LUND UNIVERSITY
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Agile Methodologies as a Management Tool for Physical Systems Engineering Development

Master Thesis

by

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Abstract

The purpose of this thesis is to investigate an alternative way of management within physical systems engineering development (PSED), a term which represents all fields of engineering where physical components are involved. More specifically, analysing how agile methodologies can be applicable with the use of technological advancements to overcome the restrictions hindering the increase of efficiency and effectiveness of PSED industries, through agility. This thesis follows an inductive research approach designed as a single case study conducted over a cross-sectional time horizon, with the utilisation of semi-structured interviews. The interviewees consisted of a combination of professionals from a consultancy firm and experts within the field. Besides empirical data, this thesis also incorporates literature from the best available knowledge of agile methodologies, product development, and management in general. The findings can be broken down into the three research questions. Firstly, the restrictions of applying agile methodologies within PSED, which consist of; cost, lead time, fragmentation, feedback, siloing, organisation and mindset. Secondly, the technological advancements for increasing the relevance of agility within PSED, which are; additive manufacturing, simulation technologies and communication systems. Thirdly, how the application of these technological advancements along with other solution approaches can contribute towards overcoming the specified restrictions, as demonstrated in a newly formed model created by the researchers. Conclusively and from a practical perspective, this thesis distinguishes organisation and mindset as the most challenging restrictions of agility within PSED. This thesis benefits the research field in the form of a developed model which comprehensively summarises how the specified restrictions of applying agile methodologies to PSED environments can be overcome in conjunction with technological advancements. This contribution is valuable to PSED organisations, as well as scholars in the field for both agile methodologies and technological change.

Keywords: Agile Methodologies, Hardware Engineering Development, Physical Systems Engineering Development, Product Development, Technological Change

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Abbreviations

3D	Three-Dimensional
CAD	Computer Aided Design
CH	Switzerland
GDP	Gross Domestic Profit
HW	Hardware
IT	Information Technology
ORG	Organisation
PROC	Process
PSED	Physical Systems Engineering Development
Q1-10	Interview Questions 1 to 10
R1-7	Restrictions 1 to 7
RQ	Research Question
SW	Software
SWE	Sweden
T1-3	Technological Advancements 1 to 3
TECHN	Technological
USA	United States of America

Terminology

Agile is a term describing different agile approaches which are based on the theory of the agile manifesto. In this thesis, agile methodologies and agility are used as terms with identical meanings.

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Authors are mentioned in this thesis to repeat the source which has been used in the previous sentence or sentences. Therefore, the word author or authors does not relate to the authors of this thesis, but to the literature sources instead.

Hardware Engineering includes computer engineering with the involvement of physical components. Besides this, there are more engineering fields including hardware components. Throughout this thesis, when hardware engineering is referred to in literature terms, physical systems engineering is implied, and vice versa.

Physical Systems Engineering Development (PSED) as an umbrella terminology, has been developed by the researchers of this thesis. The term represents all types of engineering development where physical components are involved. Within the research field, a representative definition would typically be hardware engineering. However, by explicit definition, hardware engineering only covers specific parts of engineering dealing with tangible components, neglecting more broader aspects. Hence, the use of PSED as a replacement term.

Researchers are mentioned in this thesis in relation to the two-headed research group conducting this research. Therefore, whenever the word researcher or researchers is mentioned, it relates to the writers of this thesis.

Technological Advancements is a term describing the current technology connected to the research topic in some way and is also referred to as technological change or technological changes, in this thesis.

Technological Changes is a term describing current technology connected to the research topic in some way and is also referred to as technological advancement or technological advancements, in this thesis.

1 Introduction

"How good is good enough?"
(Stanley, 2003, p. 2)

The introduction chapter contains background information about agile methodologies within PSED and introduces definitions which are used throughout the entire thesis. Furthermore, this chapter incorporates a discussion of the research problem, aim and objectives, as well as the purpose to deliberate its relevancy and delimitations of the subject matter, in order to introduce the focus and lastly outline the structure to provide a general overview.

1.1 Background

After starting a career in building software, Elon Musk founded SpaceX in 2002 with a non-conventional approach to management. This was based around the use of iterative design processes and continual improvement to prototypes, whilst traditional ways focus on robust plans prone to cost overruns (Fernholz, 2014). This "fail fast" technique promoted the building of numerous product versions and myriad testing ways, as opposed to spending forever on the "perfect" design (Berg, 2019). SpaceX's method went further beyond technology, tools, and development processes to consider culture and the working environment, encouraging close collaboration between people; programmers, scientists and technicians themselves. Utilising agile principles and their willingness to fail, SpaceX were able to secure a $1.6 billion contract with NASA after the fourth successful launch attempt of their Falcon 1 model (Aloni, 2016).

Agile methodologies had been introduced at the beginning of the 21st century (Beck et al., 2001), with the main driver being that software development was unproductive since it initially applied management methods which were actually designed for development projects involving physical components. Therefore, the processes from the software development industry required a disruptive change. With the introduction of agility, many traditional development principles were questioned and reformed. Due to the iterative nature of agile, it allows improvements to occur throughout the whole development period, allowing efficiency and effectiveness at each stage of the project. The agile manifesto includes the core of all applied agile methodologies and is therefore considered the main theoretical framework in the field.

In today's world, which is highly dependent on global value chains and constantly changing requirements (Baldwin, 2016), sequential approaches in PSED are not as powerful, efficient and effective anymore as they once were. Consequently, with the emergence and constant evolution of technology and digitalisation, there is a potential to implement agile methodologies within PSED as common practice. Thereby, the benefits of agility can also have their advantages in other fields. Rigby et al. (2016) investigated the implementation of such methodologies within research and development teams, after concerns that traditional management practices were hampering innovation. Findings show the organisation reduced project cycle times by up to 75%, team engagement and happiness increased to the top third of companywide scores, and the work velocity as measured by the accomplished work within a sprint, increased by more than 200%, with one team soaring to 800% (Rigby et al., 2016).

1.2 Problem Statement

The application of agile methodologies within physical systems engineering development will face restrictions since the management style had been more specifically established for software development, a field which does not include physical components. Therefore, the main problem this thesis is investigating is whether restrictions, based on the reliance of physical components can be overcome or not. If they are able to be diminished, it must be indicated how this may be achieved. Furthermore, if there are any restrictions which cannot be resolved, they need to be evaluated, in order to understand the impact and dynamics for improving understanding, and therefore creating a foundation for future research.

1.3 Research Purpose

The purpose of the thesis is to investigate an alternative way of management within physical systems engineering. More specifically, to analyse how agile methods as a general concept may successfully enhance the operating efficiency and effectiveness of physical systems engineering development, from a managerial perspective. In order to overcome potential restrictions of applying agile methodologies within PSED, innovation in the form of technological advancements may have a significant and integrative impact.

1.4 Research Questions

In order to assess the research purpose, the following research questions have been formed.

- **1st research question:** Within PSED, what are the primary restrictions of using agile management practices?
- **2nd research question:** Which main technological advancements have occurred successfully on an industrial level, increasing relevance of agile methods for PSED?
- **3rd research question:** How can these technological advancements contribute in enabling agile methodologies to be used within PSED?

1.5 Research Aim and Objectives

As outlined before, the purpose of the thesis is to find an alternative way of management within PSED. Thereby, the findings of this thesis may benefit any organisation dealing with the development of products including physical components, with an increase of process efficiency and effectiveness. Furthermore, scholars in the field of agile methodologies or technological change enabling new managerial approaches may be able to utilise the output of this thesis for further research. This thesis aims to contribute towards the stated points.

In human history, successfully applied approaches have been continuously transferred into new environments. For instance, wheels or combustion engines being applied to transportation systems, or after-action reviews coming from the military were applied within companies as common practice today. This thesis is based on the idea that there is such a synergy, which can be transferred with reasonable effort. The impact of manufacturing companies is remarkable. According to The World Bank (2019), 14% of Europe's GDP has been contributed from the manufacturing industry. This points towards a substantial potential of using agility to increase businesses efficiency, resulting in higher profit rates. Consequently, the research objectives are to use synergies in finding an alternative way of management within PSED.

1.6 Delimitations

This thesis incorporates the application of agile methodologies within PSED on a general level. Technological advancements are viewed as a tool to overcome restrictions based on the reliance on physical components. This thesis does not focus on introducing or discussing specific agile methodologies such as scrum, lean, kanban or extreme programming per se. The aim is to expand on the general principles from the agile manifesto, which builds upon the shared foundation of all applied agile methodologies.

1.7 Outline of the Thesis

This thesis is divided into five main parts. Firstly, an introduction to broadly outline general information about the research topic to describe the main purpose of the research, comprehensively followed by the consecutive parts. Secondly, a literature review to analytically raise the key theoretical frameworks which are used as an introduction to the research field, along with being pivotal for discussing the findings from the data at a later stage. Thirdly, the methodology component as a framework to systematically establish the methodological concepts, which have been applied for conducting this research. Fourthly, a discussion to analyse the collected data and debrief the content in relation to the theoretical frameworks. Lastly, and built up from all the preceding chapters, conclusions are drawn in order to summarise and further clarify the primary findings.

2 Literature Review

“Technological change is not additive; it is ecological.
A new technology does not merely add something;
it changes everything” (Postman, 1993, p. 18)

The literature review is the first part of the collected data. It contains available and relevant information regarding the research topic. The chapter is divided into three parts. Firstly, a section outlining an understanding of management, and the historical evolution of management practices. Secondly, a passage about agile approaches incorporating the agile manifesto as the core content of agility, and its application in both software development and PSED. Thirdly, a section introducing current technological advancements, including; additive manufacturing, simulation technologies, and communication systems.

2.1 Management

Agile methodologies are the core of this thesis. Essentially, agility is a way to manage, while situationally applying defined core principles within different contexts. Before discussing agility in depth, a general establishment of management is discussed, starting with a brief understanding. Mintzberg (2009) outlines how management occurs on a large-scale affecting society, by stating how “managing is important for anyone affected by its practice, which in our world of organisations means all of us” (Mintzberg, 2009, p. 2). It must be made clear that this is not an engineering thesis, but rather a management thesis discussing engineering contexts. Hence, it is important to contextualise a brief understanding of management, as well as the important developments of management practices over time, in order to set the foundation and highlight managerial significance. Furthermore, the evolutional dynamics of management have been incorporated to indicate that management approaches are constantly developing and are not statically independent of time. Technological advancements have always played a key role in managerial adaption as well as shifts in organisational culture, and this is also reflected in the historical evolution management section.

2.1.1 Understanding of Management

Mintzberg’s (2009) description of management is stated as being neither a science nor a profession, but rather a “practice, learned primarily through experience, and rooted in context” (p. 9). The author further expands onto explaining how managing is more about applying science rather than being an applied science and described the concept as being more dependent on art, rooted in craft. Management takes place within a triangle when the use of science, art, and craft meet (Mintzberg, 2009). Art provides the ideas and integration, science gives the order through knowledge analysis and craft creates the connections (Mintzberg, 2009). This theoretical model is represented in Figure 1. This thesis relies on the idea of managing being a constantly evolving process, and Mintzberg's own understanding is open to this concept, via three aspects; learning through experience, dependence on context, and being a practice.

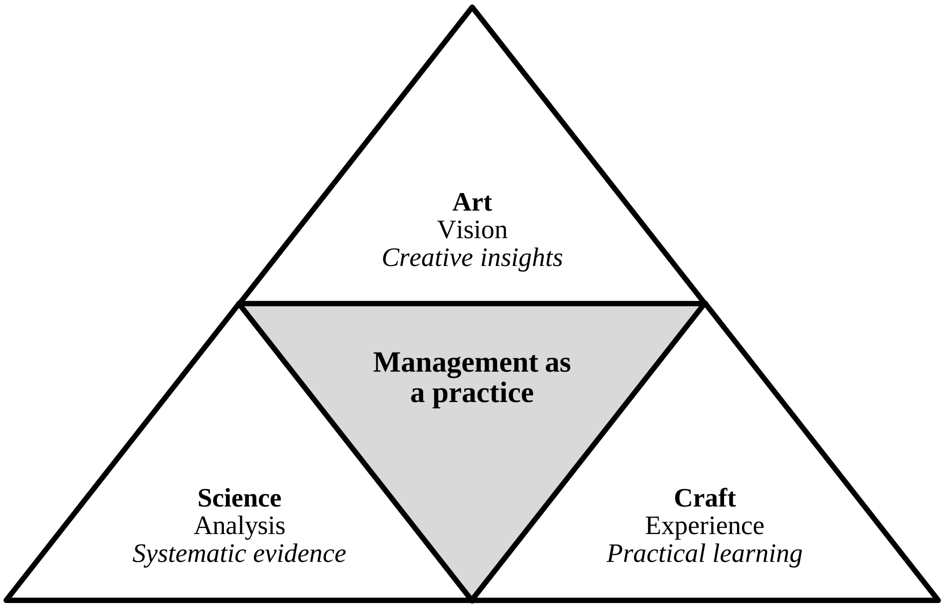

Figure 1: Managing as art, craft, science (Mintzberg, 2009, p. 11)

2.1.2 Historical Evolution of Management

Management has evolved significantly over time and is still continuously developing today, especially since we are currently living in a digital era where technology is becoming integral to majority of industries. McGrath (2014) discussed how prior to the industrial revolution, managing did not really exist or occur with anybody being responsible for handling tasks, such as planning, coordination and controlling. It was only until the early 1900s where the term management was widely used, with a focus on mass production, standardised processes, quality control and specialisation of labour (McGrath, 2014).

A very well-known example of a successful mass production management system was the assembly line. Ford took inspiration from the meat packing industry by having multiple products in parallel production (Alizon et al., 2009). Lovering (2009) expanded on how the assembly line was key to the rise of the Fordism era, with workers being specialised on distinct tasks allowing for standardised goods and hence, mass production. The functionality of the technology developed by Ford was a moving line with a serial layout, a single product type, dedicated machines and material handling systems, all to allow for high volumes of production (Hu et al., 2011). Furthermore, Ford utilised scientific management principles with the division of labour processes; conception, which involved organising methods and engineering based on skills, manufacturing, which related to deploying skilled workforces, and execution, which was linked to unskilled labour and extreme mechanisation (Lovering, 2009). This dramatically increased labour productivity, with the production time of a Model T Ford going from 12 hours and 8 minutes to 1 hour and 30 minutes, after just 6 months (Hudson, 2009). Higher productivity was achieved via the increase of line speeds dictated by managerial decisions, which enabled routine tasks to be performed at an uninterrupted pace (Hudson, 2009). This era of management heavily emphasised efficiency, production consistency, predictability and a lack of variation with the aim of optimising outputs from a specific set of inputs (McGrath, 2014).

The next major phase of management focused on intensifying expertise (McGrath, 2014). During this period, terms such as knowledge, statistics and theory became relevant. McGrath (2014) went onto explain how the mid-20th was remarkable for management theory growth, with statistical and mathematical models forming the basis of what became operations management. Science was further merged into management with the development of the theory of constraints, as well as waterfall approaches for software development (McGrath, 2014). The sequential waterfall method allowed designers an insulated time period regardless of length to generate and evaluate ideas until the best design or feature was created (Gothelf, 2012). During this age, managing knowledge became the centre of attention with a value shift from workers just producing goods and carrying out tasks, towards a focus on the information workers held and the use of it (McGrath, 2014). This is also where the theory-Y approach became more applicable, as the new management theories promoted an emphasis on motivation and employee engagement (McGrath, 2014). Essentially, this led to a change in executive attitude, from authoritative and control concepts, to active participative coaching roles (McGrath, 2014).

McGrath (2014) believes after creating scale with execution and providing advanced service with expertise, we are now currently in a new empathy era of management. McGrath (2014) points out how work is becoming more tied with emotions, how managers should be responsible for creating communities, how the demand for empathy is now above execution or expertise and how leaders must behave more like pillars during this re-form. Today's institutions which were initially designed for the business-as-machine era, are seen as exploiting employees and customers for the benefit of capital owners as well as promoting inequality, which paves the quest for management with greater empathy (McGrath, 2014).

2.2 Agile Approaches

Some notable forms of specific agile development methodologies include scrum, lean, kanban, and extreme programming. There are no specific values or standards of the agile features that each method should implement (Campanelli & Parreiras, 2015). It must be stated that for this thesis, specific agile frameworks are not the focus, but rather the entire agile concept and its approaches and principles instead (see chapter 1.6). Therefore, only a brief summary of the mentioned agile methods are outlined in this thesis, as follows (Campanelli & Parreiras, 2015):

- **Scrum** – delivers at the highest value, handles complex problems, and uses incrementation for development with cross-functional teams. Scrum focuses on experience, knowledge and making decisions based on known information.

- **Lean** – aims to deliver relevant and required features based on customer demand, and considers non-value adding activities as waste.
- **Kanban** – based on principles from the lean approach in the sense of removing unwanted aspects from the production process. Kanban rules include minimising the work in progress, measuring how long task completion takes and visualising workflows.
- **Extreme Programming** – lightweight methodology with a cost-saving focus, simple design and frequent software releases. Typically used to help small teams on projects with vague and changing requirements.

As stated by Rigby et al. (2018), agile teams are multidisciplinary, suited well to innovation and operate by breaking down large and complex problems into smaller modules in order to develop solutions for individual components, via feedback loops and prototyping. Furthermore, agile approaches place value on adapting to change as opposed to sticking to an initial plan, with accountability being held on the outcomes of profitability, customer loyalty and growth rather than outputs such as the number of new products, (Rigby et al., 2018). Agile methodologies are usually described as being iterative and incremental in regard to development, with teams being self-governing and working very closely with customers (Rigby et al., 2018). Campanelli and Parreiras (2015) affirmed that agile practices are ideal for the handling of unstable requirements, delivering software in short timespans, and allowing for rapid, adaptable and flexible change. This is what differentiates agile from traditional management.

