful company: The success of Volvo in the marketplace over many years has made PD engineers rightfully proud of their accomplishments and therefore sceptical about buying new approaches easily. Such environment requires a special attention and strategy in introducing new way of working through more engagement of the proud engineers in all steps of the initiative.

The problem definition phase: This initiative was based on the diagnosis at a high level of the organization, and lacked clarity for the lower level. The problem diagnosis at these two levels was not aligned. In implementing new ways of working, it is important to get credibility through a problem definition phase as well as shared views on each and every level of the organization involved in the change.

The tool vs. learning focus of the initiative: The initiative aimed at implementing the Taguchi Methods to improve product quality problems, and took for granted that this was the way to go. It pushed tools and predefined solutions to the PD engineers, and was not perceived well by them. Local problems could better be solved with a more humble approach, letting PD engineers test new ways of working in learning cycles and localizing the tools and methods.

The middle management[37] *role*: The initiative lacked strong involvement from the middle management. They did not lead and coach the initiative and, therefore, had less focus on creating an environment in which PD engineers could learn from and reflect on the old and new ways of working. They also did not prioritize the resources for the initiative as they should have. Successful initiatives mostly start closer to the bottom line of the organization, and utilize full commitment and leadership from middle management.

The role of internal vs. external consultants: While there are many advantages in using external consultants in change initiatives, they do not have enough insight into the context. This means they do not have enough mandate and credit to lead the initiatives and be agents of change and role models for the engineers. To achieve success in a change initiative, external consultants should not take the roles that middle management should have as the change leaders. They can

[37] Here, by middle management, I mean group and department managers in the organization.

instead support them in their role, as well as also train internal consultants to support middle managers and the rest of the organization in hands-on activities.

One important conclusion from this paper was that, in order to be able to improve the weaknesses, there is a need for localizing the initiative by creating a learning culture that supports improvements with respect to robust design principles. This culture shift should also be supported by suitable training and incentive systems to create motivation.

This paper elaborates on 'what' obstacles and weaknesses were experienced by Volvo 3P in introducing robust design; however, it does not reflect upon 'how' to tackle the weaknesses mentioned and make the required changes. This aspect is elaborated upon in the next paper, which is based on learning from the VRES project.

4.2. PAPER II

A learning alliance for robust design in product development: the case of Volvo 3P and Chalmers University of Technology

This paper is based on action research in the VRES initiative at Volvo 3P, as the second research project in this thesis. The aim of this initiative was to develop robust design practices for the company and use them in a continuous manner in the product development process. VRES was relatively successful, yet also had some weaknesses. It followed the second learning cycle of this research program (P, D, C, A, P).

The purpose of the paper is to describe and analyse how and why the collaboration between Volvo 3P and Chalmers contributed to creating learning processes for local development and utilization of robust design practices at the company. This paper contributes with the evolved concept of 'learning alliance' for facilitating learning processes in product development.

Through this second cycle of learning in this research, the following research questions are treated in this paper:

P2-RQ1: What influences the PD engineers to work in a new way aligned with robust design at Volvo 3P?

P2-RQ2: How does a 'collaborative master's thesis approach' facilitate implementing new robust design practices at Volvo 3P?

P2-RQ3: What are the key attributes in a change initiative for making new practices happen?

After the reflection on the first trial, Volvo 3P started a new initiative for robust design in 2006. The initiative was led by a core team including the researchers of this research program. The aim of the new initiative was to reduce fault frequency and therefore warranty cost through local development and utilization of robust design practices in the product development processes. The new initiative's strategy was to utilize a learning alliance together with Chalmers University of Technology, Division of Quality Sciences, for testing appropriate means. For this job a letter of intent to collaborate was written between Chalmers and Volvo 3P. Every year between four to eight master's students with different nationalities were selected to do their master's theses at Volvo 3P in relation to this initiative. They worked in groups of two together with PD engineers. In total for this initiative, 22 master's students with 15 different nationalities have been involved. Master's students got supervision on knowledge generation processes both from Chalmers and the core team at the company. They were also led and consulted by the core team concerning

the delivery in the cases they worked on for the company. The transparency between Volvo 3P and Chalmers makes the knowledge generation process more visible and reliable. Figure 11 illustrates the snapshot of the roles and relations in this initiative.

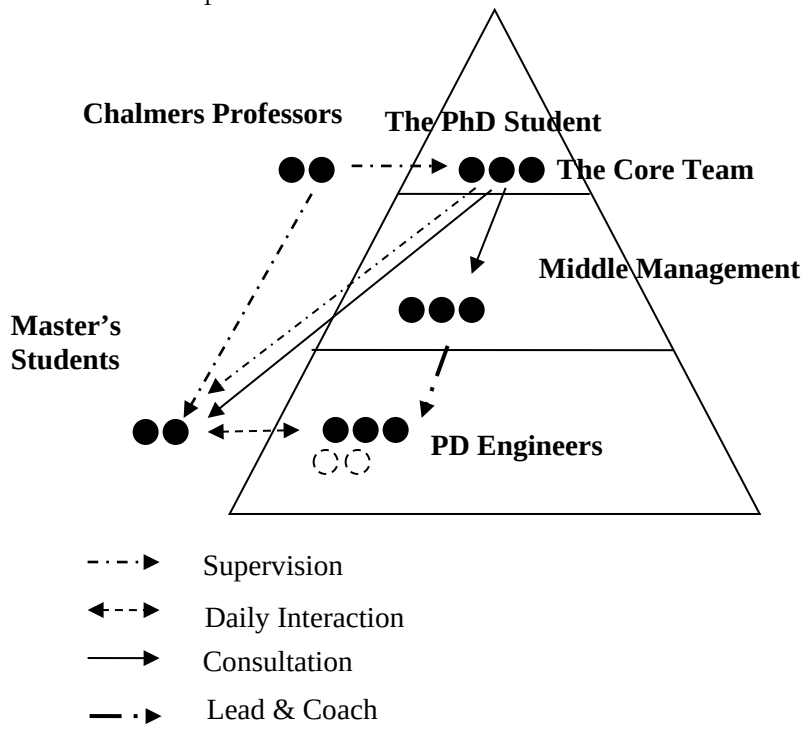


Figure 11: The second initiative set-up

In the new initiative, development of the robust design practices was embedded in their implementation process. Through this, PD engineers who would practise the change were engaged in the initiative through the learning cycles that the master's students helped to create for the cases they worked on. During this initiative, master's students and PD engineers collaborated in these learning cycles and worked closely together on a daily basis. They also followed 'pdca' cycles in each and every case as a learning cycle. They identified problems and planned for improvement together with the PD engineers for the case (p), tested new ways of working together (d), checked the results (c), and finally they reflected together on the results of their actions on development work (a). These reflections created an open environment in which the master's students could introduce the principles behind the robust design concept along with some existing tools and methods, and together with PD engineers, develop localized practices that made better sense for the next cycle.

In order to answer the first research question for this paper, the findings chapter of this paper presents eight factors that influence the PD engineers' work in the newly developed way. They are: *a) Selection of pilot cases* together with PD engineers enabled to select cases based on actual problems; *b) The work environment* in pilot cases was characterized by mutual respect and friendly relationships with master's students; *c) Questions by students* stimulated PD engineers to think and reflect on their ways of working, starting to become critical towards them, and seeing and reflecting upon the existing problems. As PD engineers were given the time to work with master's students, they got space for reflection; *d) Developing own practices*, inspired by robust design knowledge from master's students, by PD engineers created more engagement and commitment; *e) Supervision of master's students* by university professors secured utilization of robust design theories and methodologies according to 'good research practices'; *f) Mutual learning*

between PD engineers and master's students made it possible to learn from the students' fresher and out-of-the-box ideas ; *g) Balancing the insider-outsider roles* of the master's students secured that they did not 'go native' during their period of thesis work, and still stayed critical and questioning; *h) Learning at the Volvo 3P level* was through presentation of the master's thesis results to different levels of the organization as well as through PD engineers, using the developed methods on their own and with other colleagues.