Optimal conditions for agile teams are those where situations are complex, solutions are unclear and requirements in a project are likely to change (Rigby et al., 2018). Agile allows businesses to better able foresee priorities and changing conditions in order to establish adaptive solutions, thus avoiding the frequent crisis that occurs with traditional hierarchies (Rigby et al., 2018). Rigby et al. (2018) highlighted how agile methods foster an environment where disruptive behaviour eventually comes to feel less disruptive and more like adaptive business, delivering measurable improvements and thus increasing the response to customer needs, loyalty and engagement. Examples of agile management practices include customers being on-site, daily stand-up meetings and open workspaces (Campanelli & Parreiras, 2015).

In regard to learning, Campanelli and Parreiras (2015) analysed how the short iteration strategy of agile accommodates new changes, based on previous knowledge and experience within dynamic environments. Rigby et al. (2018) interestingly summed up agile in practice; step-by-step in nature and very ambitious.

2.2.1 Agile Manifesto

The agile manifesto was formed at a ski resort in Utah, when 17 people met, socialised and theorised on what later became the agile software development manifesto (Beck et al., 2001). Referring to themselves as the Agile Alliance, the 12 agile principles for software development were agreed and signed upon by all members with the hope of encouraging fellow professionals to consider software development, organisation and methodologies in new and more agile ways (Beck et al., 2001). The 12 principles in full, are stated in Table 1.

Table 1: Agile manifesto's 12 principles

1	Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
2	Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
3	Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4	Businesspeople and developers must work together daily throughout the project.
5	Build projects around motivated individuals. Give them the environment and support they need and trust them to get the job done.
6	The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
7	Working software is the primary measure of progress.
8	Agile processes promote sustainable development. The sponsors, developers and users should be able to maintain a constant pace indefinitely.
9	Continuous attention to technical excellence and good design enhances agility.
10	Simplicity: the art of maximising the amount of work not done is essential.
11	The best architectures, requirements and designs emerge from self-organising teams.
12	At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behaviour accordingly.

(Beck et al., 2001)

The agile manifesto is relevant to this thesis, because as stated by Ciric et al. (2019), many other project types share the same challenges that agile has solved in software development, with a growing number of experts recommending agile to outside industries. Ciric et al. (2019) stressed the applicability of agile for coping with dynamic and changing business environments, and hence the importance of exploring agile beyond software and IT.

2.2.2 Agile Application in Software Development

Kaushik (2016) introduced how agile methodologies are continuously substituting traditional methods for software development, due to its iterative nature and setting direct customer involvement and satisfaction at the highest priority. And why is new-age management style winning over personnel within the software industry? Today, we are experiencing great volatility and uncertainty, where talented workforces desire more control over the ways they work and interact with their customers, peers and management (Kaushik, 2016).

Ciric (2019) introduced how traditional management involves comprehensive and detailed planning based on client requirements at the very start of a project with no subsequent changes, assuming predictable circumstances and clear requirements. However, rarely do projects follow such a sequential flow with clients usually being unable to accurately define requirements only at the beginning (Ciric, 2019). Papadopoulos (2015) discussed how there is the underlying inclination to implement additional layers of management, checkpoints, intensified policies and even more processes during planning for large and distributed projects. This is radically different to how agile teams should be implemented. Papadopoulos (2015) continued to describe how agile should focus on flat hierarchies and small organisational structures with more teams and less management levels. Hunag et al. (2012) confirmed by analysing how the agile manifesto encourages individuals and interactions ahead of processes, working software rather than documentation, customer collaboration instead of negotiation and prioritising the adaption to change over following a plan. The focus for agile methodologies should always be to provide valuable software, thus achieving customer satisfaction (Papadopoulos, 2015). Tam et al. (2020) compared and contrasted traditional development approaches against agile development practices, as visualised in Table 2.

Table 2: Traditional versus agile management

Traditional	**Agile**
Top-down approach and difficult to add changes.	Experiments on different techniques are conducted with optimal solutions being gradually achieved.
Leadership working style.	Free flowing communication channel with anyone and everyone being able to present ideas.
Project phases are pre-planned.	Project phases are more flexible with workflows being subject to change on the basis of new modification requests.
Customer involvement only extends to initial gathering of requirements.	Customer involvement is crucial for the agile model to demonstrate its calibre.
Project plan arrives before commencing system development.	Project work is delivered incrementally with each module being presented to the client after preparation to ensure accurate progress.
Project manager has ownership responsibility.	Shared ownership as every member holds equal responsibility for individual contribution.
Product delivery is one-time only.	Product delivery is incremental.
Mechanical organisational structure being bureaucratic with a high degree of formalisation.	Organic structure promoting flexibility and social interaction and being aimed at small-medium organisations.

(Tam et al., 2020)

Cooper (2019) investigated the success drivers of product development projects and stressed the significance of customer input and their role within; valuable idea generation, user-requirements, specifications and design. Often, market research is conducted too late and after the design has been decided, whereas the approach should instead be to include market research in design decisions (Cooper, 2019). The same goes for testing. Customers should be integral to this as a method of verifying the most optimal design, as it is much cheaper to test and learn as opposed to developing the product before carrying out the customer assessment (Cooper, 2019). This links to agile's incremental nature and how design, testing and iteration all fit together. Adapted from Cooper (2019), Figure 2 outlines what agile cycle development processes should consist of.

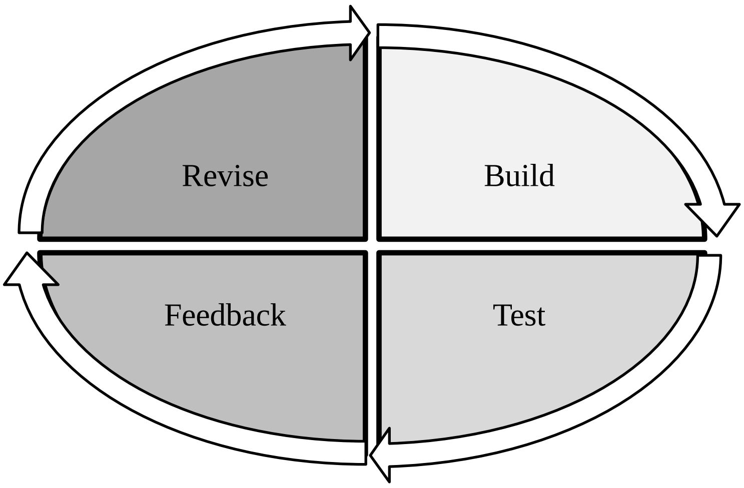

Figure 2: Agile development process cycle
(adapted from Cooper, 2019)

- **Build** – a representation of the product to present to customer through prototypes, beta versions, concepts, simulations, graphics and virtual reality.
- **Test** – test each and every version directly with the customer.
- **Feedback** – use the customer or user to gather as much feedback as possible in regard to desired features and their value perception.
- **Revise** – reset thinking about where product value belongs, reconsider product benefits and design based on feedback, and move forward to the next iteration.

Papadopoulos (2015) further argued how providing frequent deliveries to stakeholders especially when based on customer feedback, allows for enhanced project control and creates the opportunity for change requests and corrections to occur at any time, even late in a project. Moreover, while traditional procedures result in having to wait for new releases to add changes, the step-by-step style of agile allows for constant adaption and evolution, without it ever being considered too late (Papadopoulos, 2015). Cooper (2019) continued with how this strategy promotes experimentation and allows for failure to occur more often, quicker and cheaper.

Along with customer inclusion, another critical dimension of agile success in software development is people and their capability within teams. Tam et al. (2020) mentioned how individuals are fundamental to the agile movement and must be motivated, flexible and supported. Tam et al. (2020) continued to argue that standard software project failures occur less due to technical issues, but more so in relation to people and management. Papadopoulos (2015) expanded on similar points by stating that agile projects should involve flat hierarchies and cross-functional teams having self-organising attitudes, in order to foster close collaboration and coordination without unnecessary complications.

Ahimbisibwe et al. (2015) affirmed that the degree of project success with software development is strongly tied to personal characteristics of individuals and societal culture, demonstrated through two aspects; capability of teams and customer involvement. Kaushik (2016) further vouched for agile methodology by pointing out that despite a need for plan-driven development and management, the bigger growth most certainly lies in agility and flexibility.

2.2.3 Agile Application in PSED

A possible motive for applying agile methodologies into PSED contexts in based upon the shortcomings of traditional project management when it comes to handling changes within dynamic environments (Ciric et al., 2019). Moreover, Ciric et al. (2019) raised the fact that the topic of agile is most frequently found in literature related to software development but appreciated the potential beyond software, in order to allow for organisations to stay competitive through flexibility and recognising changes. There is an emerging recognition of using agile methods in alternative industries, but a lack of empirical research into the area (Ciric et al., 2019). Such statement further enhances the significance of this thesis.

Ciric et al. (2019) investigated typical reasons behind the lack of widespread agile practice outside of software and IT, citing cultural norms as a common finding related to a lack of commitment due to the investments in time and structural overhaul. There have also been practical problems reported around testing and feedback, stakeholder alignments and functional incompatibility. However, Ciric et al. (2019) concluded there is in fact a lack of a difference with these challenge perceptions, between software development and beyond.

Nevertheless, there are multiple instances of agile-inspired approaches being used within non-software related product development. Siemens started a programme to enhance the skillset of their research and development teams, based on customer needs (Burchardt & Maisch, 2018). Burchardt and Maisch (2018) studied the programme, entitled Design Thinking, as follows:

- **Hear** – during this phase, the design team collect and collate information and stories from a range of stakeholders via field research.
- **Create** – the team translates their empirical observations from the stakeholders into a framework, opportunities, solutions and prototypes. This phase involves shifting from abstract thought processes of identifying opportunities to concrete prototypes. Prototypes are simple, rapid and cheap with the aim of effectively communicating an idea in a tangible way, whilst learning through building.
- **Deliver** – solutions are realised through several rapid iterations of prototyping, testing and cost modelling. Early testing is important for reducing failure risks.

Prototyping and testing cycles were consistently presented to stakeholders during feedback sessions to accelerate learning and maintain empathy with stakeholders, in order to deeper understand their project needs (Burchardt & Maisch, 2018). The Design Thinking programme also incorporated additional agile-related elements such as cross-functional teams, synchronised information and coordination to increase development speed (Burchardt & Maisch, 2018). Burchardt and Maisch (2018) concluded the Design Thinking concept demonstrated that as well as software, dynamic agility management structures are more than appropriate for product and service development, having the ability to deal with the challenges of today’s world; uncertainty, complexity and ambiguity. The relationship between dynamicity and complexity is represented in Figure 3.

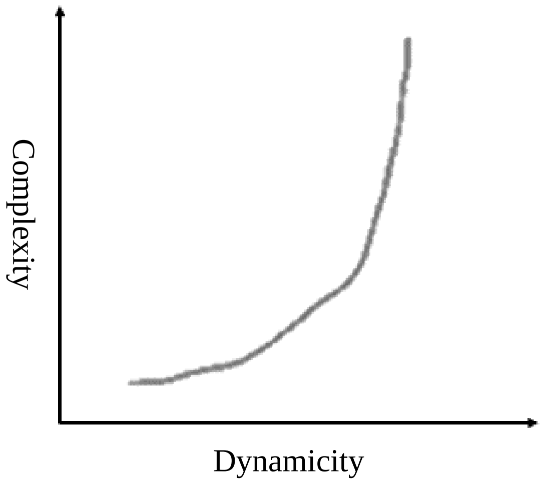

Figure 3: Complexity and dynamicity correlation
(Burchardt & Maisch, 2018, p. 205)

Gustavsson and Rönnlund (2013) conducted a study at Ericsson on the applicability of agile management within hardware development efforts. Many Ericsson employees lacked faith in the idea, solely believing agile is only for software due to the ability to make late product changes (Gustavsson and Rönnlund, 2013). However, the hardware development unit insisted that iterative processes and simulation testing could be used to understand hardware behaviour, prior to the production of products (Gustavsson & Rönnlund, 2013). Management from Ericsson stated that findings had delivered results at a higher pace than previous hardware projects, and the research also showed flexibility can be applied to certain areas of the project process (Gustavsson & Rönnlund, 2013). With their research determining early benefits and no serious problems, Gustavsson and Rönnlund (2013) concluded that agile methods can indeed benefit hardware production.

Another instance of agility being used in physical product development is extreme manufacturing, which enabled faster change, better response to customer needs and ultimately, increased profitability (Stevens, 2020). Extreme manufacturing was an agile-for-hardware approach created by Joe Justice and refers to the project entitled WIKISPEED, which involved the complete creation of a road-legal automobile from utilising the benefits of agile management (Stevens, 2020). Justice et al. (2020) deliberated the principles of what extreme manufacturing is based upon (see Figure 4), as follows:

- **Uncertainty** – hardware projects tend to have considerable material and change costs and higher risk of sunk costs, all of which increases during the project lifecycle. Extreme manufacturing uses modularity, flexible tooling for mass production, few materials and minimalist designs to combat these factors. Moreover, early prototypes are used to ensure product understanding, reduce risks and maximise learning.
- **Modularisation** – hardware project phases are split into modules separated by factors such as long lead, complex, highly regulated, testing and certification timeframes etc. Each module is tested before continuous integration with other modules in the system.
- **Interface** – designs for the interfaces used between modules should be reusable. Intricate interfaces with too many steps to connect and disconnect modules can discourage experimentation.
- **Team** – collaboration between members is encouraged, ideally to be co-located with a pair per module. Willingness to work together outside one's core expertise may also be a requirement.

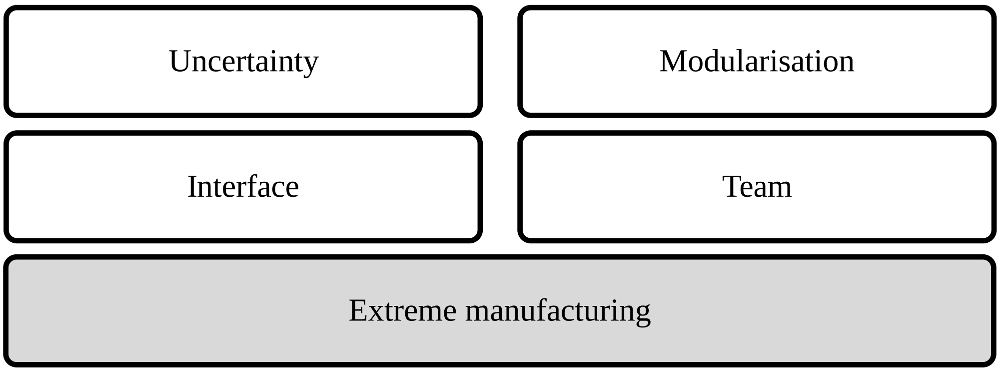

Figure 4: Principles of extreme manufacturing
(adapted from Justice et al., 2020)

Stevens (2020) analysed how these principles were applied in practice for the WIKISPEED development, starting with sub-teams being assigned to develop a total of eight defined modules such as the engine, body, cockpit etc., with simple interfaces. Simulations were initially used to conduct crash tests, with iterations being used to update with real data in order to better model future crashes (Stevens, 2020). These were cheap, repeatable and only required computer time with the simulations eventually becoming realistic enough to no longer even warrant the more expensive physical tests (Stevens, 2020).

Stevens (2020) pointed out how the strategy for designing new components focused around being as simple as possible, able to pass testing and identifying boundary conditions before the design. For example, without knowing how the emergency brake handle would appear, a cardboard box was used as a fitting reference in order to allow the team to continue on with neighbouring components. Stevens (2020) contrasted agile development by stating a slightly different view on iterations is required for hardware, in comparison to software.

Interestingly, the modularity element of extreme manufacturing is very similar to the mass flexible specialisation approach taken by Ford, during their success era in the early twentieth century. Alizon et al. (2009) introduced Ford's modular based design, where components were added or removed to suit specific needs. This went as far as tailoring bodies of models and features. For example, the Ford Touring gave customers the choice of a 4-seater automobile or the equivalent of today's pick-up truck, through the removal of the modular rear section (Alizon et al., 2009). This is represented in Figure 5.

Figure 5: Modularity demonstrated by Ford (Alizon et al., 2009, p. 596)

Regarding the suitability for agile methodologies in hardware development, Stevens (2020) wisely pointed out how software is becoming more and more integral to physical products, and hence it is "only natural to apply the successful principles and practices of software development to the challenge of creating physical things" (p. 22).

2.3 Technological Change

Technological change in this thesis includes the latest technologies which may enable agile methodologies to overcome the restrictions for becoming common practice within PSED. Furthermore, similar to managerial methods, technology is a dynamic topic evolving even more rapidly. According to Brynjolfsson and McAfee (2014), Moore's law describes this rapid transformation for circuit computing power. The authors outline that the computing power, which can be bought for one dollar, doubles every year. This is one example indicating the dynamics and the implied transience in the field of technological change. Therefore, the described impermanence must necessarily be seen as an important factor when applying new technologies.

2.3.1 Additive Manufacturing

In the twentieth century, around 1980, a series of additive manufacturing technologies had arisen as outlined by West and Kuk (2014). According to Niaki and Nonino (2018), all these approaches apply a series of thin layers on top of each other in order to create three-dimensional objects. Additive manufacturing is also known under the term of 3D printing (Niaki & Nonino 2018). These days, three basic principles of additive manufacturing techniques have crystallised out being liquid-based, powder-based and solid-based systems (Niaki & Nonino 2018). All the three systems use a building material, which differs in its form for the three techniques, but the general idea is identical with all three (Niaki & Nonino 2018). The authors describe a two-step process beginning with the commissioning of thin layers consisting of the building material, which then needs to be stabilised in a second step. For liquid-based and powder-based systems, lasers are commonly applied to solidify, whereas solid-based systems are required to be liquidised ahead of the layering process (Niaki & Nonino 2018).

Additive manufacturing finds applications in various areas, dealing with design and CAD interfaces as the design process is normally accomplished using a CAD system (Niaki & Nonino 2018). With the CAD system, three-dimensional data sets can be generated as required for the manufacturing process. According to Niaki and Nonino (2018), another way 3D data can be acquired is through reverse engineering, where physical objects are scanned to generate 3D data. In summary, 3D data is necessary and obtained from whichever procedure to feed the additive manufacturing machine with such information, in order to initiate the additive layering procedure.

Additive manufacturing has been applied in various areas, but for this thesis, its application within product development processes is of primary interest. In the field of product development, the main benefit in the researchers’ view is rapid prototyping. Niaki and Nonino (2018) define rapid prototyping as a collective name for different additive manufacturing technologies used to manufacture models or prototypes. Additive manufacturing is radically affecting prototyping scopes with a simple and affordable fabrication technique (Niaki & Nonino 2018). The authors further expect additive manufacturing to be the first and most sustainable choice for prototyping in the near future. Furthermore, the authors outline that a majority of the companies dealing with new product development are benefitting from the disruptive technology. Niaki and Nonino (2018, p. 133) state how “additive manufacturing affects the new product development process by enabling the use of a process with lower costs and which takes less time, in addition to having reduced design errors and quality costs”.

Besides prototyping, there are multiple instances where additive manufacturing adds value. Another topic which is closely connected to the scope of this thesis is the implementation of additive manufacturing to improve just-in-time production, according to Niaki and Nonino (2018), through the following four points:

- **Dematerialising supply chains** – as in 3D data being the only need for commencing production.
- **Just-in-time manufacturing** – as in reducing material distribution and inventory costs for work-in-progress.
- **Reducing set-up and time and cost** – as in additive manufacturing machines do not require tooling for the production of different parts, compared to conventional manufacturing.
- **Reducing waste** – as in 3D data being a manufacturing resource which can be directly sent to the machine, through the use of internet technologies.

2.3.2 Simulation Technologies

According to Strogatz (2007), computational simulation applies mathematical modelling performed by a computer, to predict outcomes of physical systems. Simulating a system is representing the running of a system's mathematical model (Strogatz, 2007). For instance, a mathematical model of an engine, or parts of it, can be built and afterwards simulated through iteratively running the mathematical model under defined boundary conditions. Thereby, insights about the system can be gained, without actually having to build the physical system. An important aspect while discussing computer simulation technologies is to be aware that mathematical models are representations of real-world systems (Strogatz, 2007), and are therefore only approximations. Consequently, the results provided by computational simulation must be interpreted by professionals in order to conclude meaningful findings, which can then only be applied to solving real problems. In summary, a general process includes a real system which is mathematically modelled to be computationally simulated, followed by an interpretation of the results, in order to finally conclude findings. The described process is visualised in Figure 6.

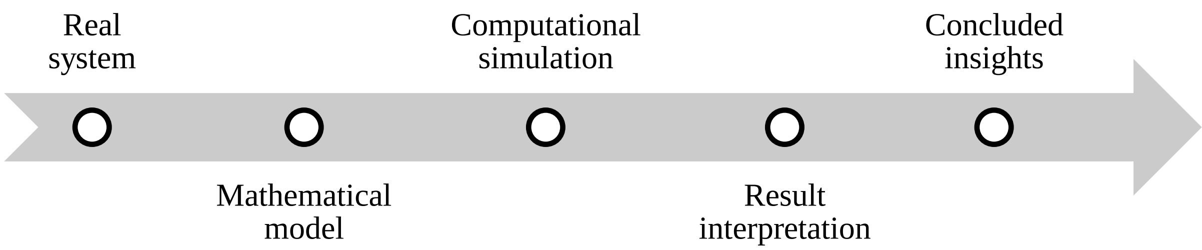

Figure 6: General computational simulation process (by Researchers)

Numerical simulations are commonly used as a supporting tool for research and development, within science and engineering (Kajishima & Taira, 2017). According to the authors, the utilisation of simulation technologies has been commercialised by the common accessibility of computers. Kajishima and Taira (2017, p. 1) state that "since numerical computations are advantageous to experiments from the aspects of speed, safety and cost in many cases, their uses have been widely accepted in the industry. Therefore, applying simulation tools appropriately can result in higher efficiency, lower investments and better safety standards. Shunmugam and Kanthababu (2020), narrowed the scope further down to the manufacturing industry, outlining the challenges being faced due to frequent changes in customer requirements. They further state that traditional experimental-based testing approaches are not sufficient in the outlined changing environment, due to intensive time and financial investment. The authors suggest simulation as a way of fulfilling the drawbacks of conventional methods through the reduction of experimental tests, and an improvement of flexibility in the design process, which both result in lower capital investment costs.

2.3.3 Communication Systems

Brynjoflsson and McAfee (2017) emphasised how conversations are important for effective transfer and interpretation of information, within many contexts. The Shannon-Weaver model of 1964 depicts the telecommunication conditions which enable signal transmission and represents the act of communication when delivering and receiving a message, on a certain medium (García-Marco, 2017). This model of a general communication process can be applied to any form of communication, such as face to face or remote. The communication flow is represented in Figure 7.

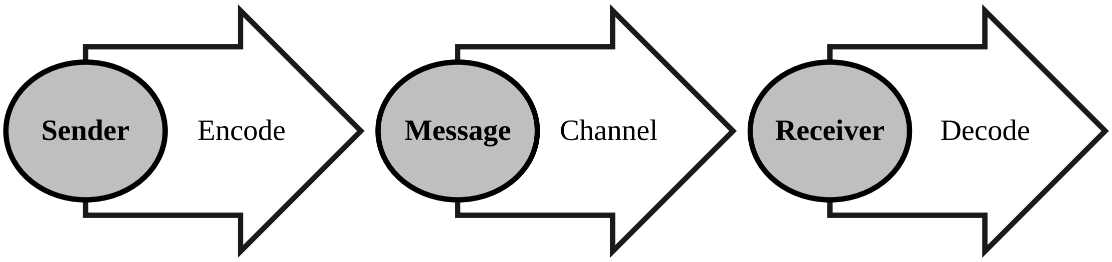

Figure 7: Communication model (adaped from Shannon & Weaver, 1964)

Brynjoflsson and McAfee (2017) also reported how the idea exchanging such information via computers as opposed to humans was once considered a far-off possibility. Moore's law, described by Brynjoflsson and McAfee (2017), outlines the highly dynamic and fast-moving field of computing power and how we are now living in a digital era where the options for communication and collaboration within the workforce are endless. Kopilevych (2020) analysed various workplace tools to aid with communication, collaboration and monitoring. According to Kopilevych (2020), these are readily available today, and are as follows:

- **Collaboration** – there are multiple project management tools such as Jira and Trello, which allow tasks to be created and assigned, sprints to be set-up, and projects to be tracked. Moreover, cloud storage can be utilised for allowing all members to view, edit and access project documentation at the same time, from anywhere in the world with changes being traceable and continuously stored. Google Drive is a perfect example.

- **Communication** – considered as essential for remote teams in different locations and time zones. The primary features a tool should provide are all forms of communication itself, such as; webchat, voice calls and video conferencing. In some circumstances such as software development, screensharing is also an important element. Such platforms should be available in two forms; desktop and mobile, in order to allow organisational members to readily respond in an instant. The video conferencing tool Zoom allows users to host meetings, webinars and training sessions with features such as screen sharing, muting or unmuting participants along with recording capabilities. The instant messaging service Slack is popular with allowing direct messaging, group chats, open and private voice calls, along with the ability to share file and image attachments.

- **Monitoring –** allows users to see the number of invested hours from remote teams, with many tools actually monitoring computer activity. For example, TimeDoctor records and creates reports of the time spent for each working task, as well as taking regular screenshots to show user activity at any certain time.

Blondeau (2017) discussed the business implications of the next generation of workplace communication, with three outcomes; mobility, remote workforces and agile models. Communications being mobile allow employees to access their office from anywhere, thus reducing overheads from central offices, downsizing workspaces and saving costs (Blondeau, 2017). Communication tools allow remote working, and therefore further reduce costs with the lack of office dependency, as well as increasing productivity due to an increase in work-life balance (Blondeau, 2017). With the possibility of sharing ideas through messaging, information becomes more free flowing, resulting in a breakdown of hierarchical norms (Blondeau, 2017).

2.4 Chapter Summary

The literature review chapter 2 contains available and relevant information to introduce the research topic and incorporate the first part of the data collection for this thesis. Therefore, the overarching chapter structure includes three main parts. Firstly, an introduction briefly outlining Mintzberg's (2009) understanding of management, followed by a historical evolution of management involving McGrath's (2014) three steps of practice evolvement. Secondly, agile approaches are presented starting with an explanation of the main characteristics and principles. Afterwards, Beck's et al. (2001) agile manifesto is identified as the core theoretical framework of this thesis. Subsequently, agile application in software development where this methodology originated from, is elaborated on by comparing traditional against agile approaches with an analysis by Tram et al. (2020), followed by the agile development process cycle introduced by Cooper (2019), and ending with the major success factors of agility. Moreover, agile application in PSED is discussed by assessing motives and drawbacks as presented by Ciric et al. (2019), along with real-life practical examples of applying agility in PSED within; Siemens, Ericsson and WIKISPEED. Thirdly, the technological changes which are relevant for the application of agile methodologies within PSED are also presented. This starts with additive manufacturing as an opportunity for rapid prototyping to decrease cost and time, as stated by Niaki and Nonino (2018). It is then followed by simulation technologies which are, according to Kajishima and Taira, (2017) and Kanthababu (2020), virtual development alternatives for improving speed and cost savings. Moreover, communication systems provide an opportunity to enable and improve collaboration between people as discussed by Kopilevych (2020) and Blondeau (2017). The literature review chapter is followed by the methodology chapter, where the chosen methodological aspects of this thesis are theoretically outlined and related back to their practical execution.

3 Methodology

"The interview method is the art of questioning and interpreting the answers."
(Qu & Dumay, 2011, p. 243)

This chapter describes and assesses the research methodologies which have been chosen for this thesis. The main aim of this chapter is to elaborate and describe how to answer the three research questions. Therefore, it firstly includes an explanation of the general research philosophy and the connected research approach. Secondly, the research design is introduced which is consistent with the chosen research strategy, research choices and the related time horizon. Lastly, this is followed by a part describing the techniques and procedures to collect, analyse and critically review the research data. The overlaying structure of this chapter is comprehensively visualised in Figure 8.

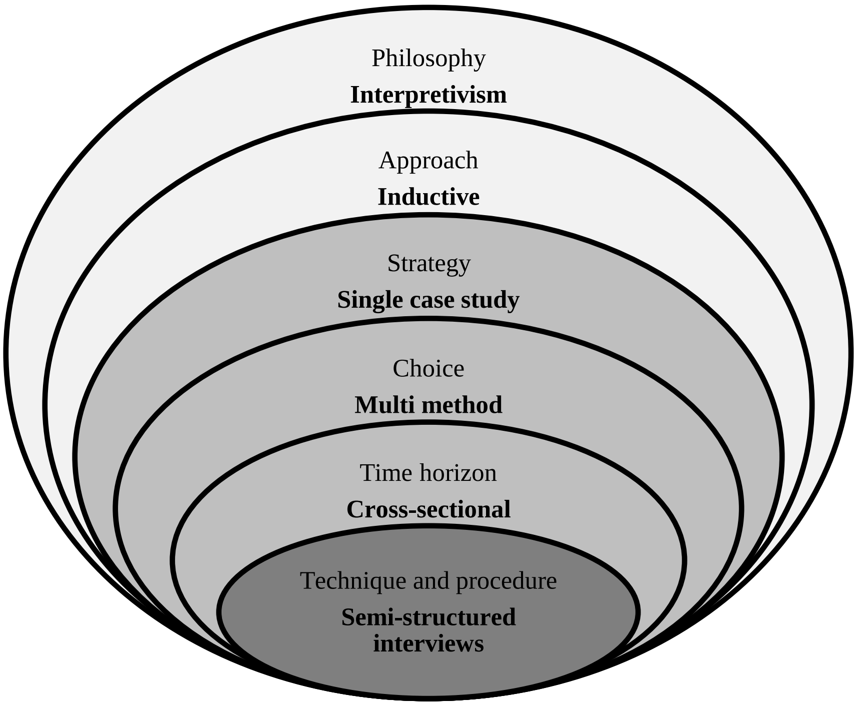

Figure 8: Methodology outlined with research onion
(adapted from Saunders et al., 2012)

3.1 Research Philosophy

The term research philosophy relates to the development of knowledge and the nature of it (Saunders et al., 2012). Therefore, the authors outline the research method which contains assumptions on how the world is perceived. This thesis is based on an interpretivism perspective. Interpretivism is encouraging the importance of understanding the difference between humans in social roles and furthermore, the difference between conducting research amongst people or objects (Saunders et al., 2012). Furthermore, Easterby-Smith et al. (2012) state that relativism does not see one truth but many truths and facts, dependant on the viewpoints of the observer. Interpretivism and relativism are not identical, but both build upon contextuality and the interpretation of different perspectives to make sense of the world. Interpreting different viewpoints of various people about a specific topic is a key aspect of this thesis. Consequently, the final conclusions are built on the described research philosophy, which is placed in the outermost shell of the methodology outline in Figure 8.

3.2 Research Approach

This thesis follows an inductive approach as indicated in Figure 8. The goal of an inductive approach is to formulate a theory, for instance, in the way of forming relationships between different matters (Saunders et al., 2012). With inductive reasoning, a specific phenomenon is observed, and, on this foundation, conclusions are derived (Sekaran & Bougie, 2016). Therefore, with such an approach, theory follows data (Saunders et al., 2012), and content moves from specific towards general (Sekaran & Bougie, 2016).

This thesis applies an inductive approach in the sense of starting with a literature review and semi-structured interviews to collect data. Afterwards, the collected data is documented, the chosen case is described, followed by data analysis including a discussion, and finally, conclusions are formed. The conclusions build a theory, which have been derived from the interpreted data. In Figure 9, a visualisation of the described research process is illustrated.

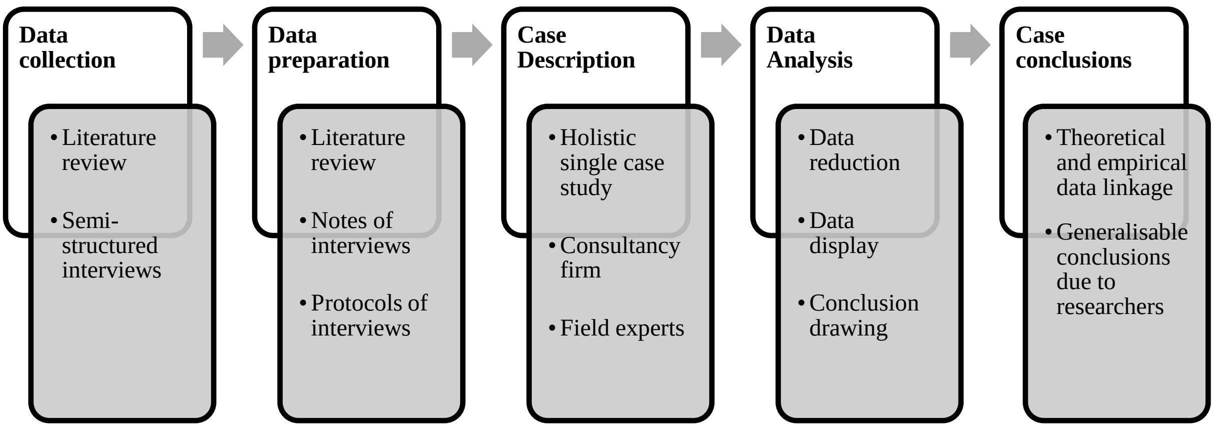

Figure 9: Five step research process (by Researchers)

3.3 Research Design

The research design consists of the research strategy, the research choices and the connected time horizon, as indicated in Figure 8. In general, this thesis is designed exploratorily. Saunders et al. (2012) describe the three principal ways of conducting exploratory research as; a search of literature, interviewing experts or conducting focus group interviews. The data from this thesis includes a literature review and semi-structured interviews from different experts within the field and therefore, its design suits the exploratory research type. Sekaran and Bougie (2016) compare explanatory research to the activities of the fictional inspector Wallander, who solves crimes in the southern Swedish town of Ystad.

3.3.1 Research Strategy

Robson (2002, p. 178) outlines a case study as a "strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real context using multiple sources of evidence". Sekaran and Bougie (2016) describe the main idea of case studies as gaining a picture of real-life problems using various perspectives to comprehensively understand them. Therefore, case studies are a powerful tool to conduct research in a specific environment or case, in order to later draw relevant conclusions describing a particular surrounding which may be generalisable to a broader context. According Yin (2003), there is a distinction between single case and multi case studies as well as embedded and holistic case studies. The author defines the difference as being, that a single case study incorporates one entity which has been investigated, whereas a multi case study includes several entities which are studied. Furthermore, Yin (2003) outlines an embedded characteristics study including multiple units of analysis, and a holistic approach involving one unit of analysis.