The discussion chapter answers the second and third research questions of the paper. It elaborates on five different attributes of the collaboration between Chalmers and Volvo, which was used in the VRES project and contributed to organizational change as well as academic knowledge generation. These attributes can be summarized as below.

The learning alliance - in this initiative, learning alliances were organized between Volvo 3P and Chalmers University of Technology as well as on the lower level between the PD engineers and the master's students. The result is learning both on an individual and an organizational level. It also contributes to academic knowledge generation through publication by master's students as well as the publication of this PhD thesis. Through these learning alliances, the PD engineers experienced what robust design offers for them in practice while at the same time affected the change initiative to better suit to their daily works. By this learning approach, the robust design practices grew internally, and became part of product development practices.

The learning relationship between PD engineers and the master's students - PD engineers and master's students had daily contact including close collaboration in action to develop and implement new robust design practices. The relationship was characterized by respect-based learning. Through this learning relationship, the learning anxiety was reduced, which positively contributed to an environment of psychological safety where learning took place and new ways of working could be developed and used.

Reflection-in-action and mutual learning - master's students provided external support for creating reflection-in-action together with the PD engineers, something that might have been much more difficult for the PD engineers alone. They were used to working in a specific way with less reflection about possible improvements. As PD engineers were assigned to help each master's student group and were given the time to support them, they had dedicated time and space for reflection. This time was difficult to get otherwise. Questions by master's students created reflection-in-action by the PD engineers about the potential existing problems, their way of working, as well as sometimes about their fundamental assumptions. The reflection-in-action with PD engineers triggered them to test new ways of working, to learn, and to improve practices with much less resistance. This reflection-in-action was also of value for the master's students about the reality of the research context and their knowledge generation processes for their master's theses.

Reflection-in-supervision between professors, students and the researchers from the company - the students needed to create scientific knowledge in their master's theses. Dedicated supervision times with university professors and with researchers in the core team at the company supported their scientific reflection process when they reflected first on analysis of observations and then on learning from the processes they had been involved in. This helped them to get somehow detached from the context and not 'go native' in the company's context. This reflection not only contributed to knowledge generation, but also to improvement of the initiative and its implementation.

Organizational learning - PD engineers took account of master's thesis results even after they left. They re-employed the reflections they had and the practices they developed in their daily work together with other members in the projects. By this method, they spread the knowledge and learning, and in some cases further developed the practices into better ones. Besides the PD engineers' effort in sharing and spreading the new practices, the core team at the company standardized the practices through global instructions, experience transfer sessions, as well as classroom trainings. Each instruction had an owner who followed the progress and evolution of the practices and updated the instructions.

One important conclusion from this paper is that a learning alliance between a company and university, in this case between Volvo 3P and Chalmers University of Technology, can support organizational learning and, thereby, successfully change implementation as well as academic knowledge generation. The transparency between Volvo 3P and Chalmers makes the knowledge generation process more visible and reliable. Such an alliance is cascaded down to a lower level between PD engineers and master's students in order to evolve local practices by PD engineers and master's students so that they learn and experience from application of their academic knowledge.

This paper presents one way of making learning processes happen in a change initiative and discusses the key attributes of such an initiative as the reasons behind its success. The importance of creating time and space for reflection is highlighted by this paper. People involved in an organization often lack time for reflection. To create this space among all important daily activities might be a challenge for any organization. The presented learning alliance in this paper is one way to create this dedicated time and make sure that it is used for reflection.

The paper, however, does not present the content of the practices that were locally developed and utilized in the VRES initiative. In other words, it reflects upon the process of the change and not that much on the content of the change. Therefore, Paper III is written to bridge this gap in the reflection.

In the learning alliance presented in this paper, the role of line managers as leaders and coaches for PD engineers in their collaboration with master's students is highlighted. They got support and consultation from the initiative core team in this role. However, how line managers can learn to be better leaders and coaches for their employees in change processes is not focused on in this initiative. Additionally, in the learning alliance presented in this paper, master's students have been the facilitators of learning and reflection; however, the potential application of such a role with the help of insiders at a company is not elaborated upon. These two aspects have been studied, discussed and further developed in the third learning cycle of the research, which is presented in Paper IV.

4.3. PAPER III

The Volvo Robust Engineering System: How to make robust design work in an industrial context

This paper is the second paper based on the VRES initiative at Volvo 3P. It followed the second learning cycle of this research program and focuses on the 'C' and 'A' steps of this cycle. It focuses mostly on the results of the developed and standardized practices, and reflects upon their effectiveness and weaknesses. The previous paper elaborates upon and reflects on the process of the change, and this paper does the same for the content of the change. From the methodological perspective in an action research cycle, the 'A' step should encompass the

reflection on both processes of change and the results or contents of the change as standardized practices.

The purpose of the paper is to describe and discuss the content and structuring of a robust design approach that was developed and validated in a practical industrial application. It also analyses this industrial adaptation of robust design and compares it to the previous literature-based approaches. It also contributes to the knowledge of what to consider while implementing robust design.

Through this second cycle of leaning in this research, the paper aims to answer the following research questions:

> *P3-RQ1: What is the content and structuring of robust design that has been developed and validated in product development at Volvo 3P?*
>
> *P3-RQ2: What are the differences between an industrial adaptation of robust design and a literature-based approach?*
>
> *P3-RQ3: What is the learning from this local adaptation of robust design for a wider application of new practices in Product Development?*

In the VRES initiative, the focus was on 'practice-pulling' in contrast to the Taguchi Methods initiative, which was 'tool-pushing'. It focused on local learning processes, which were facilitated by learning alliances between PD engineers and the master's students. VRES focused on cultivating new practices in relation to problems that addressed robustness. As a result, five principles and eight practices of robust design were developed, utilized and integrated in the product development process. In order to answer the first research question of the paper, these principles and practices and their structure in the product development system are described in the empirical chapter of this paper. Figure 12 illustrates these principles and practices.

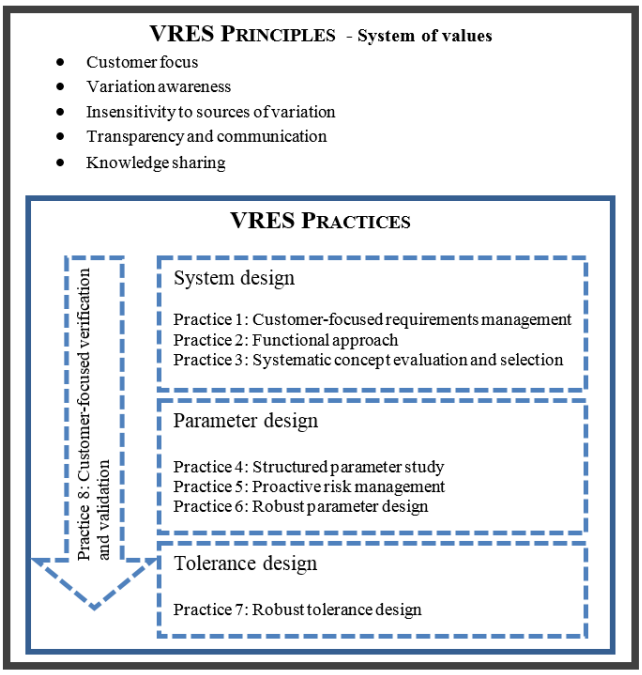


Figure 12: VRES principles and practices

The discussion chapter of this paper first elaborates on the differences between VRES as a practice-based approach, and RDM (Hasenkamp et al. 2008) as a literature-based approach. In this chapter the paper answers its second research question. The discussion chapter claims that in spite of all the differences, VRES content is an expansion and evolution of the RDM approach. This is aligned with the action research's purpose, which is to further develop existing theories through learning in action.

To answer the third research question the discussion chapter also summarizes how the learning from the VRES content has been input to its further development to the LPD content and model for the Volvo Group. In this regard, the LPD model is summarized in modules like 'team work', 'standard way of working', 'process simplicity', 'cross-functional concurrent engineering', 'project assurance practices', and 'knowledge sharing'.

Finally, this chapter reflects upon VRES content that is the result of a local adaptation process and a single VRES practice that is partly context-related. It claims that the value of VRES lies in the process of developing it, and for other companies it will be valuable to start with VRES as an initial concept, then test, learn and further develop it into their local needs. This could be done as a new action research project.