This thesis follows a holistic single case strategy (see Figure 8) to answer the research questions. In order to break down the research strategy comprehensively into the three research questions, an illustration of the division can be found in Figure 10. The case includes two parties. Firstly, a Swedish consultancy firm specialising in software and hardware engineering using agile methodologies. Software engineering describes the development of non-tangible logic, representing the core of software. Hardware engineering describes a field of engineering where physical components are included. The consultants in this firm have experience in agility within both software and hardware engineering. Furthermore, the consultancy offers training for those interested in applying agile methodologies in hardware environments. Investigation has shown that there are few companies dealing with this very thematic, which made this specific company highly valuable for this case. Secondly, international experts of the field such as a book author, an agile trainer and a pioneer build the other case party. It is reasonable to suggest the expertise of these people can be considered rare, since the idea of industrially applying agile methodologies within PSED is not common, as of yet. Therefore, the combination of the local consultancy firm and the international experts can be seen as a solid foundation for the setup of a holistic single case strategy (see chapter 3.4.). Elaborating on the geographical aspect of the case parties' domiciles, the researchers see value with having majority of the people from one Swedish company, complemented with field experts linked to Switzerland, USA, and Sweden.

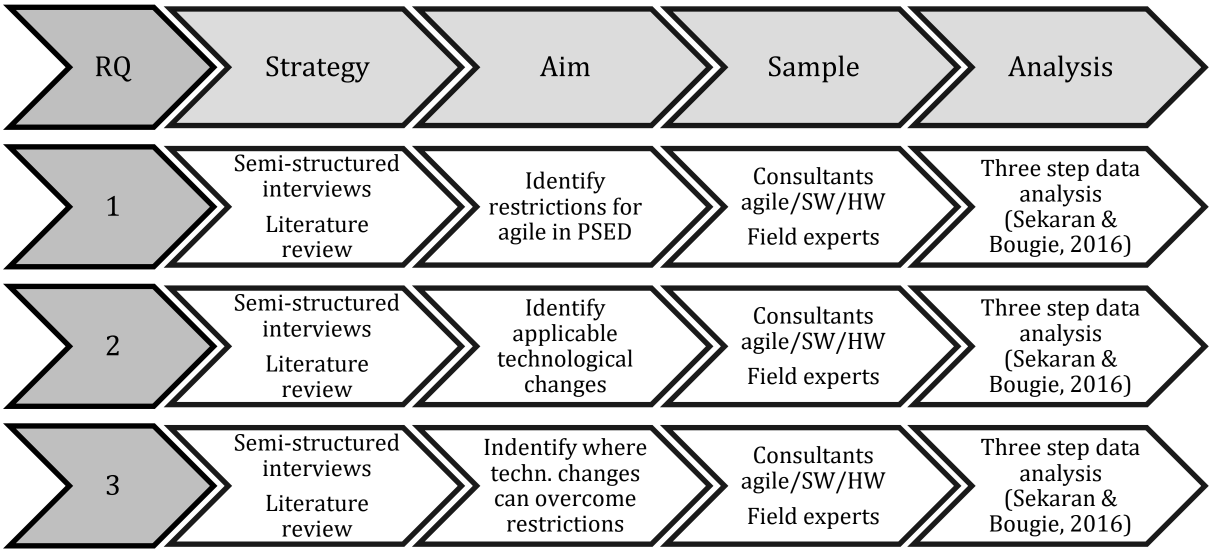

Figure 10: Research strategy per research question (by Researchers)

3.3.2 Research Choices

According to Saunders et al. (2012), research choices include the distinction between mono method and multiple method approaches. The authors outline how mono method research only applies one data collection and analysis technique, whereas multiple method research uses different approaches. This thesis is designed as a multiple method approach (see Figure 8) including two different data sources being; qualitative semi-structured interviews and literature. In this setting, an important factor was to focus on a qualitative way, while ensuring to collect extensive, specific and detailed data from the two parties involved in the case. Thereby, the required boundary conditions are considered for creating a beneficial foundation in order to make the case's details graspable, and to draw meaningful conclusions.

3.3.3 Research Time Horizon

According to both Sekaran and Bougie (2016) and Saunders et al. (2012), time horizon is an integral part of the research design. Sekaran and Bougie (2016) introduce the topic with the distinction between cross-sectional and longitudinal studies. The authors use an analogy to define the difference in comparing cross-sectional studies as a snapshot in time, whereas longitudinal studies have a rather diary-like characteristic. Therefore, cross-sectional studies conduct research once over a period of weeks or months, whereas longitudinal studies conduct data at more than one point in time over a longer period (Sekaran & Bougie, 2016). One main advantage of longitudinal studies is the possibility to exercise a measure of control over the variables, which are of interest (Adams & Schvaneveldt, 1991). On the contrary, a disadvantage is the connected time, effort and cost which are higher compared to cross-sectional studies (Sekaran & Bougie, 2016). Since the time scope of this master thesis is approximately six months, a cross-sectional study has been conducted as indicated in Figure 8.

3.4 Sampling

According to Sekaran & Bougie (2016), qualitative sampling begins with a definition of the target population of the case study. For this case, the population is defined as knowledgeable and experienced professionals in the area of agile methodologies and the interface between software development and PSED, where physical components are involved. The selection process behind is described by Saunders et al. (2012) as purposive sampling. According to the authors, purposive sampling enables the researcher to decide which case will allow answering the research question, and therefore meeting the objectives of this thesis. This way of sampling is commonly applied in case studies which are notably informative (Neuman, 2000). In practice, a consultancy firm in the field of agile, software and hardware engineering has been contributing intensively, complemented with different experts of the field. Consequently, this case study includes two main sources of information. The people incorporated in the two parties were found on the networking platform LinkedIn, where a search for experienced and knowledgeable professionals in the field of agile, software and PSED was conducted. Since the research field is rather new, and the density of companies and experts is not particularly high, the combination of the two main sources of information is seen as a well-founded basis for the data collection. Furthermore, snowball sampling is defined as, "non-probability sampling procedure in which subsequent respondents are obtained from information provided by initial respondents" (Saunders et al., 2012, p. 611). In practice, this was applied with asking the participants at the end of an interview if they knew other professionals within their network to further provide insights to this research. However, applying snowball sampling is connected to the risk of having an imbalance of certain network groups (Harrell & Bradley, 2009).

3.5 Data Collection Method

The data for the thesis had been collected through a literature review which was introduced earlier, and through semi-structured interviews. The two sources of information for the case study are consultants of a consultancy firm and field experts (see chapters 3.3.1 and 3.4). Table 3 visualises the interview parties who had been selected for the data collection.

Table 3: Interview case parties

Consultants	**Field experts**
The consultants are experienced senior professionals in the fields of agility, software and hardware engineering.	The interviewed field experts all have profound experiences and knowledge within the specific research field.
The consultants have all taken higher education, combined with additional agility certifications, and are very enthusiastic about the research field.	All experts are leading figures in the movement of applying agile within PSED, as well as within traditional surroundings.

(by Researchers)

3.5.1 Semi-Structured Interviews

According to Saunders et al. (2012), interviews as a data collection method can be divided into three categories such as; structured, semi-structured and unstructured interviews. As discussed in the beginning of this chapter, when outlining the research philosophy of this thesis, a key aspect is contextuality. Semi-structured interviews allow the researcher to define the interview focus and in parallel, to adapt the procedure to contextualities which may be of importance (Saunders et al., 2012). Therefore, the data was collected using semi-structured interviews (see Figure 8). Having a basis around human conversations, semi-structured interviews are flexible, accessible and provide the opportunity to reveal hidden aspects of human and organisational behaviour (Qu & Dumay, 2011). In comparison, structured interviews are pre-designed and follow defined procedures (Sekaran & Bougie, 2016). Consequently, semi-structured interviews are located in between the two extrema of unstructured and structured interviews.

3.5.2 Interview Design

The interview is divided into two general parts. The first part is to outline the restrictions of applying agile within PSED, whereas the second part is designed to find technological advancements which may contribute towards overcoming the specified restrictions. Both parts were divided between a process section, and an organisation section. A visualisation of the interview structure can be found in Figure 11. Even though the interview was predesigned and organised, the researchers aimed to include the opportunity of adding additional aspects situationally, in order to discover other factors which may not been considered during the design of the interview. In chapter 3.5.3, this point will be discussed further.

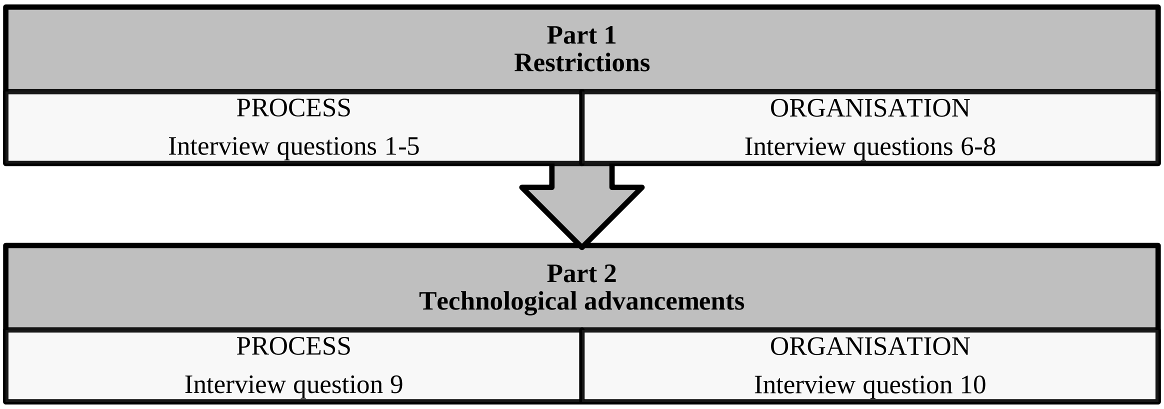

Figure 11: Interview design (by Researchers)

While designing the ten interview questions (see Appendix A), an analytical framework was applied to link and support the questions with theoretical aspects. This process allowed basing the questions on a solid foundation, ensuring to cover essential aspects of the research field. The framework is the agile manifesto's twelve principles introduced in chapter 2.2.1. These principles define the core doctrines of the general agile management approach and are therefore used to indicate the possible restrictions of applying agile within PSED. The ten interview questions are based on ten of the twelve principles. Not all principles resulted in a question as, according to the researchers, the points 5, 7, 9 and 12 make no difference whether they are applied to a software or a PSED environment. Furthermore, applying core agile principles as an analytical framework contributed profoundly to the process of analysing the interview data, and later discussing the interview findings in different contexts (see chapter 4). According to Saunders et al. (2012), a pre-set analytical framework provides guidance during data analysis.

3.5.3 Interview Conduction

As outlined above, the interview questions were prepared prior to set the interview focus, and to set the discussion areas. Conducting semi-structured interviews allowed the researchers to add supplementary questions or reorder them when necessary. Alternatively, the interviewees also had the opportunity to elaborate on topics which were of special interest to them. The interviews started with a brief introduction presenting the research team, outlining the study purpose and covering confidentiality. The six consultants were mentioned anonymously, whereas the field experts agreed with waiving anonymity, as to further add to their recognition as well-known, notable figures in the field. During the interview conduction, one researcher was asking the questions and interacting with the participant, while the other researcher focused on taking notes. At the end of the meeting, the interviewees were requested for further participants according to snowball sampling discussed in chapter 3.4. Due to the current pandemic situation publicly known as COVID-19, all interviews were conducted remotely using the Zoom tool. The software allowed meetings to be video recorded, which were stored for later data analysis. From the recordings and the notes taken, protocols for each interview were created (see Appendices B). A consolidated version of the protocols is stated in Table 4.

Table 4: Consolidated interview protocols

Assigned title	**Date**	**Duration**	**Role**	**Background**	**Domicile**	**Data**
Consultant 1	01 April 2020	60 min	Scrum Master	Hardware	SWE	Recorded
Consultant 2	06 April 2020	60 min	Senior Consultant	Software	SWE	Recorded
Consultant 3	06 April 2020	60 min	Consultant	Software	SWE	Recorded
Consultant 4	06 April 2020	60 min	CEO	Hardware	SWE	Recorded
Consultant 5	07 April 2020	60 min	Product Owner	Software	SWE	Recorded
Consultant 6	23 April 2020	40 mins	Founder	Hardware	SWE	Recorded
Peter Stevens	07 April 2020	60 min	Author	Software	CH	Recorded
Arne Åhlander	08 April 2020	50 min	Agile Trainer	Hardware	SWE	Recorded
Joe Justice	20 April 2020	100 min	Pioneer	Software	USA	Recorded

(by Researchers)

3.6 Data Analysis

According to Sekaran and Bougie (2016), data analysis is divided into three steps, being; data reduction, data display and drawing conclusions. The authors further specify that data reduction includes the phases of coding and categorisation, with data display comprising of presenting the data in ways to contribute the illustration of patterns, and drawing conclusions incorporates the answering of the research questions. Figure 12 visualises the structure of the data analysis process, including the relevant sub-elements.

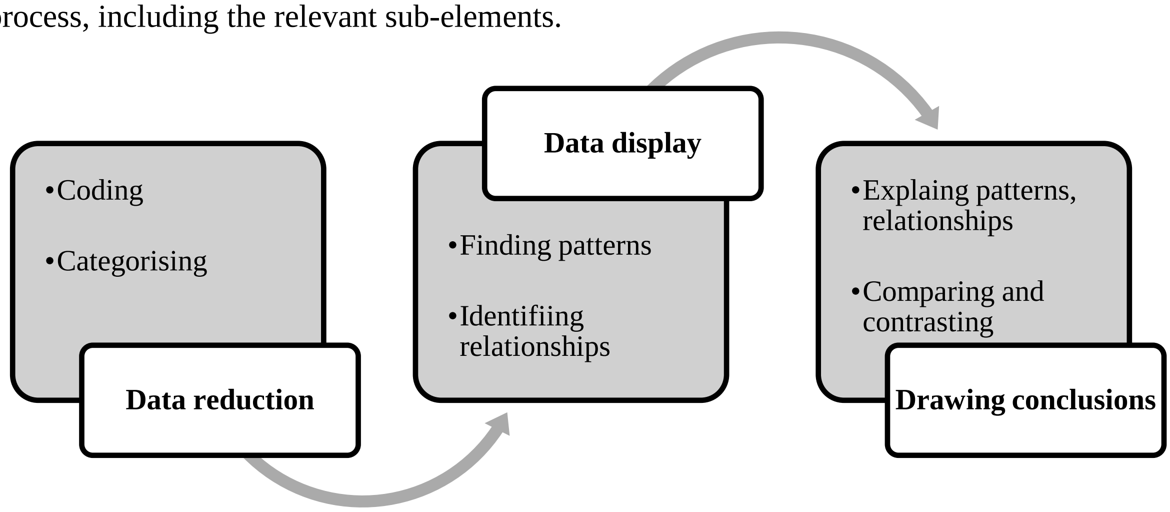

Figure 12: Data analysis process (adapted from Sekaran & Bougie, 2016)

Starting the data reduction with coding, Sekaran and Bougie (2016) discuss different scopes from words to sentences, and themes. Themes are defined by Kassarjian as “a single assertion about a subject” (Kassarjian, 1977, p. 12). According to Minichiello et al. (1990), when using themes as coding units, expressions of specific ideas should be looked for. The coding unit of this thesis is a theme which has been interpreted as a meaningful scope by the researchers, because the questions of the semi-structured interviews were specific enough to obtain answers, which were codable in such way. This is how the qualitative data was reduced in the first step. After the coding, categorisation aspects followed. According to Sekaran and Bougie (2016), categorisation is a process to organise, arrange and classify the outlined codes. The authors further state that through organising the data, categories and subcategories will arise which indicate patterns and relationships. The described procedure has been applied exactly as outlined in the data reduction step of the data analysis for this thesis. For both coding and categorisation, Sekaran and Bougie (2016) suggest basing the findings on preliminary theory. The theory which has been applied for this is outlined and discussed in the literature review.

Miles and Huberman (1994) see data display as the second foremost step when analysing qualitative data. Data display aims to visualise the reduced data in a structured and compressed way (Sekaran & Bougie, 2016). The authors further suggest using visualisation tools such as matrices, diagrams or graphs, to enable and simplify the pattern and relationship, for finding the procedure and thereby, facilitating the next conclusion drawing step. The data display in this thesis includes matrices (see Table 5) and charts (see Figure 13, Figure 14, Figure 15 and Figure 16) to document and visualise the empirical data, derived from the evaluated categories of the interviews.

Drawing conclusions is the last step of the qualitative data analysis. Sekaran and Bougie (2016) see the essence of it, by defining the main aim of the step as answering the research questions. According to the authors, this can be achieved via determining what the identified findings stand for as discovered from data reduction and data display, through understanding and explaining the found patterns and relationships, or by comparing and contrasting. Drawing conclusions in this thesis includes an interpretation of the visualised empirical data, combined with discussing both interview findings and literature review data to finally conclude findings.