This paper provides an expanded view of the robust design concept and a modified structure for its use. This enables the change from looking at robust design narrowly as just a statistical tool, to instead as system of integrated practices that aim to tackle local problems that cause a lack of robustness.

Papers II and III of this thesis are based on the learning from a change initiative, VRES, aimed at the local development and utilization of new robust design practices. This reflection encompasses both the process of change (Paper II) and the content of the change (Paper III). Paper II argues that the learning alliances approach has broader applications than just this one case, and has provided a couple of reference examples also.

These two papers are the result of action research on one initiative (VRES) and one concept (robust design) in a medium-sized company (Volvo 3P). Even though VRES is a relatively successful initiative, attaining an extended application of it in every part of Volvo 3P through the presented learning alliances has been a challenge, and was not fully achieved during the project period. Volvo 3P had limited access to master's students, and the master's students had an academic obligation to fulfil as well. This could have been an even bigger challenge if VRES or a more extended concept were to be implemented in a larger company like the Volvo Group. The learning alliances presented and their set-up might be either time consuming or insufficient.

These two papers do not reflect on how this way of facilitating learning processes could be expanded and applied to a more extended concept like LPD or in a larger company like the Volvo Group. To get a continual application of LPD in the Volvo Group, the level of learning alliances in the VRES initiative might not be enough. The next paper presents a new cycle of action research on a new project. In this new project, LPD is applied in the Volvo Group and its Business Areas (BAs).

4.4. PAPER IV

Implementing lean product development in the Volvo Group

This paper is based on action research in the RnD30 initiative at the Volvo Group. As the third research project in this thesis, it follows the third learning cycle (P, D, C, A, P), as illustrated in Table 10. It focuses on the RnD30 initiative at the Volvo Group and Volvo Penta from 2010 to 2014.

The aim of this paper is to empirically contribute to the knowledge of how organizations can implement LPD practices, in other words, how to transform an organization to Lean Product Development. It describes how the Volvo Group RnD30 initiative was organized, how it was structured on the Volvo Group level and how the initiative was cascaded down and adapted to the Volvo Penta level. Furthermore, this paper contributes and discusses a theoretical concept referred to as a 'platform for learning' in order to make the LPD practices continually used.

Through this third cycle of learning in the research, the paper aims to answer the following research questions:

P4-RQ1: How was Volvo's LPD initiative organized at the Volvo Group level?

P4-RQ2: How was the LPD initiative cascaded down, and adapted to the Volvo Penta level?

P4-RQ3: How can a platform for learning facilitate transformation to LPD in a company group like Volvo?

In the RnD30 pre-project (2008-2009) phase, the learning from the VRES initiative, both content and change processes, were collected as input. Through this work, the VRES content was evolved to the LPD model at the Volvo Group, and the VRES change process called 'learning alliances' (Fazl Mashhadi et al. 2014, Paper II) was evolved to a broader concept called a 'platform for learning'. The Volvo Group started to establish this platform for learning for the RnD30 initiative in 2010; however, during the journey the concept evolved further and resulted in what I have described in this paper. In order to simplify understanding for the audiences of this paper, I have used LPD initiative instead of RnD30 throughout the paper.

The platform for learning in the LPD initiative at Volvo had two system levels, one on the Volvo Group level, and another on the level of respective BAs'. In this case, Volvo Penta as one BA is focused upon. These two levels are interconnected, and have as the main goal learning and making improvements.

In order to answer the first and second research questions of this paper the empirical chapter presents these two system levels in the LPD initiative's platform for learning. It also describes different components and the role of each component in this platform. At the Volvo Group level, the platform for learning encompasses an operational steering committee, a program management team, and eight learning alliances presented as work-streams. At the Volvo Penta level, it encompasses a steering committee, a project team, and several working groups.

The empirical chapter of this paper also describes how these two systems levels are interconnected, how they share members and what the role of each component is. It indicates the focus for each component, whether this is decision-making, coordination, or learning.

A 'platform for learning', is then introduced as a theoretical concept including learning components meant to achieve learning between different actors on different system levels. The learning components in this platform consist of several learning alliances, the eight work-streams at the Volvo Group level, the project team and the working groups at the Volvo Penta level. Each learning alliance had its own learning objectives but in the interlinked system, they all used their efforts to achieve the overarching goal of the change initiative. The platform for learning defines the working processes and corresponding tasks to reach the objectives of the learning alliances and the main goal of the initiative.

The focus of learning on higher system level, the Volvo Group level, was to learn what to improve and why, by focusing on the shared problem definition and the consequences on the business. The underlying theme was the creation of an environment in which managers are involved in thinking and profound reflection with regard to their fundamental assumptions about existing problems and their consequences (Schön 1983). Learning on this system level was also about the systematic sharing of the learning from the actual implementation. On the lower system level (Volvo Penta level), the focus was on cyclical learning in action and improving behaviours and ways of working. Most of the local development and implementation of the LPD practices took place at the lower system level. At this platform for learning, the learning in these two system levels combined to create a cyclical process of improving actions through greater awareness, understanding and 'integration' of what has been learned.

To answer the third research question of this paper, the discussion chapter summarizes some characteristics of the platform for learning in this initiative:

> *Top-down and bottom-up engagement*: The platform for learning provides a balanced mix between traditional top-down and bottom-up approaches for change. The directions and decisions are steered from the top so that they are aligned with the company's high level strategies. There is also ample space and time for learning and generating innovative solutions at the bottom of the organization. The bottom level of the organization is engaged and motivated by intrinsic incentives in the form of making progress in meaningful work. The top-down engagement positively influenced this motivation by actions such as setting clear goals, and allowing autonomy in testing and developing innovative solutions. People involved in this platform get recognition and are proud of being a part of this platform.
>
> *The triple learning of line managers*: Line managers are the key asset of learning in this platform for learning. They are taking part in all learning components of this platform. They are also given time for learning by their managers. Through this platform they were engaged in three different types of learning activities together with managers from the same level of the organization with similar responsibilities or areas of expertise. They a) Learn to see problems functionally and cross-functionally in order to make sure that the right issues are addressed in the change; b) Learn to be leaders, coaches and teachers for improvement; c) Learn to reflect and share with others aiming for a sustainable change. There should be a strategy and plan in a platform for learning for these three types of learning in order to achieve a stable result. Sharing and continuous improvement of the practices were facilitated through documentation, spreading good examples, and communities of knowledge (cf. Wenger et al. 2002). Communities of knowledge consist of a network of the practitioners who have insights and can share their ways of working in their area of expertise. In the LPD initiative at the Volvo Group, a community of knowledge has been used in one area (problem solving and knowledge management) for further development of the practices in a continual manner.

System boundary: The scope of implementation for the platform for learning (or its system boundary) is a key input to forming and organizing the initiative. This makes it much clearer concerning what to include and what to exclude, including different units, suppliers or customers, for example. A wider system boundary might create lots of opportunity for learning and improvement as well as more complexity and, therefore, difficulty in utilizing those opportunities. There should always be a clear system boundary for a platform for learning. In the Volvo case, the suppliers and the dealers were outside the scope of the initiative and not included in the platform for learning. In spite of the risk of sub-optimization, this boundary limitation helped to create clarity for the initiative and align all efforts towards the most important learning and improvements.

This paper empirically contributes to the knowledge of how to transform an organization to Lean Product Development (LPD). While most of the previous research elaborate on the content of LPD and how an LPD organization works, the platform for learning presented in this paper outlines a way towards an LPD transformation. The platform for learning, through its learning alliances, puts people's development at the centre of the transformation. The learning alliances include people from different system levels who have insight from the actual context (Beer et al. 1991). The platform for learning creates confidence in the *people transformation* journey through its mutual learning processes. People with quite similar daily work and responsibility, learn together in the group and share from their experiences (Frischer et al. 2000). They are allowed to fail as long as they learn from their failures, improve and test new ways of working until they find a better solution. The platform for learning can be viewed as a way to create time and organize space for the previously mentioned three main learning activities for the people transformation towards LPD. The platform for learning touches upon the *process transformation* in LPD through the working agenda of its learning components (the work-streams, the Project Meeting and the working groups). In this regard the working agenda of the mentioned learning components in the platform for learning is built upon the PDCA cycle, as a mechanism for continuous improvement. It is about creating awareness of the product development processes - current state, ideal state and the gap between these two before any improvement works. With regards to *technology and tool transformation*, the platform for learning utilizes various lean methods most importantly visualization of the problem statements, wanted position and contracts for improvement.

Finally, this paper concludes that the platform for learning used by the Volvo Group in the LPD initiative is an example of its application in a short-term breakthrough program; the application of this concept has not been used for continual improvement, but might be of interest for future research.

5. DISCUSSION

This thesis provides an insight into the research subject, orchestrating[38] the implementation of new practices in product development, through the four appended papers. In the following, the total contribution of the papers is discussed in regard to the research questions. How the research subject has evolved through this PhD work over the nine years of action research will be illustrated. Even though each paper is written based on the results and learning of one research project, from a holistic view, each research question mentioned for the thesis could be answered through more than one paper. Table 11 repeats a summary of how research questions in this thesis are answered by the papers.

Table 11: Research questions in the thesis connected to their answers from each paper

	Kappa	**Paper I**	**Paper II**	**Paper III**	**Paper IV**
RQ1	X	XX	XX	X	X
RQ2	X		XX	XX	XX
RQ3	X		X		XX
RQ4	XX		X	X	X

The main research questions in this thesis are phrased in a general way even though my research context has been Volvo. To be able to use the results of this inquiry in a new context, it is important to interpret and tailor the results internally to the unique characteristics of that context. It would be unreasonable to attempt to generalize from Volvo, as a single example, the best case for introducing change in a product development organization (Liker & Morgan 2011). Volvo is unique in its culture and starting point. Nevertheless, I do believe there are some lessons from this journey at Volvo that are worthwhile, and which are transferable to other companies attempting such journey.

Observation and reflection: I have asked myself about the result of the LPD initiative at Volvo Penta; shall I take it for granted that my approach in this project would succeed in another company? Volvo Penta has a unique culture. There are things at Volvo Penta which have supported me in my work a lot. I had a high level of mandate in designing and performing the initiative. I was challenged by my boss but never directed in detail on what and how to do. People have been available at Volvo Penta, I seldom faced people declining to cooperate due to lack of time. We have had the culture of talking face-to-face about issues, ideas and openly discuss. I also got full support from my boss, he was always available for me. I have never called him without getting response; even if he was busy I always got an SMS that we could talk later. Sometimes we talked later in the evening but always the same day as I had called him. We, in product development, have been mainly located in Sweden,

[38] To orchestrate means to arrange and control the elements and infrastructure of e.g. music, a political campaign, or in this case a process of transformation in order to achieve a coordinated effect.

and in Gothenburg. People at Volvo Penta meet each other even outside the working hours for dinner or just have fun. People at Volvo Penta are also open to share and discuss new ideas. We have this approach of testing new ideas and see if they are working; if they work then we invest on them. I could list many other characteristics here about the culture of Volvo Penta as I perceived it but the question is how this has affected my journey. In my final reflection, I realized I cannot take this for granted; I cannot say that my journey would have been the same in another context. What I can say is that this culture at Volvo Penta has positively contributed to the success of the approach in this change initiative.

This chapter discusses an answer to each research question using the results of the papers as well as the mentioned theories[39].

RQ1: What hinders or facilitates implementation of new practices[40] **to be used by product development organizations?**

In the first cycle of this research (Paper I) the main obstacles in implementation of the Robust Design Method at Volvo 3P are described through a case study of a relatively unsuccessful initiative. This first case study aims to understand the mechanism and process of change through learning from a failure. According to this study, the obstacles in acceptance of the new method could partly be found in PD engineers' rightful pride from having contributed to their corporation's success in the marketplace (O'Reilly & Tushman 1997). However, there could also be several weaknesses in the initiative change process, causing the content of the change to remain external to the PD engineers and their immediate line managers. These weaknesses can be summarized as: 1) Using an external consultant to push some pre-defined tools into the organization did not influence the proud engineers' way of working. The external consultant was perceived to have a biased assessment of the situation (Kotter and Schlesinger 2008). This is also what Mellby (2006) has referred to as 'the change initiatives which are forced from the outside'; 2) Too much focus on tool implementation instead of change in the way of working, values and behaviours of PD engineers to reach underlying principles of the required change; 3) Lack of problem identification and diagnosis done together with line managers and PD engineers caused lack of commitment and trust by them and, therefore, the new practices could not be integrated in daily project work. This can be compared to Beer et al. (1990), who argue for mobilizing commitment to change through joint diagnosis of business problems; 4) Lack of line managers' involvement with influencing employee behaviours and practices (Bergquist & Albing 2006, Tanco et al. 2010). Here involvement means that they should take an active role in being coaches and leaders of change, not only through verbal commitment and delegation of the change to others; 5) Lack of prerequisite knowledge of the concept creates learning anxiety for PD engineers and, therefore, more resistance to change (Tanco et al. 2009, Bergquist 2015, Schein 1996); and 6) Focus on classroom training rather than on culture change of managers and engineers, thus helping them learn to see potentials by tools (Bergquist 2015).

[39] The first research question here is about 'what's'. I reflect on many reasons as hindrances and as facilitators. The second and third research questions are about 'how's'. I discuss how to make learning processes happen.
[40] By practices, I mean the way of working by individuals that is also embedded in the individuals' assumptions, values and behaviours. A practice is followed by most of the individuals in an organization. The practices are typically not the same as the written procedures or tools.

The second cycle of this research (Papers II, III) is the study of a more successful initiative. It has elaborated on the characteristics of such initiatives and presented influential factors in facilitating implementation of new practices. This is also verified in the third cycle of this research (Paper IV). According to these studies, learning and learning processes are identified as key influential factors that facilitate individuals experiencing what lies in the change for them in practice and experimenting with new ways of working openly (Argyris & Schön 1978). Learning could start by creating time and space for reflection by individuals on the weaknesses and problems existing in their way of working and on their fundamental assumptions. The resulting awareness can stimulate them and increase their interest in alternative ways. In this regard, Shiba et al. (1993) advised us not to skip directly from 'sense problem' to 'standardize solution'.

Many researchers who do research on different methods try to highlight mostly hindrances in the content and perception of the method in an organization (e.g. Tanco et al. 2009, Kalrsson and Ahlström 1996). Other researchers who do research on change management mostly highlight hindrances due to the processes of introducing a change (e.g. Beer et al. 1990, Argyris & Schön 1996). Here the attempt has been to integrate these two aspects and make a joint contribution with more emphasis on the process of change through learning from an implementation of specific methods in product development; in this case it is robust design and Lean Product Development (LPD).

Observation and reflection: While I was reading Womack et al. 1990, I faced a sentence saying 'in the absence of a crisis threatening the very survival of the company, only limited progress seems to be possible.' I also read a similar statement in Liker and Morgan 2011, saying Ford 'faced unique circumstances including near bankruptcy' when they introduced LPD, which was clearly a strong driving factor for change. One question can be if one can transform people practices only in crises when the 'survival anxiety' is high? In the Volvo Penta case, there was no financial crisis when we started the LPD initiative. Instead the 'learning anxiety' seems to be very low due to the Volvo Penta culture. People have often been open to testing new ideas and acting based on the learning from that test. I have many times heard my manager saying 'we can test it and see if it works', when I introduced him to a new idea or approach. What he was keen on was more the reasoning why to do things. When he agreed that we should do something or we had a problem, then he was open to discuss potential solutions and test. The only requirement was that it should not be too complex. This was not only relevant for my manager but I faced this culture in the product development organization is most of the cases.

So in my reflection in this case the success of change was not due to any evident crisis, but due to perceiving the change as an opportunity for becoming even better. I see differences between companies which drive the change relying on people being afraid of losing job and, in contrast, companies which rely on people who have passion for products and the job and eager to make them even better.