3.7 Validity and Reliability

According to Bryman and Bell (2011), a recognised approach for evaluating the validity and reliability of qualitative research has been mentioned by Gouba and Lincoln (1985, 1994 cited in Bryman & Bell, 2011). They state the importance of specifying terms and ways of assessing the quality of qualitative research. The authors propose to distinguish between authenticity and trustworthiness. Firstly, authenticity is concerned with respecting and considering the different perspectives of the members from the social setting (Bryman & Bell, 2011). This thesis has considered such, while sampling different case parties of the social sphere. Secondly, trustworthiness includes four criteria all having a corresponding principle in quantitative research, being; credibility which parallels internal validity, transferability which parallels external validity, dependability which parallels reliability and confirmability which parallels objectivity (Gouba & Lincoln, 1985,1994 cited in Bryman & Bell, 2011).

- **Credibility** – acknowledging that researchers have understood the surrounding social world which is being investigated (Bryman & Bell, 2011). This has been attained through a close collaboration with the academic supervisor, and by numerous discussions with field professionals.
- **Transferability** – as in asking the question of whether or not findings hold in different contexts or in the same context at another time (Gouba & Lincoln, 1985,1994 cited in Bryman & Bell, 2011). This has been accounted for in the limitations chapter (see chapter 3.8), due to the fact that qualitative research and especially case studies are per definition, focusing on specific contexts and are therefore described by the research characteristic of depth, rather than breadth (Bryman & Bell, 2011).
- **Dependability** – as in the idea of including some sort of auditing approach for the different research phases, establishing a control system to ensure that proper procedures have been applied (Gouba & Lincoln, 1985,1994 cited in Bryman & Bell, 2011). This had been realised through frequent feedback sessions with the academic supervisor and the research team, including both of the two researchers questioning and validating decisions which had been made throughout the whole project.
- **Confirmability** – as in ensuring that while business research is never completely objective, the researchers are able to present having acted in good faith (Bryman & Bell, 2011). This has been realised with the use of the same auditing approach, as described under the latter point of dependability.

3.8 Limitations

Case studies are dependent on context where the boundaries between the studied phenomenon and context are not plainly evident, within where it has been studied (Yin, 2003). Furthermore, the idea of a case study is to examine a research phenomenon in real life situations from various angles (Sekaran & Bougie, 2016). Consequently, these perspectives, which have been chosen by the researchers, might not cover every part of the studied phenomena, but focuses on distinct contexts. Taking this fact into consideration, the findings of this thesis do indeed apply for the chosen context but cannot necessarily be generalised to a broader scope. Nevertheless, the researchers have formulated considerations about what aspects might be generalisable to a wider range, by discussing leading arguments profoundly. There are other methodological choices which may be deemed limiting aspects. The chosen purposive sampling approach of letting the researchers choose the case parties allows for answering the research questions (Saunders et al., 2012). This indicates the dependency of the thesis findings on choices made by the researchers' subjective judgment of situations. The snowball sampling approach, as the second sampling method of this thesis, is connected to the risk of having an imbalance of certain network groups (Harrell & Bradley, 2009). Furthermore, the interview design building on agility's twelve principles as an analytical framework is an approach for the researchers to narrow down the interview topic. Again, this process builds on the prioritisation of subjective judgements. Lastly, the chosen qualitative data analysis process builds further on data interpretation, which is another potential source of human failure.

3.9 Chapter Summary

The methodology chapter 3 outlines the chosen methodology for this thesis. The onion model introduced by Saunders et al. (2012) is used as an overarching chapter structure, including an interpretivism research philosophy, an inductive research approach followed by a single case study strategy, combined with multi method research choices conducted over a cross-sectional time horizon through the utilisation of semi-structured interviews. Furthermore, purposive sampling procedures are applied in connection with snowball approaches. Moreover, data analysis applies a three-step approach, introduced by Sekaran and Bougie (2016), including; data reduction, data display and drawing conclusions. Lastly, validity and reliability of the data are discussed with authenticity and trustworthiness, as stated by Bryman and Bell (2011). The methodology chapter is followed by the data analysis and discussion chapter, where the described steps of data analysis, as outlined in the methodology chapter, are executed and documented.

4 Data Analysis and Discussion

"If you torture the data long enough, it will confess."
(Coase, 1994, p. 817)

The aim of this chapter is to analyse and discuss the collected qualitative data from the semi-structured interviews as outlined in the data analysis part (see chapter 3.6) of the methodology chapter. Therefore, this chapter is divided into four parts. Firstly, data analysis where the collected data from the semi-structured interviews is presented. Secondly, data quality where a short quality review of the empirical data is conducted. Thirdly, data discussion where the empirical data from the semi-structured interviews is discussed in context of the data collected from the literature review, and with the scope of the research questions. And lastly, concluded findings are drawn based on part one, two and three.

4.1 Data Analysis

In the data analysis section of the methodology chapter, the approach was firstly, to code the empirical data from the semi-structured interviews, and secondly, to categorise the found codes that had been discovered. In Table 5, the found codes and the derived categories are visualised. Both the codes and categories are divided into the two parts of the interview (see Figure 11), firstly, being restrictions of applying agile methodologies to PSED, and secondly, technological advancements which may contribute to overcoming the restrictions. In total, there are ten categories. Seven of the categories are summarising the previously mentioned restrictions, and three are incorporating the technological changes stated by the interviewees.

Starting with a description of the restriction categories, stated as R1-R7 in Table 5, the cost aspect incorporates everything related to additional costs with applying agile methodologies to PSED. The category lead time is referring to longer delivery intervals compared to software environments. Fragmentation includes the fact that products with physical components consist of multiple parts which build up the final product itself, once combined. Feedback describes the principle of agility with decreasing feedback time for gaining customer responses as quickly and as frequently as possible. Siloing incorporates organisational and geographical reasons as to why company units are segregated. The organisational aspect deals with structural and legal issues. Mindset refers to traditional approaches which are still very present in the minds of many professionals working within PSED. Furthermore, the technological advancements categories, stated as T1-T3 in Table 5, incorporate firstly, additive manufacturing techniques improving prototyping efforts, secondly, simulation aspects automating human activities, and thirdly, communication systems enabling advanced ways of collaboration.

Table 5: From codes to categories

	Codes	Categories	Number
Restrictions of agility in PSED	Cost of change, Sunk Cost	Cost	R1
	Lead time, Time	Lead time	R2
	Fragmentation, Update	Fragmentation	R3
	Feedback time, Milestones	Feedback	R4
	Siloing, Geography	Siloing	R5
	Organisation, Legal	Organisation	R6
	Mindset	Mindset	R7
Technological advancements	Additive Manufacturing, Rapid Prototyping	Additive Manufacturing	T1
	Simulation, Virtual Reality, Automated Testing	Simulation Technologies	T2
	Communication Systems, Cloud Computing	Communication Systems	T3

(by Researchers)

In order to quantify the qualitative data from the semi-structured interviews (see Appendices B), a bar chart has been created (see Figure 13) illustrating the collected empirical data. On the x-axis of the diagram, the ten codes are displayed, whereas the accumulated interviewee answers are plotted on the y-axis. Therefore, each bar incorporates one category and the amount of times it has been mentioned in the interviews, by all the interviewees. In the legend on the bottom of the chart, a colour code can be found assigning a colour to all of the ten interview questions, referred to as Q1-Q10, which had been asked. The bars of the chart are built on these colours, thereby, one can see the contribution of each interview question to the total bar value.

The case study includes the two different parties or sources of information, being consultants and field experts. In order to compare the different answer distributions of the two, another bar chart has been created (see Figure 14). Due to the fact that there are six consultants and three field experts, a relative comparison instead of an absolute one has been chosen. Again, on the x-axis of the diagram, the ten categories are displayed whereas the average answer value per individual of each group is plotted on the y-axis. Thereby, the average amount of answers per category and per capita of each group are used for the illustration. In the legend on the bottom of the chart, a colour code can be found assigning a colour to both consultants and field experts. The bars of the chart are again built on these colours which enable the contribution to be seen for both consultants and field experts to the final bar value, in a relative manner.

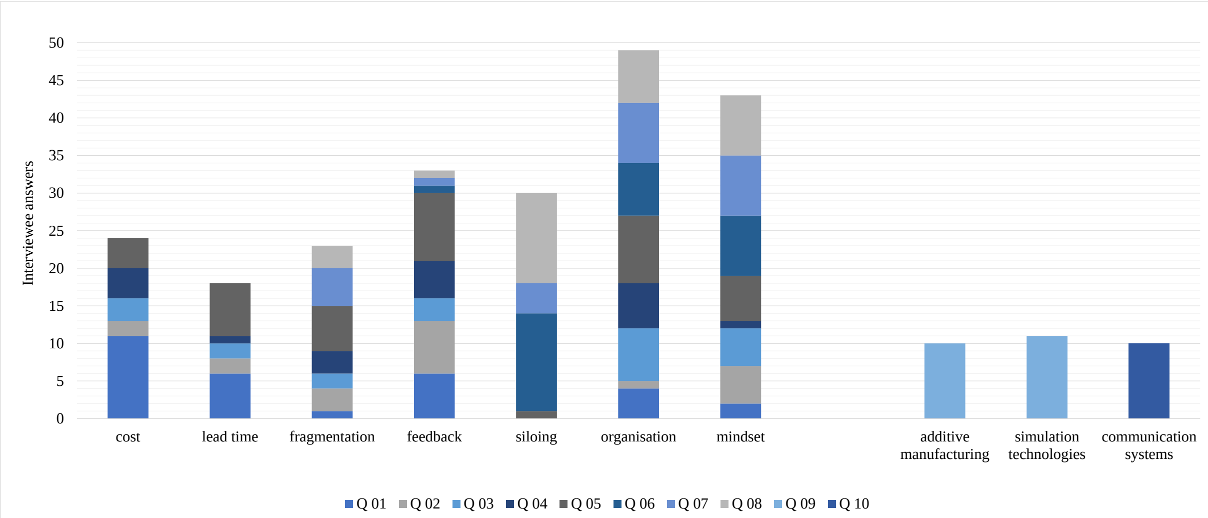

Figure 13: Consolidated interview data (by Researchers)

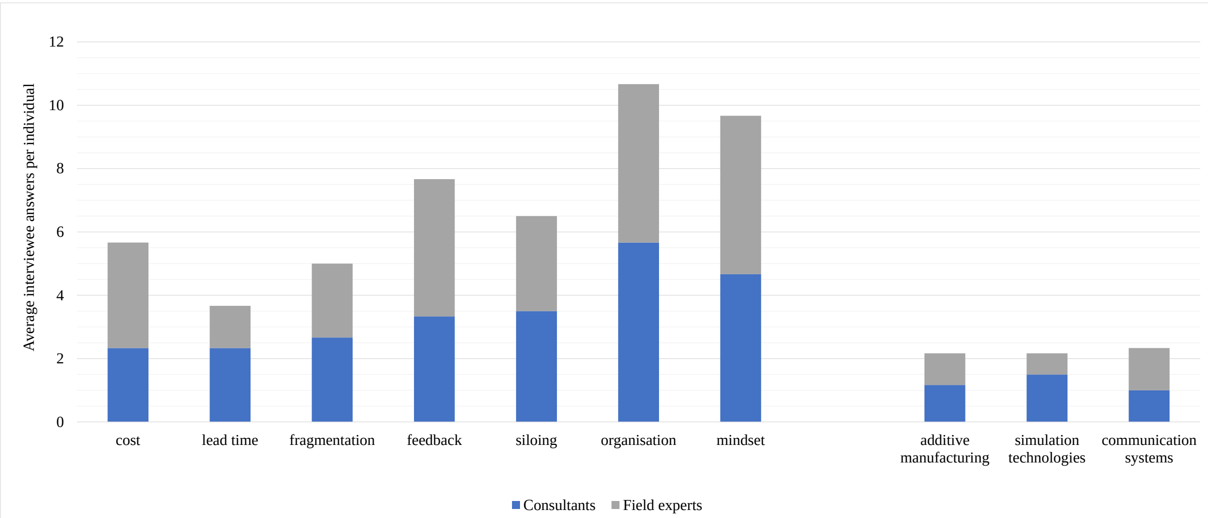

Figure 14: Average contribution per consultant and field expert (by Researchers)

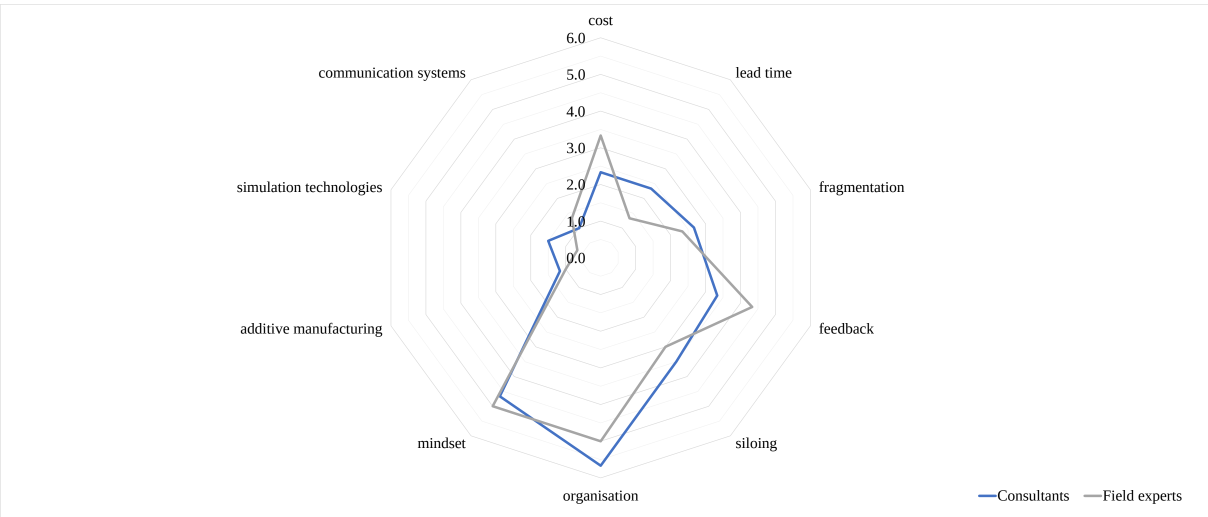

Figure 15: Deviation between consultants and field experts (by Researchers)

In order to visualise the answer patterns and the implied deviation of the two parties being consultants and field experts, a net diagram has been created (see Figure 15). The edges of the net represent the ten categories, whereas the different net layers state the average answer value per capita. Therefore, this chart is also a relative evaluation focusing on the average amount of answers per category, and per individual of each group. Again, in the legend at the bottom of the chart, a colour code can be found assigning a colour to both consultants and field experts. The answer deviation can be seen through the comparison of the two lines indicating consultants and field experts, as created by connecting the ten average answer values of the categories.

In addition to the empirical data which has been presented so far, the interviewees gave some personal solution approaches describing important aspects to overcome the restrictions of applying agile methodologies within PSED. Since semi-structured interviews had been conducted, this extra information, which was not specifically requested, was generated additionally. These topics are visualised in a pie chart (see Figure 16). The coloured sections in the chart relatively represent the frequency the solution approaches were mentioned by both the consultants and the field experts. Unlike Figure 13, Figure 14 and Figure 15, which are connected to each other, Figure 16 has no direct link to the latter three charts.

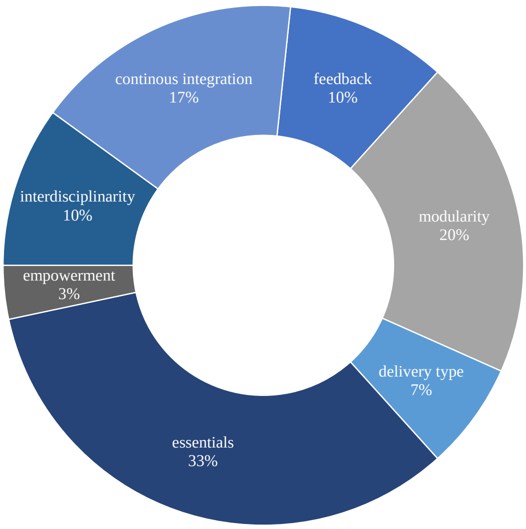

Figure 16: Personal solution approaches from interviewees (by Researchers)

4.2 Data Quality

Besides the literature data, the empirical data is the foundation of the conclusions for this thesis. Therefore, a short quality review of the interview data is relevant. Firstly, eight out of ten interview questions were about restrictions and therefore, their total answer volumes are higher compared to technological advancements. Secondly, Figure 13 indicates the interviewee answers were aligned due to the frequency of the categories that were stated. Thirdly, every category was mentioned by both consultants and field experts. Figure 14 and Figure 15 prove this, and provide an indication that answer patterns from the two groups are aligned. These points lead to the conclusion that the available data set is representative and comprehensive.

4.3 Data Discussion

In the data discussion section, the presented interview data is discussed with a scope of the three research questions, which can be reviewed in chapter 1.4. This results in three sections for discussing the interview findings in context with the data collected from the literature review. In order to answer the research questions, the sections are structured by the categories which have previously been evaluated. This allows for a comprehensive discussion covering all categories, while relating them back to theoretical knowledge, in order to set the foundation for the following part which elaborates on the concluded findings of this thesis.

4.3.1 Answering the First Research Question

Cost: *"Maximising the work not done is a trade-off with costs."*
(Consultant 3, 2020)

The researchers' interpretation of the interview and literature data highlights the significance of the cost category as a prevention factor for applying agility within PSED. Moreover, the data interpretation indicates that field experts emphasise cost more than consultants. The interview data implies that the most significant are costs in change and sunk costs. Unlike software, tangible components need to be scrapped and physically re-produced for testing or changing requirements, which may contribute to high expenses. This is agreed by Rigby et al. (2018), who outlines how traditional management approaches have to deal with the crisis that occurs with changing conditions within product development. These costs can cause disruption in business environments, and Rigby et al. (2018) continues to discuss how agile methodologies can enable organisations to become more adaptive, flexible and resistant to the challenges of changing requirements. This is also in alignment with the agile manifesto principle from Beck et al. (2001) on welcoming late process changing requirements to sustain a customer's competitive advantage. Campanelli and Parreiras (2015) agree with agile methodologies being ideal for the handling of unstable requirements, which are likely to be responsible for problematic factors such as cost, amongst others. The interview data raises the point of how PSED requires higher investments and change costs, compared to software development, in relation to; certification, tooling, and building supply chain stock. Moreover, the interview data also discusses the loss in human morale from regression requirements to re-plan, re-evaluate and re-assign funding. This would not only be independent for PSED, but more so the case due to the stated extra efforts physical products demand, from having to build up integrated systems. The interview data introduces how traditional management procedures are troublesome, most notably when change requests come after passing certain tollgates and milestones within the project lifecycle, or after large investments have already been made. Papadopoulos' (2015) analysis aligns with how traditional practices have the inclination to implement layers of management, stronger organisational policies and more planning processes, all of which contribute to higher sunk and change costs when projects fail to follow the initial scope. The interview data states the importance of adaptability and flexibility for product development. This is confirmed by the following literature findings. Starting with Ciric (2019), who highlights how projects very rarely follow a sequential flow, as the consumer typically struggles to define their needs so accurately at the beginning. Cooper (2019) also mentions how agility can promote experimentation and allows for failure to not only occur quicker, but also cheaper. Stevens (2020) reports how the extreme manufacturing approach solved the uncertainty involved in hardware projects, specifically addressing material, change and sunk costs before underlining how agile methodologies played a significant role in increasing profitability for the WIKISPEED project. Finally, Kanthababu (2020) theorises on how lower capital investment can be achieved with flexibility in product design. It is reasonable to state this reduces the risk of a sunk cost.

Lead time: *"If you are trying to get something new every week, you need to think about how you can get it today." (Joe Justice, 2020)*

The interpretation of interview and literature data from the researchers outline lead time as being a notable prevention factor, which was shared by both consultants and field experts. However, data interpretation also points towards consultants emphasising the restriction more than field experts. The interview data suggests how lead times are more problematic with PSED, as physical and mechanical parts need to be sourced through external suppliers or partners. This is not the case with software development, with the interview data indicating lead times are typically the biggest difference between the two disciplines. Literature from Niaki and Nonino (2018) addresses the interview findings and focuses on the need for reducing material distribution in order to improve just-in-time production, which becomes increasingly difficult for processes with long lead times. The interview data provides the example of how SpaceX selected certain landing legs, not for being the best on the market but rather for having the shortest available dispatch time. This point also fits with Beck's et al. (2001) agile manifesto argument of setting the highest priority to satisfy early and continuous delivery. The interview data also proposes how speed of reaction is critical for providing this early and continuous product delivery and criticises traditional supply chain for focusing global sourcing on cost, ahead of time. Findings from Campanelli and Parreiras (2015) along with Beck et al. (2001) are in accordance with the benefit of short timespans for product delivery within agile methodologies, when contrasting against traditional management.

Fragmentation: *"Build simple, elegant products." (Joe Justice, 2020)*

The interview and literature data interpreted by the researchers indicates that consultants emphasise fragmentation more, compared to the field experts, whilst such interpretations still show that both groups indicate the importance of this category. The interview data insinuates that fragmentation is related to the intricacy of physical products, and the issues caused from having to acquire all necessary components before a product is complete. Moreover, the interview data hints at how physical products also include many additional features which further complicates and lengthens the design and production process. Additionally, with PSED involving all these multiple fragments, there are challenges posed when attempting to continuously integrate physical products. The interview data discusses how PSED should focus on value stream mapping, and only build the bare minimum required, as many features are actually rarely used due to the length of development cycles, i.e., those features are no longer desired by customers after such a time. This aligns well with discussions from McGrath (2014), who analyses how a lack of variation during the Fordism era allowed for mass production, as simpler physical products can be produced more quickly and efficiently. The interview findings also link with the agile manifesto from Beck et al. (2001), who states how simplicity is essential, and maximising the work not done is key to success. In agreement, Stevens (2020) reports how WIKISPEED's design strategy was focused on being as simple as absolute possible in order to combat the uncertainty involved within hardware projects. The interview data specifies how PSED must find ways to split physical systems over time in order to continuously deliver, as opposed to delivering after X years of production. The interview data highlights the key question being how to enable physical products to be changeable, as this would allow for product upgrades and optimisation. Literature from Gustavsson and Rönnlund (2013) agree and describe how the challenge of hardware development is making late product changes. Of course, this is difficult with any tangible good, as opposed to software where only codes need to be adjusted. However, the more complex a product, the more intricate it is to apply changes.

Feedback: *"Not until you have feedback, will you know if you are successful." (Consultant 2, 2020)*

From data interpretations of interviews and literature conducted by the researchers, the feedback category is identified as a main restriction by both consultants and field experts. Moreover, the interpretations hint that field experts appreciate the magnitude of a lack of feedback more than the consultants. The interview data highlights the benefit of having customers try out products before reaching the final development stages, with Rigby et al. (2018) stating how feedback plays a big part in configuring solutions, when faced with complex problems. Moreover, Tam et al. (2020) analyses how customer involvement is only restricted to initial gathering of requirements in traditional management practices, whereas agile approaches utilise customer feedback throughout the entire project lifecycle. Cooper's (2019) analysis of product development success drivers being customer input in the form of feedback, also aligns with the interview data which implies how early and continuous feedback will determine product viability, and the omnipresent question of how good is good enough. Furthermore, the interview data suggests how the agile manifesto principal of feedback from Beck et al. (2001) is most relevant when cycles are as rapid as possible, optimising product development and increasing the number of releases. Statements from Burchardt and Maisch (2018) agree, with the identification of feedback having importance for project learning and maintaining stakeholder empathy, in order to fully understand project needs.

Siloing: *"People choose to live next to people who think like they do, which makes them intellectually more isolated." (Peter Stevens, 2020)*

The interview and literature data interpreted by the researchers signifies siloing as another restriction with the consultants understanding this to be more consequential than the field experts. The interview data states how siloing refers to the organisational segregation of individuals, usually based on competencies, e.g., engineers being seated in the basement whilst the corporate individuals have offices on the top floor. This prevents the close and daily cooperation between businesspeople and developers, with the interview data highlighting siloing being more problematic in PSED due to the more diverse competencies required, in contrast to software development. This links with the study conducted by Tam et al. (2020), who critiques the traditional management organisational structure as being very bureaucratic, with a high degree of formulisation and leadership, as opposed to the flexible, organic, and free flowing style of agile methodologies. The interview data suggests that such separation of organisational units with different goals and measures worsen in traditional centralised management systems, where people become further apart. The interview data goes onto discuss how delays, lags, and misunderstandings are due to the too many layers of people, and how the barrier to cooperation is not sharing knowledge. Papadopoulos' (2015) analysis agrees with the lack of alliance and stressed the importance of cross-functionality and self-organising attitudes, in order to enable close collaboration within teams. The interview data focuses on how a lack of collaboration is the reason for a lack of understanding of each other's role within an organisation. This problem fits with a statement from Kaushik (2016), who mentions how workforces are currently seeking a stronger desire in today's age to interact with their peers, whilst Hunag et al. (2012) also focuses on an agile manifesto principle from Beck et al. (2001) of prioritising individuals and interactions ahead of processes. The agile manifesto from Beck et al. (2001) also signifies cooperation between competencies, face to face interactions and peer support. The interview data also hints at siloing also referring to geographical separation. This concerns any production within PSED being offshored to other continents, and thus complicating coordination especially if different languages are involved.

Organisation: *"There is a lot that happens when you give engineers mandate." (Consultant 6, 2020)*

From all the derived categories, the researchers' analysis of interview and literature data points towards organisation as being another prime restriction. Such data interpretations indicate that consultants emphasise organisation more than the field experts. The interview data breaks down organisational issues into various concepts including legal requirements that physical products must abide by, organisations outsourcing and being dependant on external suppliers, and the lack of mandate development teams are given in PSED. The interview data goes hand in hand with Papadopoulos (2015) recognising the benefits of flat hierarchies, small organisational structures, less management levels and more teams. These further apply to the responses of the interview data which signifies the lack of ownership and empowerment given to teams, thus hindering product quality. This links to findings by Tam et al. (2020) on how traditional management focuses around leadership, as opposed to free-flowing communication where everyone can present their ideas, and Beck's et al. (2001) agile manifesto principle of providing individuals with support and trust. Regarding speed of product development, the interview data also discusses outsourcing as a big issue as organisations depend on the cycle times of external suppliers. This is just one of many planning processes and checkpoints involved in large projects, which Papadopoulos (2015) reports.

Mindset: *"Saying you can't do something is the mistake." (Consultant 5, 2020)*

Literature and interview data interpretations from the researchers recognise mindset as another main restriction. This analysis continues to indicate that the field experts saw this category as having more weight than the consultants did. The interview data implies that mindset can vary with many different factors, such as; older companies being accustomed to and unwilling to change traditional management ways, PSED organisations having a lack of commitment with switching to agile methodologies, the challenges of encouraging self-managing teams to accept accountability and organisations decentralising units to reduce barriers between different departments. This relates well to an analysis conducted by McGrath (2014) into the different management eras, and how a mindset shift is able to complement the technological advancements available for evolving the practice of management itself. McGrath (2014) also points out how management never initially existed before the industrial revolution. It is fair to assume that it was indeed a change in thinking that allowed for society to establish new forms of managing people, knowledge and empathy. This relates to Beck's et al. (2001) agile manifesto principle of building projects around motivated individuals, which further emphasises mindset as being fundamental.

4.3.2 Answering the Second Research Question

Additive manufacturing: *"Let's see what happens in five years when additive manufacturing takes off." (Consultant 1, 2020)*

Additive manufacturing is appreciated as a significant technological advancement for PSED, according to the researchers' interpretations of literature and interview data. This goes on to hint at how the consultants see additive manufacturing as being more noteworthy than the field experts. The interview data implies that additive manufacturing technologies can decrease the time and costs to build prototypes and therefore, decrease feedback cycles. This is aligned with Niaki and Nonino's (2018) understanding of rapid prototyping, a collective name for different additive manufacturing technologies radically affecting the prototyping scopes with a simple, affordable, time efficient technique unaffected by design error. Technical excellence is recognised by Beck et al. (2001) in their agile manifesto for enhancing agility. Furthermore, the interview data implies that manufacturing should take place close to the customers in order to obtain faster feedback. Again, Niaki and Nonino's (2018) outline the most significant requirement enabling manufacturing are 3D data sets from CAD designs or reverse engineering. This indicates that manufacturing processes can take place close to the customer, since digital files can be transferred almost effortless between different additive manufacturing machines.

Simulation technologies: *"Environments where you can simulate physical systems engineering products can be very powerful." (Consultant 4, 2020)*

Shared by both consultants and field experts, the researchers' data analysis from interviews and literature identify simulation technologies as being another paramount technological advancement option. Data interpretations perceive that consultants emphasise simulation technologies more than the field experts. Similar to additive manufacturing technologies, the interview data implies that virtual representations of real systems can decrease time and cost when acquiring answers about system behaviour and thus, directly decreasing feedback cycle time. This aligns with Kajishima and Taira's (2017) statement of virtual simulations being advantageous in many cases in terms of speed, cost and safety. The interview data indicates how virtual models allow for designing, visualising and testing products without having to build all the required physical components. This links well to Kanthababu (2020), who further outlines that frequent changes in customer requirements can indeed be conquered with the application of simulation technologies. Nevertheless, virtual models are only representations of real-world systems as Strogatz (2007) points out, and due to being just approximations, human interpretations are indeed required in order to conclude meaningful results.

Communication systems: *"The disadvantage of geographical distribution is that communication becomes a lot harder." (Arne Åhlander, 2020)*

Literature and interview data analysis highlights communication systems as being another very critical technological advancement to solve PSED restrictions, according to the researchers. These interpretations indicate how field experts emphasise this category more in comparison to the consultants. The interview data implies that communication systems are key for enabling and improving decentralised collaboration between people. This directly results in decreasing feedback cycle times of collaboration. Various remote communications systems and cloud providers are contributing towards increasing communication quality for scenarios where it is not possible to communicate in person. Furthermore, the interview data indicates that communication systems can provide additional value for face to face communication, when visualising or managing tasks. Kopilevych (2020) supports these ideas by outlining the main advantages of today's workplace communication systems, as being; firstly, collaboration as in task management and the integration of people, secondly, communication as in the enablement of remote communication in various ways, and thirdly, monitoring as in the detection of individual computer activities. In addition, Blondeau (2017) points out the potential cost decrease due to central office downsizing, facilitated by the benefit of such broad information access.

4.3.3 Answering the Third Research Question

Feedback: "*Agile is about shortening feedback loops." (Arne Åhlander, 2020)*

Technological advancements can significantly contribute towards overcoming restrictions, as derived from the interview data. Nevertheless, there are further factors which contribute towards conquering the restrictions. Therefore, the attributes as stated in Figure 16, from the interviewees also need to be accounted for in order to meaningfully answer the third research question. Furthermore, the categorised restrictions are clustered since the same technological advancements, as well as additional factors for overcoming limitations can be applied to each specific group. Concretely speaking, costs and lead times are paired up since both categories are related to means which involve significant investments. Siloing and fragmentation are connected since they are linked to separation and segmentation. Organisation and mindset are associated since the two aspects are focused around individuals and people. It must be made explicitly clear that the category of feedback should be conveyed as both a restriction and a solution. It is reasonable to state that the other six restriction categories; cost, lead time, fragmentation, siloing, organisation, and mindset are present and occurring within PSED as hampering factors, based on the researchers' findings from literature and interview data. However, feedback does not entirely exist within PSED, i.e., feedback is insufficient and severely lacking. This is where the restriction lies. The obvious response to this lacking factor is providing continuous feedback. This is where the solution lies. Therefore, feedback as a category, overlaps between being a restriction and a solution. Feedback can therefore be seen as a standalone category, not connected with the other six.

***Means:** "Good enough is when you don't make any more money by continuing the development" (Consultant 1, 2020)*

Means incorporating costs and lead times can firstly be defeated by the use of additive manufacturing and simulation technologies, reducing the invested necessities of cost and lead times as outlined in chapter 4.3.2. Secondly, focusing on essentials (see Figure 16) and simplicity, as in maximising the work not done in order to solely concentrate on meeting the bare minimum customer and legal requirements, when developing physical products. Thirdly, and closely related to the latter point, is to strive for modularity (see Figure 16). Modularity is concerned with allowing physical product parts to be configured and adjusted to meet customer needs. Regarding changing requirements within PSED, the connected costs and lead times can be dramatically reduced through defined interfaces between different modules, which are designed to be interchangeable. Lastly, feedback (see Figure 16) in regard to improving feedback cycles, is further able to reduce the connected categories of cost and lead time.

***Segments:** "There is a natural tendency to group people by level or function." (Peter Stevens, 2020)*

The segment group incorporating siloing and fragmentation can, firstly, be conquered by the use of additive manufacturing and simulation technologies, to enable the integration of segments. In other words, this refers to bringing manufacturing closer to the customer or the application of virtual models combining cybernetic elements as a whole, outlined in chapter 4.3.2. Secondly, continuous integration (see Figure 16) in the sense of constantly and consistently bringing pieces together in order to conquer a system, i.e., products, or an organisation, i.e., people's tendency to disintegrate. Thirdly, interdisciplinarity (see Figure 16) encourages cross-functionality, knowledge sharing and close collaboration between people to combat the negative effects of siloing. Fourthly, modularity (see Figure 16) can complement the issues caused by fragmentation as allowing parts to be easily replaced and configured as per customer demand reduces the effects of having to go back and re-develop complex, intricate and fragmented physical products. Modularity can be further utilised from frequent deliveries regarding various delivery types (see Figure 16) such as drawings, models or concepts along with traditional deliveries, when showing specific modules. This links directly to the last aspect being feedback (see Figure 16), as in emphasising on customer feedback to continuously integrate changing requirements focusing on integration rather than segmentation.

***People:** "Ownership of the work is greater when you give a team mandate, which enhances product quality." (Consultant 6, 2020)*

This group including organisation and mindset restrictions can, firstly, be overcome by the use of communication systems in order to align people and improve communication and collaboration between different individuals, as outlined in chapter 4.3.2. Secondly, interdisciplinarity (see Figure 16) being the way units or teams are designed within an organisation to bring together different mindsets, skills and knowledge to foster the idea of a company coordinating, in order to be capable of changing traditional approaches. Thirdly, empowerment (see Figure 16) in the sense of giving mandate to interdisciplinary units, encouraging decision-making, and the development of their own practices. Lastly, feedback (see Figure 16) as in facilitating an understanding between stakeholders to align diverse people.

4.4 Concluded Findings

In order to summarise and conclude the findings of this thesis, a comprehensive model has been developed by the researchers, which is represented in Figure 17. The model consists of three main vertical classifications; taking action, creating impact and conquering restrictions. This model depicts how the restrictions of applying agile methodologies within PSED can be overcome by implementing continuous feedback as an overall solution.