RQ2: How can new practices be cultivated[41]for continual[42]use by product development organizations?

The answer to this research question is partly embedded in the answer to the first research question. As mentioned above, reflection, learning and learning processes are discussed as the key influential factor for facilitating implementation of new practices. The second cycle of this research (Papers II and III) presents an evolution of the learning alliance as a concept (Alänge & Frischer, 1998) to facilitate the learning processes in product development. In this case a learning alliance between Volvo 3P and Chalmers was instrumental to support organizational learning and thereby successful change implementation. It also contributes to academic knowledge generation. Such an alliance is cascaded down to a lower system level between PD engineers and master's students. Learning alliances between PD engineers and master's students create an environment with all the prerequisites for PD engineers to practice new ways of working and to learn and further develop these new practices, making them suitable for the local context. This is referred to as cultivation of new practices. Mellby (2006) has referred to it as 'the change initiative which is cultivated from the inside'. For master's students, it also creates an opportunity to learn and gain experience from the application of their academic knowledge.

In this cycle of learning, the importance of creating time and space for reflection is highlighted. Time and space for reflection is crucial in creating learning processes and facilitating implementation of new practices. Reflection by individuals is not only essential for problem awareness, but also in every step of the improvement including reflection: 1) while in action planning an improvement; 2) while testing and making an improvement; and 3) when learning from each improvement. People involved in an organization often lack time for reflection. To create this space among all important daily activities can be a challenge for any organization. The learning alliance is presented as one way to create this dedicated time and make sure that the time is used for reflection by PD engineers. An initiative with time and space for reflection creates an environment in which a concept is cultivated in the context through learning, and could better contribute to continual use of the concept. Through this approach, the change will be initiated by practitioners who have insight, intervention and interpersonal skills, and are involved in the learning processes and spreading without pushing from the top (Beer et al. 1990). Research reveals that the transformations often fail when new practices are injected into an organization from the top (Beer 2001).

The key characteristics of a learning alliance are: 1) a learning relationship in order to create opportunities for learning (Frischer et al. 2000); 2) reflection-in-action in order to 'unfreeze' the context and contribute to the culture of thinking in terms of the change principles (Argyris & Schön 1996, Lewin 1951); 3) mutual learning between involved actors in the learning alliance in order to develop own practices and learn how to continually act according to them; and 4) sharing of learning from change content and implementation process on the organizational level in order to achieve suitable use and improvement of the new practices. Organizational learning is achieved when the awareness and learning are shared among individuals, and is exemplified through new practices in daily activities (Argyris & Schön 1996). This sharing can be done, for

[41] By cultivation, I mean the process of creating prerequisites for growing and developing local practices in context. Cultivation puts more emphasis on developing a local version of any concept which is adapted to the local context. Cultivation encompasses culture change. I use the word cultivation instead of implementation, which is more rigid and symbolizes more 'push' from the top. Cultivation opens up for a 'pull' from the bottom of the organization through involvement.

[42] By continual use, I mean repetitive use in a natural way (Book 2006) and in a dynamic manner, meaning that it is further developed when there is a need for an improvement.

instance, through documentation, experience sharing seminars, spreading of good examples (Beer et al. 1990), and through communities of knowledge (cf. Wenger et al. 2002).

The evolution of the learning alliance concept between Volvo 3P and Chalmers University of Technology, as well as between PD engineers and master's students, is a contribution from the second cycle of research. It represents an alternative way to generate learning processes and support the cultivation of new practices. This contribution provides 'how' to transform the product development practices, that have previously been introduced as a gap in the field. Learning alliances are also used and verified in the third cycle of this research (Paper IV).

RQ3: How can change of practices in product development be orchestrated in company groups?

The answer to this question is also embedded in the answer to the first and second research questions. As mentioned above, a learning alliance is one way to facilitate learning and learning is a key influential factor in making a change in the practices of product development. The third cycle of this research (Paper IV) introduces a new evolved concept, a 'platform for learning'. This concept encompasses the orchestration of several learning alliances between insiders from different organizational levels and units, all having the aim of achieving breakthrough changes in practices within product development.

The learning alliance concept that was developed based on the observation of the cooperation between Chalmers and Volvo 3P in the VRES project has some limitations. Due to limited access to the master's students and their short period of engagement as well as their academic obligations, getting an extended application of a change through such collaboration might take too long time and not be adequate. The challenge could be even bigger if the content of the change is a more extended concept like LPD and/or the context of the change is a larger company group like the Volvo Group. The learning alliances and their set-up might not be enough. In such a case the 'platform for learning' is presented as an evolution of the 'learning alliance' concept. This concept is more suitable for company-wide changes with more complex content or in a more complex context, in other words, when aiming for changes in a large company with several subsidiaries.

This third cycle of the research presents a case where a platform for learning is developed and used by the Volvo Group that includes all Business Areas (BAs) involved in product development work.

A platform for learning focuses on autonomy and the empowerment of the people for change. In a platform for learning, different people with the power to contribute to change are involved in different learning alliances in order to create a guiding coalition (Kotter 1995). Each learning alliance has specific learning goals shared among the team members. Learning alliances are interconnected and aim at reaching the main goal of the change initiative.

In a platform for learning the directions are defined from the top in order to secure that they are aligned with the long-term strategies. Thus, learning and the generation of innovative solutions are bottom-up. This is accomplished through creating time and space for skilful people so as to ensure that those with the right knowledge and understanding of the daily operations develop and use new local innovative practices (Beer et al. 1990, Beer 2001, Bottrup 2004, Lifvergren 2013). Thus, the level of engagement in a platform for learning is high, thanks to intrinsic incentives. People are involved in a bigger context than their local BA. They are involved in an

initiative defined from the top of the organization. Still they are given time, space and autonomy to develop local innovative solutions. Therefore people feel to make contribution to meaningful improvements and are proud of that (Amabile 2012). A platform for learning has high level of confidence for the people involved (Alänge & Frischer 1998, Liker & Morgan 2011) through mutual learning processes (Frischer et al. 2000). People are gathered to test, potentially fail, reflect and learn. There is a high level of psychological safety (Schein 1996) in the platform for learning. This pride, intrinsic motivation, and confidence provide a high level of engagement in a platform for learning.

A platform for learning has a cultivation strategy for transforming a company. It facilitates development of the local practices based on local problems through its learning alliances (Beer et al. 1990, Shiba et al. 1993). A platform for learning attempts not to copy the existing tools (Sobek et al 1998, Liker & Morgan 2011) but instead to learn from the existing principles, cultivate them in the local context and develop local practices based on the company's local problems and culture. It does not only have as a goal, the application of tools but also the integration of what Morgan and Liker (2006) present as people transformation, process transformation and technology transformation.

Line managers are key assets of learning in this platform and involved in many of the learning alliances. Line managers can learn to see problems, learn to be leaders, coaches and teachers for improvement (Tichy & Cohen 1998, Tanco et al. 2009, Bergquist 2015), and become specialists in the change content. Thus, the mechanism of learning is spread throughout the organization by line managers. They can also learn to reflect and share with others in order to achieve a continual use of the new practices (Argyris & Schön 1996).

> *Observation and reflection:* In May 2016 I changed my job to a new position within Volvo Penta, and outside of product development. When it was my finishing ceremony, my manager in PD had a speech. He appreciated my work and pinpointed my contribution as "you have helped the product development to learn, we have learnt together". He also added that "We have helped you to learn Swedish instead." When I started my first job at Volvo Penta in 2011 I could not understand Swedish language, but I tried to speak and learn. One reflection is that the language was not hinder for me but more as a credit as I was also in a learning process and they could teach me.

The platform for learning presented in this cycle of the research is one alternative way to orchestrate change of practices in product development in a large company. This is also aligned with the gap in the field, as lack of empirical studies providing how organizations, even less a company group, can overcome hindrances and transform practices of people in product development.