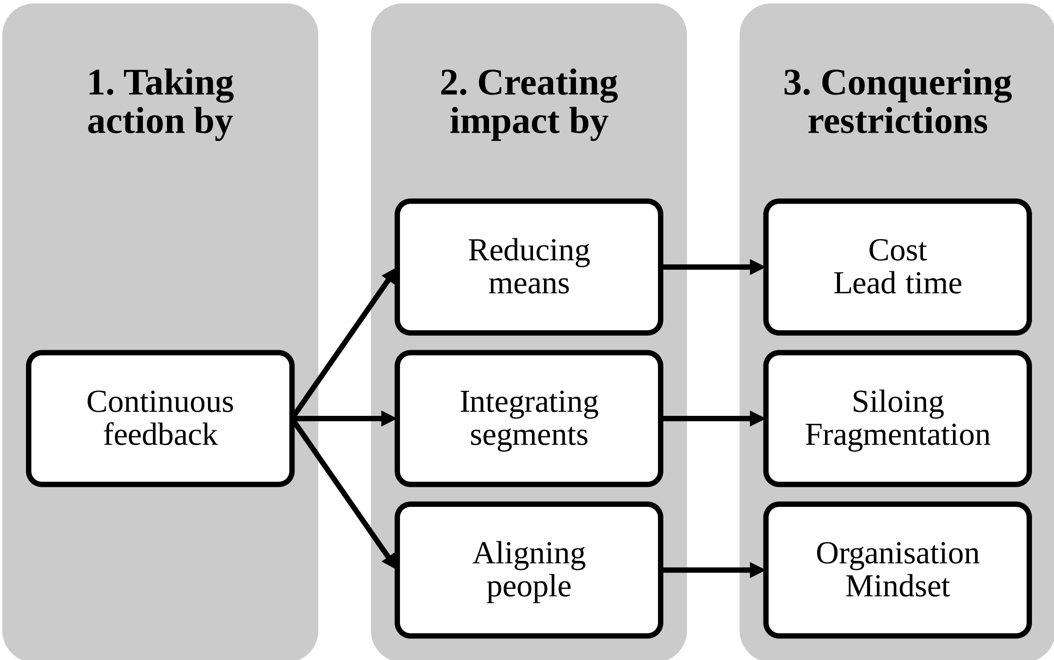

Figure 17: The Arnold & Bashir model (by Researchers)

Taking action – as outlined in chapter 4.3.3, the category of feedback can be described as a restriction where there is a lack of or insufficient feedback processes during PSED. However, the obvious solution to a lack of feedback is continuous feedback, hence why the solution rather than the restriction itself, becomes relevant for this model. This model envisions continuous feedback as the focal point with the aim of flowing through PSED in order to reduce means, integrate segments and align people.

Creating impact – reducing means relates to decreasing development costs and lead times, whereas integrating segments is described as bringing competencies together and continuously merging physical products, whilst aligning people is linked to individual mindsets and organisational practices. Technological advancements such as additive manufacturing and simulation tools are able to contribute to reducing development means. Furthermore, similar initiatives can be used to target the integration of segments within PSED. Finally, communication systems along with other organisational practices can be implemented to better align people. Technological advancements and other solution approaches all arrive in the form of continuous feedback, which is integral to reducing means, integrating segments and aligning people, therefore, creating impact within PSED to eventually overcome the restrictions outlined in chapter 4.3.1.

Conquering restrictions – beginning with cost and lead time, early and continuous feedback can arrive in the form of certain technological advancements, notably, additive manufacturing and simulation technologies. PSED teams can rapidly and cheaply create mock-ups before obtaining feedback and redeveloping new prototypes during fresh iterations. Continuous feedback in this form reduces costs related to having to physically redevelop products in the event of changing requirements. Simulation technologies allow instant testing environments and visual representations without having to fully develop the physical product. Continuous feedback in this form allows for instantaneous testing to occur, therefore reducing the effects of long lead times within PSED. Additional solutions such as modularity allow for customer requirements and feedback to be more easily and readily implemented. Continuous feedback in this form reduces costs associated with changing requirements, as well as lead time effects since complete redevelopment work is not required, but rather the interchanging of modules.

Regarding siloing and fragmentation, early and continuous feedback can arrive to PSED in the form of certain technological advancements, notably, additive manufacturing and simulation technologies. These allow physical products to be more readily and rapidly tried via either prototype testing or virtual testing environments. Continuous feedback in this form allows for continuous integration of fragmented physical products to occur consistently. This softens issues related to changing or adjusting already complex and intricate multicomponent products. Furthermore, additive manufacturing and simulation technologies can allow testing to be carried out from anywhere in the world, even close to the location of the customer. Continuous feedback in this form prevents the practical repercussions of siloing and segregation, and therefore presents an opportunity for close collaboration between different competencies within PSED teams. Additional solutions such as interdisciplinarity facilitates an environment where individuals share feedback, knowledge and ideas. Continuous feedback in this form allows for cross-collaboration and a better understanding of each other’s roles within a team, therefore increasing project quality and product quality, whilst combating the negative consequences of siloing.

Lastly, organisation and mindset for early and continuous feedback can arrive to PSED in the form of communication systems. Such technology is able to enhance coordination between people, and ensure face-to-face communication is still always possible, no matter the circumstances. Continuous feedback in this form allows knowledge to be constantly shared and developed, in order to better align people and eventually improve operations within PSED. Additional solutions such as empowerment gives appropriate mandate to appropriate people. Continuous feedback in this form gives relevant individuals the right to generate their own practices, make their own decisions and have their own input, thus utilising people and breaking down the hierarchical traits within traditional organisations, in order to continually align individuals and their mindsets.

4.5 Chapter Summary

The data analysis and discussion chapter 4 addresses the empirical data from the semi-structured interviews, together with the literature review data. Therefore, the overarching chapter structure includes four main parts. Firstly, a data analysis where the empirical data is visually presented through introducing the discovered categories. Secondly, data quality where the quality of the empirical data is assessed and summarised as valid and reliable. Thirdly, the data discussion where the collected data of this thesis is discussed with the literature review and data from the semi-structured interviews. The entire discussion uses the scope of the three research questions. The discussion of the first research question involves restrictions incorporating cost, lead time, fragmentation, feedback, siloing, organisation and mindset by outlining why these categories are identified as restrictions in an integrated way, again utilising literature and empirical data. The discussion regarding the second research question touches on technological advancements including additive manufacturing, simulation technologies and communication systems and outlines why they are relevant for applying agile methodologies within PSED. The discussion of the third research question analyses how the technologies from the second research question can support in conquering the restrictions of applying agile methodologies within PSED outlined in the first research question. This also includes additional solution approaches on how to overcome such limitations. Lastly, the concluded findings introduce a comprehensive model to overcome the restrictions of agility in PSED and links the outlined restrictions to three different ways of continuous feedback, complemented with technological advancements. This chapter is followed by the conclusion chapter where points from the introduction are resumed, research value contribution is discussed and an outlook for the future is included.

5 Conclusion

"No one can be a great thinker who does not recognise that as a thinker it is his first duty to follow his intellect to whatever conclusions it may lead." (Mill, 1859, p. 62)

The aim of this chapter is to finally bring the pieces together. Therefore, it is divided into five parts. Firstly, the research purpose presented in the introduction is directed to discuss how and to what extent the research questions have been answered. Secondly, the research aim and objectives are expounded to contextually outline exactly what and how the research has contributed to the field. Thirdly, practical consequences are discussed to describe effects associated when the main findings are applied into practice. Fourthly, the researchers' considerations of how the findings might be generalisable beyond this case study. Lastly, ideas for future research are revealed, contributing towards a more comprehensive understanding.

5.1 Research Purpose

The research purpose of the thesis has been defined as finding an alternative way of management within PSED. More specifically, to analyse how agile methods as a general concept may successfully enhance the operating efficiency and effectiveness of PSED from a managerial perspective. To overcome restrictions of applying agile within PSED, innovation in the form of technological advancements have a significant impact. To comprehensively summarise the findings of this thesis, the three research questions are answered as follows:

1st research question: Within PSED, what are the primary restrictions of using agile management practices? The analysis of the collected data including the literature review and semi-structured interviews, crystallises out seven main restrictions. These are; cost in relation to expenditure when implementing changing requirements, lead time being the wait required when sourcing physical components from external suppliers, fragmentation in connection to the intricacy of physical products being multicomponent, feedback referring to a lack of feedback cycles and processes within PSED, siloing defined as the typical segregation of knowledge and competencies, organisation relating to hierarchy and other hindering management practices, and mindset discussing traditional thought processes and a lack of willingness to adapt. These restrictive categories have been clustered further into three main groups, being; means including cost and lead time, segments incorporating siloing and fragmentation, and people integrating organisation and mindset. Feedback is seen as a restriction, but only in the sense of PSED typically lacking feedback processes. Hence, this restriction is standalone and not clustered.

2nd research question: Which main technological advancements have occurred successfully on an industrial level, increasing the relevance of agile methodologies for PSED? The research has outlined three main technological advancements for overcoming the restrictions of applying agile methodologies to PSED. Firstly, additive manufacturing allowing rapid prototyping to improve feedback cycles within the development process. Furthermore, additive manufacturing techniques enable decentralised production since the process is mostly only dependant on 3D data sets, which can be transferred almost effortless between different machines. Secondly, simulation technologies virtually representing systems to understand system behaviour, which improves feedback cycles in the development process to enable the integration of different virtual components, towards a virtual product. Thirdly, communication systems as in improving feedback cycles by aligning people, while improving communication and collaboration.

3rd research question: How can these technological advancements contribute in enabling agile methodologies to be used within PSED? Derived from this research, the three technological advancements can contribute towards overcoming the restrictions of applying agile within PSED, but there are further aspects which add to conquering the limitations. As stated in the Arnold & Bashir model (see Figure 17), the overarching solution element is continuous feedback. In this case, feedback can be applied in three different ways; firstly, reducing means, secondly, integrating segments, and thirdly, aligning people. The found technological advancements do complement these three main goals. Additive manufacturing improves feedback cycles and thereby, directly decreases cost and lead time. Furthermore, additive manufacturing enables decentralised manufacturing and thereby, adds to conquering siloing tendencies in companies. Simulation technologies can also improve feedback and thereby, decrease cost and lead time. Moreover, virtual models empower embeddedness and therefore, contribute towards overcoming the fragmentation restrictions. Communication systems improve feedback cycles by aligning people, while enabling and improving communication and collaboration, which can add towards conquering organisation and mindset restrictions.

Concluding remarks: Having fully answered the three research questions above and in chapter 4.3., along with considering each restriction of implementing agile within PSED, the researchers of this thesis believe the most challenging are related to mindset and organisation. Even in this current era, organisations are still structured with traditional approaches and people are constantly trapped within these traditional ways of thinking and working. However, and also in today's age, the technology, the digitalisation, and the capabilities exist to enable the agile possibility to become a reality. It is already happening and can continue to occur at an even greater scale, depending on two factors; whether individuals are willing to change the way they think, and whether organisations are willing to change the way they act.

5.2 Research Aim and Objectives

The research purpose has been introduced as finding an alternative way of management for PSED, where the research aim was derived from as in increasing process efficiency and effectiveness of companies dealing with the development of products involving physical components. This case study has taken into consideration one consultancy firm and different field experts, in order to investigate how agile methodologies as the alternative form of management, can be applied within PSED. By applying the main findings of this thesis stated in the Arnold & Bashir model visualised in Figure 17, a PSED company can increase its process efficiency and effectiveness and thereby increase profits. The second part of the aim directs towards making a contribution to the research field for scholars working within agile methodologies and technological change. Again, the Arnold & Bashir model presents the summarised findings in addition to the research topic, which is interesting for such scholars as both agile methodologies and technological advancements are addressed.

The objective of this thesis has been outlined as using synergies in order to enable agile methodologies within PSED. Due to the fact that agility was created for software development, the main synergy which can be used is derived from the software development industry. The theoretical foundation of this thesis is Beck’s et al. (2001) agile manifesto, again based on software development. Therefore, all the conclusions are built on the practices of software development. Consequently, this study has profited from the implied synergy, which enables the conduction of this research, following the idea of applying agile methodologies within physical systems engineering development.

5.3 Practical Implications

Practical implications are outlining the implied effects when applying the findings into practice. As outlined before, this thesis brought up mitigations contributing towards overcoming the found restrictions of applying agile methodologies within PSED. This has been comprehensively presented in the Arnold & Bashir model, which can be viewed in Figure 17. Nevertheless, when applying the findings into practice, certain aspects must be emphasised. When utilising the discovered model, there is an opportunity for PSED businesses to apply agility to increase efficiency and effectiveness, and thus resulting in a profitability surge. Some restrictions are longer lasting in regard to overcoming them, such as mindset and organisation, as changing these characteristics require significant efforts from both organisations and their people. However, it is indeed possible and in the researchers’ view, also meaningful. Success examples such as SpaceX indicate the huge potential of applying agile within PSED, which further justifies the required effort and possible outcomes when successfully implemented.

5.4 Research Considerations

The findings of this case study incorporating a consultancy firm and field experts, are valid for this very case. Nevertheless, the researchers have recommendations about how the findings can be interpreted for generalising them further. At this point, it must be stated that this section is about the researchers’ personal perception and must not be seen as proof. The case parties include consultants and field experts who have worked in various different positions and industries as professionals but also as consultants, and due to this fact, the researchers assume that the concluded findings of this thesis can be applied to any development company active within a PSED environment. The general dynamics in the Arnold & Bashir model are assumed to be similar, but not identical to different business surroundings. There may be additional restrictions for different corporate or industrial environments. Nevertheless, the researchers do assume that the Arnold & Bashir model's three ways of creating impact through feedback by reducing means, integrating segments and aligning people can in fact be applied generally. Furthermore, is it assumed that the found technological advancements can enable and support the three ways of creating impact within various contexts, beside this very case. Finally, it is reasonable to suggest this entire thesis can inspire all managers regardless of industry type to reconsider their managerial practices and be open to change.

5.5 Future Research

In order to evaluate the researchers' idea of generalising the findings of this thesis, a further research study could help test the researcher's considerations. Thereby, the Arnold & Bashir model could be applied to different PSED companies and an analysis could be conducted into whether it can be incorporated meaningfully, as interpreted by the researchers of this thesis. Potential additional restrictions could also be studied. Continuing such research would build on the hypothesis of; the Arnold & Bashir model being applicable to any PSED company as an alternative form of management, for increasing process efficiency and effectiveness. Therefore, future research would follow a deductive approach for testing the Arnold & Bashir model, and its generalisable ability of applying to a broader context other than the case of this thesis.

5.6 Chapter Summary

The conclusion chapter 5 reviews the findings and refers to the introduction. The chapter contains five parts. Firstly, research purpose where it is stated that the research questions have been fully answered and that agile methodologies can be an alternative way of management within PSED. Secondly, aim and objectives outlining the application of the Arnold & Bashir model (see Figure 17), and how it can contribute towards increasing process efficiency and effectiveness of companies, with the developed model being the contribution to the research topic. The objectives are addressed as this thesis is based on synergies deriving from software development. Thirdly, practical considerations emphasise that overcoming organisational and mindset restrictions are long-lasting processes requiring significant effort from both companies and their people. Fourthly, the researchers' considerations stating how the concluded findings can be applied to broader contexts, outside this very case. Lastly, future research is suggested for testing whether the developed model can successfully apply to any PSED company.