> *Observation and reflection:* When it comes to continual use of the practices, the only measurement I have had is the project gate precisions, in other words, the percentage of passed gate deliverables at each gate as the practices are integrated in the gate deliverables. This might not fully represent the continual use of the practices. Yet as an insider, I have observed cultural changes in how people ask for support for these new practices, how people come up with new ideas to improve them, how many new versions of the guidelines have been released and, most importantly, how managers ask new types of questions which lead to pulling the new practices. I could also hear that the way managers spoke had changes, both at

the meetings and even when I passed them in the corridors at the product development offices. As an example, the concept of 'knowledge gap' is often used when PD managers talk to each other regarding relevant concerns.

Viewing the three cycles of learning in these three initiatives at the company from a holistic point of view, it is important to highlight that the action research process has played a role in creating learning both for the company as well as for academia. This role is elaborated upon in the next research question.

RQ4: How can action research support orchestrating the implementation of new practices in product development?

Through this research program, action research is used not only to generate applicable practical knowledge for academia (Reason & Bradbury 2001), but also to support a company in understanding the change mechanisms and in building knowledge of how to make changes in people's practices inside the company. This knowledge has evolved through cycles of learning in the initiatives at the company. The action research process has provided benefits for the company by building such knowledge, as well as in also organizing change initiatives in a more effective manner. This is what Lewin (1951) has referred to as 'to understand and change certain social practices'. Table 12 summarizes and illustrates how the arrangement of the change initiatives at the Volvo Group has been evolved through the three cycles of this action research. Through this table it is clear how the company, through action research, has built knowledge about the mechanism of each change and thereby changed the arrangement of each initiative.

Table 12: The evolution of initiatives arrangement through the three learning cycles

	First cycle Taguchi Methods initiative	**Second cycle VRES initiative**	**Third cycle RnD30 initiative**
Set-up of the initiative	**Utilizing external consultant** to affect engineers' way of working External consultant was a leader and teacher for the change	**Utilizing learning alliances** between Volvo 3P and Chalmers to generate organizational change and academic knowledge Additionally learning alliances between PD engineers and students who stimulated PD engineers to think and reflect on their ways of working Line managers were mostly involved by being accountable for leading and coaching PD engineers in their collaboration with master's students	**Utilizing a platform for learning** including several learning alliances between line managers and PD engineers at different levels and in different companies in the Volvo Group Line managers as leaders, coaches and teachers for improvement Line managers as key assets of learning, engaged in the learning processes Line managers learn to be coaches and teachers for improvement in the learning processes PD engineers also involved in learning through the working groups to implement and further develop solutions
Purpose of the initiative	Implementation of robust design methods	Achieving more robust products Achieving innovative local robust design practices	Achieving more efficiency through learning cycles Achieving continual use of LPD practices
Implementation strategy of the initiative	Tools-pushing Top-down	Practice-pulling by PD engineers through developing own practices inspired by robust design knowledge provided by master's students Bottom-up	Practice-pulling through developing local practices inspired by best practices existing in the Volvo Group and benchmarked companies Balanced mix of top-down and bottom-up
Incentives	-	Autonomy through local development of the practices together with master's student	Intrinsic incentives by making contribution into a meaningful and important improvement Autonomy in development and implementation of local solutions Recognition from managers
Integration of the initiative	Selection of the pilot by line managers through push from the top	Selection of pilot by line managers together with PD engineers based on actual problems in product projects	Selection of the pilot cases by line managers and involved PD engineers Managing the pilots through

	Not integrated in projects' daily activities Lack of line management involvement	Sharing of the results through e.g. PD engineers and using their developed methods in other projects	local working groups Sharing of the results in the whole Volvo Group through work streams, conferences or developed networks Initiating community of knowledge in one area in the Volvo Group
Knowledge building for the initiative	Classroom training in statistical tools for PD engineers and their managers	Training on-the-job and learning by doing for the PD engineers Supervision of master's students by university professors, secured utilization of robust design theories and methodologies, all according to 'good research practices'	Learning from existing best practices in the working groups Learning from mistakes and successes in the learning alliances together with other colleagues Line managers learn to see problems, learn to be leaders, coaches and teachers for improvement, and learn to share with others for continual use of the new practices Lean conference in the Volvo Group and internally at Volvo Penta Managers as teacher in classroom trainings for lean practices
Culture associated with the initiative	Lack of focus on culture change	Culture of mutual respect and learning between PD engineers and master's students	Culture of learning, reflecting and sharing with others Line managers as culture ambassadors

How has action research helped the Volvo Group in this evolution? The gradual evolution in how the Volvo Group has arranged the three initiatives is the result of cyclic reflection and learning processes through action research, contributing to the knowledge of driving change (Argyris et al. 1985). Some of the most important contributions of the action research for the Volvo Group is summarized below. Here we also reflect upon contributions of action research to academia:

1) *Facilitating reflection and learning:* It is easy to misunderstand the 'Act' step in the PDCA cycle. This step is not only about the standardization of the result, but also about reflection and learning. This misunderstanding is partly due to ignorance as well as a lack of time. In most of the companies it is difficult to prioritize space and time for reflection among all other important and urgent activities. Reflection supports that all learning from the change content as well as the change process (pros and cons) are gathered. The action research process is one way to create the space for reflection that supports companies in focusing on the 'Act' step of the PDCA. The insider action researchers, in other words, are employed by companies for facilitating reflection

and learning. Reflexivity is also embedded as one of the quality criteria of action research (Reason & Bradbury 2001).

2) *Reusing and building upon internal knowledge:* It is easy to miss sharing of learning and reuse of internal knowledge in different change initiatives especially in a large company like the Volvo Group. This is important in order to avoid repeating mistakes, to reuse the winning factors, and to build upon the knowledge of driving change and improving successively. The action research process can support this to a high degree. The sharing and cyclic reuse of learning in action is an academic quality criteria for action research (Argyris et al. 1985, Reason & Bradbury 2001), which is secured through the cyclical manner of the process. In action research the knowledge is shared through 'learning-by-doing' in consequent cycles. This could also be strengthened through diary keeping by action researchers, publishing articles, presentations at the companies and universities, and also by sharing in communities of knowledge at the companies (cf. Wenger et al. 2002, Wenger 2008). The insider action researchers, in an industrial context, could act like specialists who collect and build upon learning from processes of change and lead communities of knowledge for such knowledge areas at the company. This could better secure reuse of knowledge and avoid repeating failures due to lack of communication especially in a larger companies like the Volvo Group.

3) *Reusing and building upon external knowledge:* A challenge for both academia and industry is the use of generated scientific knowledge in academia by industry and the contribution of industry to build scientific knowledge in academia. Companies require rapid adoption of new knowledge of innovative solutions in internal practices, and a clue to this is the fast growth of management consultancy companies and business schools (Beer 2001). To be rapid here, a company should not rebuild existing academic knowledge, instead it should reuse it and build upon it. On the other hand, academia has to take a greater responsibility for ensuring that the generated knowledge is applicable. As Churchman and Mitroff (1995) have explained, truth is what makes a significant difference in human affairs. Action research processes empower industry and academia in this mutual interest through their emphasis on continuities between the activities of science and the activities of learning-in-action by practitioners. The action researchers, as insiders with insight, have good access to empirical data through participation, and no matter the subject they do research on, they are acting as a bridge between researchers and practitioners (Schön 1983). Insider action researchers contribute to understanding and to the change of certain social practices at companies (Lewin 1951) with the help of existing knowledge from academia. At the same time, insider action researchers contribute to a wider body of practical knowledge both for the research subject as well as the action research process.

Insider action researchers often have problems of role duality as they have both organizational roles and researcher roles. As a part of the organizational role, insider researchers are integrated in the organizational context; however, as a part of the researcher role, they need to have separation from that context at least during certain periods of reflection. They need to keep themselves as outside-insider researchers (de Guerre 2002; Herr & Anderson 2014), detached from the context, close to the boundary, but still engaged in the initiative. To keep the action researcher detached from the context, the universities have a big role. The professors/ supervisors, and research colleagues at the university should pay attention and make an extra contribution to the reflection process of the research. They can support the insider action researchers in reflecting upon data, as well as its interpretation and analysis, which may contribute to less bias, or rather an increased awareness, of the researchers' own subjectivity (Bryman & Bell 2015).

6. CONCLUSIONS AND CONTRIBUTIONS

After nine years of driving this iterative action research and transformation process at Volvo, there are many learning points which contributed to academic knowledge generation as well as to practical knowledge on how to create sustainable change in product development. I believe these contributions are of value especially to the quality and change management research field. Moreover, companies which are dealing with difficulties in implementing new concepts could get benefit from these contributions.

Some researchers elaborate on the absence of a crisis as a jeopardizing factor for needed change (Womack et al. 1990). In line with this, Liker & Morgan (2011) present an example of a successful transformation of product development practices while the company experienced a crisis. This is referred to by Schein (1983) as 'survival anxiety' which can positively affect the change progress. However, in this perspective the Volvo cases presented in this thesis can be viewed as the *first empirical contribution* as they were not initiated due to a crisis. Neither Volvo 3P in the VRES project, nor Volvo Penta in the RnD30 project were in financial crisis. Instead, the approaches of the VRES and the RnD30 projects, focusing on creating a learning environment in which people feel comfortable to learn and change, and lowered what Schein (1983) refers to as 'learning anxiety'. Also, Volvo Penta's culture of being open to testing new ideas and learning, positively contributed to change.

Throughout this research process as well as the work I did at the Volvo Group, there has been an evolution in what I do research on. This evolution is the result of our mutual learning and clearly visible in how the Volvo Group has designed every initiative and how I have arranged every research cycle. This learning and evolution could contribute both to the research community, especially researchers in the quality management or change management field, and to the industry who are constantly dealing with change. The *second contribution* of this thesis is a movement to the concept of 'practice-pulling' instead of 'tool-pushing'. A practice-pulling approach emphasizes on evolvement of new local practices by practitioners who are going to use the practices. The new practices could get inspirations from external sources like what academia contributes or what other companies have, however there is a need to adapt them locally based on local problems. This view perceives new practices as natural activities and choices of individuals in the organization, therefore the development of new practices are always embedded in their implementation.

Building upon the second contribution, a question could be how to create practice-pulling. Here comes the *third contribution* of this thesis. This contribution emphasises on learning processes in implementing change, learning on how to act in terms of underlying principles of a concept instead of associated tools. Learning refers to an iterative process of studying existing practices, thinking, reflecting upon, and developing and using new practices. This view encompasses the necessity of learning and reflection as a base to challenge existing ways of thinking and acting and therefore change in the practices by individuals. The sustainable application of new practices depends on whether the organization has learnt to keep, reinforce and spread the approach or

not. This relies on everybody's engagement in iterative learning processes, for cultivation of a concept and therefore continual use of it.

The *fourth contribution* of this thesis is the evolved concept of 'learning alliance' as a potential way to create learning processes in product development. The learning alliance can support individual and organizational learning, and thereby successful change implementation. A learning alliance is built upon the fact that learning happens in relationship between actors with mutual learning interests. A learning relationship is a relationship in which it is easier to stimulate thinking, reflection, and growth of new practices. This thesis presents some applications of learning alliances for changes in practices in industry, including at different organizational levels. Examples of this application are the learning alliance between Chalmers University of Technology and Volvo 3P, and respectively between the master's students and PD engineers (Fazl Mashhadi et al., 2014). The other application is learning alliances between different Business Areas within the Volvo Group and, correspondingly, between line managers in these Business Areas.

The *fifth contribution* of this thesis is the concept of a 'platform for learning' as a potential way to orchestrate several learning alliances for transforming practices of product development in a large company with several subsidiaries. A platform for learning includes several learning alliances, each with different learning aims, yet interconnected towards the main goal of the change. A platform for learning also includes other components; in other words, there are several coordination and decision-making components as well. A platform for learning is directed from the top in order to secure alignment with high-level strategies, but with most learning and development from the bottom to secure local development of innovative practices by practitioners who should use them. This thesis presents one application of a 'platform for learning' in the Volvo Group.

The *sixth contribution* of this thesis is the importance of the line managers' role in a platform for learning. They need to learn to be leaders and teachers for improvement. Change initiatives also need to include an emphasis on line managers' development of coaching skills for change and for facilitating learning processes.

Not the least but the last, the *seventh contribution* of this thesis is the potential use of action research by companies in stimulating and facilitating learning and implementing change. A challenge for both academia and industry is the use of generated scientific knowledge in academia by industry and the contribution of industry to build scientific knowledge in academia. Academia is known as a context for learning more than companies are; therefore, using action research is an opportunity to strengthen learning at the companies with the help of academia. Insider action researchers, in an industrial context, support change initiatives by facilitating reflection and learning, and reusing and building upon internal and external knowledge. Insider action researchers can act like specialists who collect and build upon knowledge for change management. On the other hand, as part of academia, they have to take a greater responsibility for ensuring that the generated knowledge is applicable in and transferable to other contexts. Action research processes empower the industry and academia in this mutual interest by acting as a bridge between academia and practitioners, with action researchers functioning as boundary spanners.

7. FUTURE RESEARCH

This thesis contributes with some evolved theories for implementing changes in product development practices. Through the papers, some areas have been highlighted as gaps, and are proposed as future research possibilities. Additionally, in the kappa of this thesis, there are some areas which have been touched upon while the research was being conducted.

This chapter presents some of the most important topics of interest for future research. They are based on the reflection in this thesis and the academic gap identified by the researcher in connection to the needs of the company researched.

The proposed learning alliance between Chalmers University of Technology and Volvo in this thesis is one way to create reflection-in-action and stimulate learning processes with the help of the master's students. In this context, the master's students have the advantage of being outsider-insiders who can see things with fresh new eyes and think out of the box, detached from the norms at the company. Maybe not all companies can work with students from the university in this way, but most of the companies employ new people sometimes. The new employees, at the beginning of their careers in each company, have the same advantage as the master's students. How to utilize this advantage of the new employees in the form of a learning alliance to support the learning processes in introducing a change? This could be an area of interest for many companies, and therefore an area of potential future research. Additionally, utilization of job rotation between different units of a large company in change initiatives for the same reason could be another subject of interest.

The Volvo Group is a multi-cultural organization that has product development sites in many countries. There are also many people who change work in between the sites. Therefore no matter the site, we always face a multi-cultural working environment at the Volvo Group. Some of the employees' nationalities involved in this research program included Swedish, French, Brazilian, American and Japanese. This is even more pronounced considering the nationalities of the master's students involved. One reflection in this thesis is the role of a multi-cultural working environment in change initiatives. How could a company use its multi-cultural working environment as a cooperating factor and asset in its change initiative, finding a way to create more reflection-in-action and facilitate learning processes? This is another area of interest for research that has not been studied in this thesis.

Another concept which is introduced in this thesis, is a platform for learning as a means of orchestrating the implementation of a change initiative. This thesis has focused on the utilization of the concept in a breakthrough project; however, the potential application of such a platform in continual improvement work has not been elaborated upon. The potential application of a platform for learning as a sustainable platform for continual improvement work by employees in a company is another subject of interest for further study.

The application of this concept in transforming a company together with suppliers and perhaps even with customers is also not studied in this thesis. How to further development this concept into a means of learning with suppliers and customers could be of interest for future research.

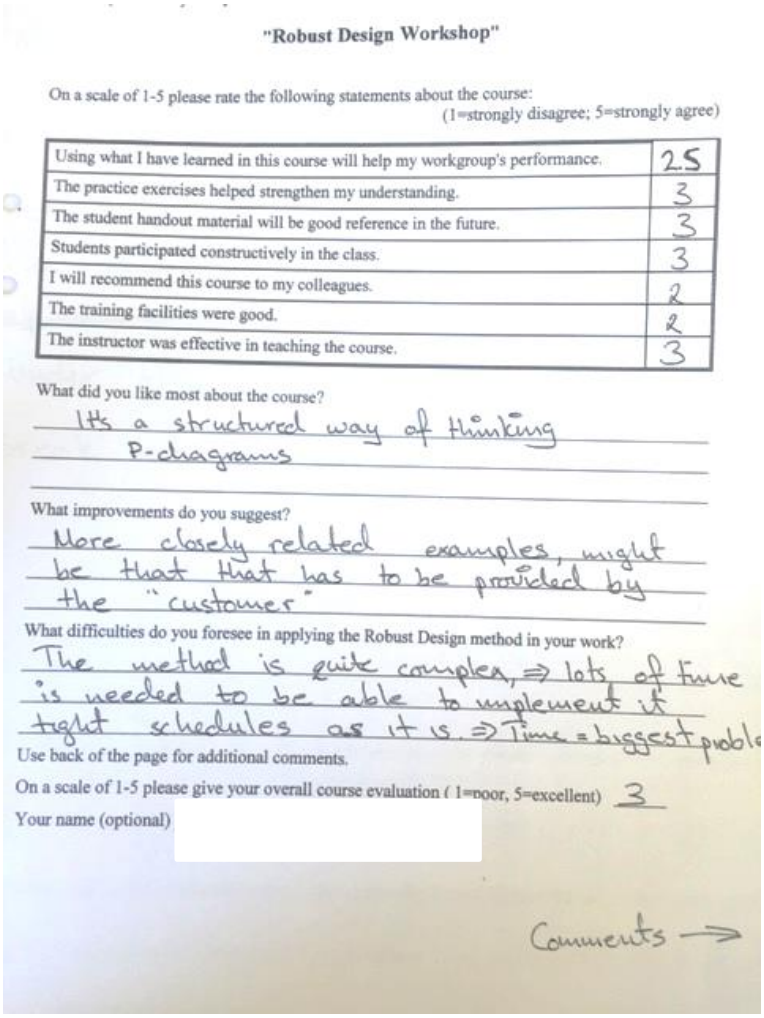
In the lean product development initiative at the Volvo Group, when it comes to sharing and further development of the practices, using communities of knowledge has been tested in one area. While the initiative was at large successful, the extended application of the communities of knowledge has not fully succeeded. Communities of knowledge represent a potential way of creating networks of the practitioners who share the ways of working in their area of expertise and could be a subject of further research interest for many companies as well as academia. The role of action researchers in the communities of knowledge as an extra means for facilitating the learning processes is another subject worth being researched further It would also be interesting to study whether the communities of knowledge could be initiated or whether they are spontaneously organized, as argued by (cf. Wenger et al. 2002). The action researchers, in an industrial context, could act like specialists who collect and build upon learning from practices through leading the communities of knowledge.

8. APPENDICES

8.1. QUESTIONNAIRE, INTERVIEW WITH ENGINEERS FOR PAPER I

1. **Is the concept of Robust Design quite clear to you now? If not, what should be more emphasized?**
2. **Are the tools and how to implement it clear to you? If not what why and what is your suggestion to improve this?**
3. **Where do you find the biggest obstacle to applying the tools?**
4. **How do you find the acceptance from the pilot team members? Elaborate?**
5. **How was working with the consultant? How do you find the support from the Consultant? Elaborate?**
6. **How do you find the support from the commodity managers?**
7. **Any ideas to improve the implementation?**

8.2. EVALUATION FROM THE ROBUST DESIGN WORKSHOP



"Robust Design Workshop"

On a scale of 1-5 please rate the following statements about the course:
(1=strongly disagree; 5=strongly agree)

Using what I have learned in this course will help my workgroup's performance.	2.5
The practice exercises helped strengthen my understanding.	3
The student handout material will be good reference in the future.	3
Students participated constructively in the class.	3
I will recommend this course to my colleagues.	2
The training facilities were good.	2
The instructor was effective in teaching the course.	3

What did you like most about the course?
Its a structured way of thinking
P-diagrams

What improvements do you suggest?
More closely related examples, might be that that has to be provided by the "customer"

What difficulties do you foresee in applying the Robust Design method in your work?
The method is quite complex, ⇒ lots of time is needed to be able to implement it tight schedules as it is ⇒ Time = biggest proble

Use back of the page for additional comments.

On a scale of 1-5 please give your overall course evaluation (1=poor, 5=excellent) 3

Your name (optional)

Comments →

8.3. QUESTIONNAIRE, INTERVIEW WITH PD ENGINEERS FOR PAPER II AND III

Purpose of the interview:
The objective of this interview is to collect empirical data for an article concerning the learning process happening between master students and Product Development (PD) engineers when a master thesis is settled. The aim is to find out what is happening between the two parties and what kind of relationship is created. It is also to find out the pros and cons with the master thesis approach as a collaboration with university master students to introduce a change. This will help to suggest a model for Volvo to continuously learn and develop better ways of working.

Conditions:
The interviewee will be anonymous in this article (if in case we use the data in a way that the person will be identified, we always ask for permission from the person to do so).

Questions:

1. What was/is your job/role while working the student?
2. How many students have you worked with so far?
3. How were the students introduced to you? Exemplify.
4. How did you work with them? Exemplify.
5. Was it only formal meeting or was it also informal?

6. **What was your experience working with students? (concerning the Robust Design master students or other areas). Exemplify.**
7. **Was it worth the time you spent with students?**
8. **What was the most important thing that you wanted to convey to the students? Exemplify**.
9. What did you share with the students?
10. **What do you believe that the students learned from you? Exemplify.**

11. **What did you as a person gain from the students? Exemplify**.
12. What did the project gain from working with the students here? Exemplify.
13. **Did it happen any time that a question from the student made you reflect? (They ask things you did not know or did not pay attention to before). Exemplify.**
14. **What happens really when they ask question? How did you feel and react? Exemplify**
15. **What was your reaction when a student came up with an idea? Exemplify**

16. **What did you gain from having the students working with you? Exemplify**
17. What was your expectation from the students? (The role of students, to follow your plan or to be reflective on the job)
18. Did they fulfil it?

19. **What was good and bad with having the student inside Volvo? Exemplify**
20. Has your experience been different with different students? Why?

21. **How would you characterize your relationship with the students? Exemplify**
22. **Do you have any suggestion on how we should improve?**

Summary:

8.4. EVALUATION QUESTIONNAIRE ANSWERED BY MASTER STUDENTS FOR PAPER II AND III

How do you feel working at Volvo 3P?
How was your relationship with PD engineers?
How did you work with them? Exemplify.
Was it only formal meeting or was it also informal?
What was your experience working with PD engineers? Exemplify.

What did you share with the PD engineer?
What did you as a person learnt from the PD engineer? Exemplify.
How was the support from facilitating team?
Do you feel that you have enough responsibility and authority to take decision?
How was the support from the rest of the organization?
Do you have any suggestion for improvement in any above items?

8.5. Evaluation Questionnaire Answered by Knowledge Managers and PD Engineers for Paper III

Questions – how to support and strengthen the implementation of VRES
Preface

We are to reflect over what is good, what is bad and what can be improved. Hence, we ask you to answer the questions below and add your comments where needed.

1. ***Is the concept VRES quite clear to you? If not: What should be more emphasized?***

Tool application:

2. ***Are the tools and procedure and how to implement them clear to you? If not what is your suggestion to improve this?***
3. ***Where do you find the biggest obstacle to apply the tools?***
4. ***Where do you find it easiest?***
5. ***Is there any special tool or approach that is more difficult to apply than others? If yes why?***

Support from the PM and project team:

6. ***How do you find the acceptance from the project team members?***

Support from the RD Facilitating team:

7. ***How do you find the support from the Facilitating team?***

Support from the Group and Section manager:

8. ***How do you find the support from the commodity and section managers?***
9. ***Any ideas to improve the implementation?***

8.6. Example of Questions in Evaluating Tools in VRES Application

Example of questions in evaluating the application of P-diagram
What are your impressions about the P-Diagram?
Is it useful?
Do you think the P-Diagram was useful for concept selection? Why?
Does it create awareness of variation?
Do you think it fits in your way of working?
What do you think about some of the benefits which this tool brings to a project?
Do you have suggestions how to run the P-Diagram?

Do you have any suggestions for improvement?
What are your overall impressions of the VRES?

Example of questions in evaluating the application of Pugh matrix
Do you think the Pugh tool was useful for concept selection? Why?
Do you think it fits in your way of working?
Do you have suggestions for the way we collect information for final concept selection session and put it into Pugh matrix, the session itself?
Other comments or suggestions?

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