"There is a lot of agile in this thesis, even in the way it was conducted."
(Arnold & Bashir)

References

Adams, G., & Schvaneveldt, J. (1991). Understanding Research Methods, New York: Longman

Ahimbisibwe, A., Cavana, R., & Daellenbach, U. (2015). A Contingency Fit Model of Critical Success Factors for Software Development Projects, *Journal of Enterprise Information Management*, vol. 28, no. 1, pp. 7-33, Available online: https://doi.org/10.1108/JEIM-08-2013-0060 [Accessed 5 April 2020]

Alizon, F., Shooter, S., & Simpson, T. (2009). Henry Ford and the Model T: Lessons for product platforming and mass customization, *Design Studies*, vol. 30, no. 5, pp. 588-605, Available online: https://doi.org/10.1016/j.destud.2009.03.003 [Accessed 5 April 2020]

Aloni, I. (2016). How SpaceX Reached Orbit, Turning Aerospace on Its Head, *Medium*, Available online: https://medium.com/the-paragon-of-innovation/how-spacex-reached-orbit-turning-aerospace-on-its-head-9383c9e8f031 [Accessed 11 May 2020]

Baldwin, R. (2016). The Great Convergence: Information technology and the new globalisation, Cambridge: The Belknap Press of Harvard Business University Press

Berg, C. (2019). SpaceX's Use of Agile Methods, *Medium*, Available online: https://medium.com/@cliffberg/spacexs-use-of-agile-methods-c63042178a33 [Accessed 11 May 2020]

Blondeau, G. (2017). Here Is What the Next Generation of Workplace Communication Looks Like, *Proxyclick*, Available online: https://www.proxyclick.com/blog/next-generation-of-workplace-communication [Accessed 16 April 2020]

Bryman, A., & Bell, E. (2011). Business Research Methods, 3rd edn, Oxford: Oxford University Press

Brynjolfsson, E., & McAfee, A. (2014). The Second Machine Age: Work, progress, and prosperity in a time of brilliant technologies, New York: W. W. Norton & Company

Burchardt, C., & Maisch, B. (2018). Advanced Agile Approaches to Improve Engineering Activities, *Procedia Manufacturing*, vol. 25, pp. 202-212, Available online: https://doi.org/10.1016/j.promfg.2018.06.075 [Accessed 5 April 2020]

Campanelli, A., & Parreiras, F. (2015). Agile Methods Tailoring – A systematic Literature Review, *Journal of Systems and Software*, vol. 110, pp. 85-100, Available online: https://doi.org/10.1016/j.jss.2015.08.035 [Accessed 5 April 2020]

Ciric, D., Lalic, B., Gracanin, D., Tasic, N., Delic, M., & Medic, N. (2019). Agile vs. Traditional Approach in Project Management: Strategies, challenges and reasons to introduce agile, *Procedia Manufacturing*, vol. 39, pp. 1407-1414, Available online: https://doi.org/10.1016/j.promfg.2020.01.314 [Accessed 5 April 2020]

Coase, R. H. (1994). Essays on Economics and Economists, Chicago: University of Chicago Press

Cooper, R. (2019). The Drivers of Success in New-Product Development, *Industrial Marketing Management,* vol. 76, pp. 36-47, Available online: https://doi.org/10.1016/j.indmarman.2018.07.005 [Accessed 5 April 2020]

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2012). Management Research, 4th edn, London: Sage

Fernholz, T. (2014). What It Took for Elon Musk's SpaceX to Disrupt Boeing, Leapfrog NASA, and Become a Serious Space Company, *Quartz,* Available online: https://qz.com/281619/what-it-took-for-elon-musks-spacex-to-disrupt-boeing-leapfrog-nasa-and-become-a-serious-space-company [Accessed 11 May 2020]

García-Marco, F. (2017). The Relevance of Communicative Competence in The Context of Information Literacy Programs, in D. Sales & M. Pinto (eds), *Pathways into Information Literacy and Communities of Practice: Teaching approaches and case studies*, pp. 135-166, Kidlington: Chandos Publishing, Available online: https://doi.org/10.1016/B978-0-08-100673-3.00006-X [Accessed 5 April 2020]

Gothelf, J. (2012). How We Finally Made Agile Development Work, *Harvard Business Review,* Available online: https://hbr.org/2012/10/how-we-finally-made-agile-development-work [Accessed 7 April 2020]

Gustavsson, T., & Rönnlund, P. (2013). Agile Adoption at Ericsson Hardware Product Development, 22nd Nordic Academy of Management Conference NNF 2013, pp. 7, Available online: https://www.researchgate.net/publication/267924034_Agile_adoption_at_Ericsson_hardware_product_development [Accessed 14 April 2020]

Harrell, M. C., & Bradley, M. A. (2009). Data Collection Methods: Semi-structured interviews and focus groups, Santa Monica: Rand National Defence Research Institute, Available online: https://www.rand.org/pubs/technical_reports/TR718.html [Accessed 5 April 2020]

Hu, S., Ko, J., Weyand, L., El Maraghy, H., Lien, T., Koren, Y., Bley, H., Chryssolouris, G., Nasr, N.; & Shpitalni, M. (2011). Assembly System Design and Operations for Product Variety, *CIRP Annals*, vol. 60, no. 2, pp. 715-733, Available online: https://doi.org/10.1016/j.cirp.2011.05.004 [Accessed 5 April 2020]

Huang, P. M., Darrin, A. G., & Knuth, A. A. (2012). Agile Hardware and Software System Engineering for Innovation, IEEE Aerospace Conference 2012, pp. 1–10, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 14 April 2020]

Hudson, R. (2009). Fordism, in R. Kitchin & N. Thrift (eds), *International Encyclopaedia of Human Geography*, pp. 226-231, Available online: https://doi.org/10.1016/B978-008044910-4.00166-8 [Accessed 3 April 2020]

Justice, J., Schwartz, F., Newing, W., Wallace, C., & Justice, M. (2017). Scrum in Hardware Guide, *Scrum Inc*, Available online: https://www.scruminc.com/scrum-in-hardware-guide [Accessed 14 April 2020]

Kajishima, T., & Taira, K. (2017). Computational Fluid Dynamics: Incompressible turbulent flows, Cham: Springer International Publishing, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 5 April 2020]

Kassarjian, H. H. (1977). Content-Analysis in Consumer Research, *Journal of Consumer Research*, vol. 4, no. 1, pp. 8–18, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 5 April 2020]

Kaushik, A. (2016). A Literature Review on Agile Software Development. *IJARCCE: International Journal of Advanced Research in Computer and Communication Engineering*, vol. 5, no. 9, pp. 337-339, Available online: https://ijarcce.com/wp-content/uploads/2016/09/IJARCCE-71.pdf [Accessed 5 April 2020]

Kopilevych, D. (2020). 10 Best Tools for Your Remote Product Development Teams' Sync, *Relevant Software*, Available online: https://relevant.software/blog/10-best-tools-for-your-remote-product-development-teams-sync [Accessed 16 April 2020]

Lovering, J. (2009). Fordism, Postfordism, and Flexible Specialization, in R. Kitchin & N. Thrift (eds), *International Encyclopedia of Human Geography*, pp. 209-218, Available online: https://doi.org/10.1016/B978-008044910-4.00213-3 [Accessed 3 April 2020]

McGrath, R. (2014). Management's Three Eras: A brief history, *Harvard Business Review*, Available online: https://hbr.org/2014/07/managements-three-eras-a-brief-history [Accessed 8 April 2020]

Miles, M. B., & Huberman, A. M. (1994). Qualitative Data Analysis, 2nd edn, Thousand Oaks: Sage

Mill, J. S. (1859). On Liberty, London: John W. Parker and Son

Minichiello, V., Aroni, R., Timewell, E., & Alexander, L. (1990). In-Depth Interviewing: Researching people, Melbourne: Longman Cheshire

Mintzberg, H. (2009). Managing, San Francisco: Berrett-Koehler Publishers, Inc

Neuman, W. L. (2000). Social Research Methods, 2nd edn, London: Allyn and Bacon

Niaki M. K., & Nonino F. (2018). The Management of Additive Manufacturing: Enhancing business value, Cham: Springer Verlag, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 5 April 2020]

Papadopoulos, G. (2015). Moving From Traditional to Agile Software Development Methodologies Also on Large, Distributed Projects, *Procedia - Social and Behavioural Sciences*, vol. 175, pp. 455-463, Available online: https://doi.org/10.1016/j.sbspro.2015.01.1223 [Accessed 5 April 2020]

Postman, N. (1993). Technopoly: The surrender of culture to technology, New York: Vintage Books

Qu, S. Q., & Dumay, J. (2011). The Qualitative Research Interview, *Qualitative Research in Accounting & Management*, vol. 8, no. 3, pp. 238–264, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 3 April 2020]

Rigby, D., Sutherland, J., & Noble, A. (2018). Agile at Scale, *Harvard Business Review*, Available online: https://hbr.org/2018/05/agile-at-scale [Accessed 10 April 2020]

Rigby, D., Sutherland, J., & Takeuchi, H. (2016). Embracing Agile: How to master the process that's transforming management, *Harvard Business Review*, Available online: https://hbr.org/2016/05/embracing-agile [Accessed 11 May 2020]

Saunders, M, Lewis, P., & Thornhill, A. (2012). Research Methods for Business Students, Harlow: Person Education

Sekaran, U., & Bougie, R. (2016). Research Methods for Business: A skill-building approach, 7th edn, Chichester: John Wiley and Sons Ltd

Shannon, C., & Weaver, W. (1964). The Mathematical Theory of Communication, 10th edn, Urbana: The University Press of Illinois

Shunmugam M. S., & Kanthababu M. (2020). Advances in Simulation, Product Design and Development: Proceeding of AIMTDR 2018, Singapore: Springer Verlag, Available through: LUSEM Library website https://www.lusem.lu.se/library [Accessed 1 May 2020]

Stanley, A. (2003). How Good is Good Enough?, Colorado: Multnomah Books

Stevens, P. (2020). Extreme Manufacturing Explained, 5th edn, Saat Network GmbH

Strogatz, S. (2007). The End of Insight, in J. Brockman (ed), *What Is Your Dangerous Idea?*, pp. 130-131, New York: Harper Collins

Tam, C., Moura, E., Oliveira, T., & Varajão, J. (2020). The Factors Influencing the Success of Ongoing Agile Software Development Projects, *International Journal of Project* Management, vol. 38, no. 3, pp. 165-176, Available online: https://doi.org/10.1016/j.ijproman.2020.02.001 [Accessed 5 April 2020]

The World Bank. (2019). Manufacturing, Value Added (% of GDP) EU, Available online: https://data.worldbank.org/indicator/NV.IND.MANF.ZS?end=2018&locations=EU&name_desc=false&start=2015 [Accessed 10 April 2020]

West, J., & Kuk, G. (2014). Proprietary Benefits from Open Communities: How makerbot leveraged thingiverse in 3D printing, *Academy of Management Annual Meeting Proceedings*, Available online: https://dx.doi.org/10.2139/ssrn.2544970 [Accessed 5 April 2020]

Yin, R. K. (2003). Case Study Research: Design and method, London: Sage

Appendix A

Interview Questions

Qualitative data collection part 1 – restrictions

Process

1. What impact may changing requirements have, within physical systems engineering development?
2. What impact might the need for frequent deliveries in the development process have, within physical systems engineering?
3. What restrictions prohibit a constant and sustainable pace of development, within physical systems engineering?
4. What are the consequences of maximising the work not done, within physical systems engineering? (How good is good enough?)
5. What are hampering factors having early and continuous delivery of valuable products to customers?

Organisation

6. What restrictions are prohibiting the close, daily cooperation between businesspeople and developers, within physical systems engineering?
7. What restrictions would prohibit implementing self-managing teams, as a mandatory measure, within physical systems engineering?
8. What restrictions prohibit face-to-face cooperation, within physical systems engineering?

Qualitative data Collection part 2 – technological advancements

Process

9. What technological advancements might overcome the process restrictions?

Organisation

10. What technological advancements might overcome the organisational restrictions?

Appendix B

Summarised Interview Protocol Consultant 1

Date: 01/04/2020
Current Role: Scrum Master
Previous: Background in hardware

Table 6: Interview protocol consultant 1

Question	Response
1	High sunk cost and cost in change with changing requirements after passing certain milestones || Long lead times with supply chain and bulk buying || Legal requirements with physical products
2	Frequent deliveries are required to be shown to relevant people || Hardware engineers are not used to delivering products which are not fully complete
3	Changing requirements are stress cause for engineers || Restrictions if developers are not consulted during planning and expected to follow timelines
4	Legal requirements must be clear || Maximising work not done may result in lowering priority in some areas || Where to place investment enable decision making processes of what can be left at the end || Physical products are more intertwined, hence difficult to calculate ROI unlike software || “Good enough” means no more expenditure after investment which is hard to determine
5	Customers want customisation || Having a process too large is a restriction || Every member must understand entire process || Restrictions also extend to manufacturing technology limitations
6	Products are developed in one country and sold in another || Engineers do not communicate with end user || Concerns organisation maturity as software companies have these issues less as they are much younger || Ultimately, it is not a hardware vs. software question
7	Must have development, testing and deployment in the same room || Company culture is the only restriction || Traditional hardware companies just take older, less-inclusive approaches
8	Restriction is the will to change || Legal issues may pose some restrictions (i.e. inaccessible areas) but this can be overcome || Software companies also have developers across the world
9	Additive Manufacturing || Build as many and as early prototypes as possible || If requirements change, testing also changes || Standardised continuous test system would be advantageous
10	Remote tools || Sound and image quality can be issues || No reason to make user interface simpler

(by Researchers)

Summarised Interview Protocol Consultant 2

Date: 06/04/2020
Current Role: Senior Consultant
Previous: Background in software

Table 7: Interview protocol consultant 2

Question	Response
1	Distinct time points where certain decisions are made after significant investments in PSED || Agile processes welcome late changes
2	Continuous releasable products in software development || Need to elaborate on what is being released (products or knowledge) || Minimum, viable knowledge needs to be evaluated in order to decide whether investment or production should occur || Feedback will determine success rate || PSED does not allow the time or money for another iteration unlike in agile || All about a mindset shift
3	Constant pace of development relates to team size and how much work is occurring || Small teams have different phases and experiences and therefore, different estimations for activities || Large teams allow for easier measurements as there are multiple on-going activities || Central decision-making required of accomplishable workload to ensure team leads pace of work themselves
4	Consequences are “we won’t do the product” if early feedback suggests prototype is not viable – ultimate maximising of work not done || In some cases, regulatory requirements must be met for product to be sold || Business decision constitutes good enough – must find the balance, which depends on industry
5	Depends on whether product is B2B or B2C || Mindset shift – agile suggests partnering with suppliers instead of contracts to ensure they are aware of your own problems to better develop solutions || Communication, true feedback will be hampered due to political and financial reasons without partnerships || Product type determines whether prototypes can be used for feedback
6	Belonging to different organisational units with different goals and being measured on different things || Worsens in larger organisations as the further away people become || Business people have little time for R&D due to a lack of collaboration || Centralised organisations do not spread or receive information
7	Culture issue – people are used to being taught to work in a certain way and being told what to do || Mindset must shift to allow teams to take responsibility
8	Distance is an issue with PSED – e.g. engineering teams being located in Europe, but production plants are in Asia || Digital tools may be the solution
9	Continuous integration, continuous deployment and automation allowed faster feedback responses thus, faster product releases in the previous immature software industry || Simulations are effective for forecasting problems and getting automatic feedback || 3D printing provides fast development feedback || Decentralise manufacturing close to customer for faster development feedback
10	Remote working || Mindset shift to survive competition

(by Researchers)

Summarised Interview Protocol Consultant 3

Date: 06/04/2020
Current Role: Consultant
Previous: Background in software

Table 8: Interview protocol consultant 3

Question	Response
1	Biggest difference is lead times in PSED compared to software || Ordering a tool could take a couple months to arrive and then the requirements may change
2	Impact allows decisions to be made on facts where outputs can be taken from each increment leading to tangible results || Impact is beneficial but hard to obtain
3	No difference between PSED and software
4	Difficult in PSED as there usually need to be a complete machine || Should allow customers to try product out before it reaches final development stages || Tougher in PSED due to dealing with "bolts and nuts" as costs are higher for upgrades || Maximising the work not done is a trade-off with costs
5	Cost and time prevent early and continuous delivery || Product usually needs to be in shape the first time as it is too costly to revise again and again || Easier to update software products compared to physical products
6	No difference between PSED and software || Development, manufacturing and businesspeople are in different sites talking different languages || Different competencies between different people further segregate them
7	Too many competencies involved in huge teams which is problematic || Need to break down competencies into smaller pieces within teams || PSED usually requires more diversity of competencies than software (which are more similar)
8	Same as Q7 – so many competencies required, and some are not available on site
9	Continuous integration and delivery which is simple in software but requires tools for PSED || PSED projects need to utilise design data to get feedback as early as possible || Simulations and ability to create mock-ups || Developers need to take more responsibility – from CAD to testing themselves || Cultural shift required
10	Organisations are used to optimising on competence || Remote working allows easier communication || Storing data in one central location throughout the organisation would help || More about how to organise the organisation

(by Researchers)

Summarised Interview Protocol Consultant 4

Date: 06/04/2020
Current Role: CEO
Previous: Background in hardware

Table 9: Interview protocol consultant 4

Question	Response
1	Lead times when ordering components || Every sprint improves learning and understanding of the product – better to ask ourselves here if we are on track to deliver what the customer wants than to continue || Limited flexibility
2	Must consider how to deliver value over time rather than delivering after X years of production – i.e., how to split the physical systems over time || The more modular you can design a system, the more frequently you can deliver and configure product combinations to suit customer needs
3	Software environments allow features to be more easily split up and delivered || Software teams can develop complete product themselves whereas product owners also have project management responsibility || Complexity lies with the dependency on outside expert help, test labs, suppliers etc., in PSED || Must have tight collaboration with stakeholders to constantly align on top priorities and prevent overloading teams || Scrum and cross-functional teams are needed
4	Dynamics between product owner and team || Trade-off required
5	Lead times are a hinderance when hardware components are involved || Bad architecture increase difficulty – a modular system would help || Mindset shift with re-working the development process to support a new way of working
6	Line organisations are problematic – separate business units who report to the top || Organisations should be set up as a value stream || Business people spent too little time with developers and this connection is important || Too many layers of people between teams and end-customers – ideally, should only be the product owner here || Layers cause lags, delays and misunderstandings
7	Success relies on implementing roles in a meaningful way – everyone should know their own role and should spend time on coaching with other roles
8	No restrictions || Set up cross-functional teams || Possible to have competences in other places which is required (e.g. test environments in another location)
9	Virtual simulation environments || 3D printers for new increments – plastic components can be developed over night or within hours || Can also simulate new features on existing products
10	Collaboration tools such as remote working || Hologram goggles can be used for testing || Cameras can be used to show results of testing at faraway sites

(by Researchers)

Summarised Interview Protocol Consultant 5

Date: 07/04/2020
Current Role: Product Owner
Previous: Background in software

Table 10: Interview protocol consultant 5

Question	Response
1	Field makes no difference || Based on requirements and how they are set
2	Testing and delivering quicker allows quicker learning and better work the next time || Impact also depends on context
3	Saying you “can’t do something” is the mistake
4	Based on where you are what and what position you are in || Good enough is based on what the customer says is good enough and this can change || Depends on who the customer is and what needs to be delivered
5	Continuous delivery should be valuable to the customer || Delivering early allows feedback on the product to understand how good is good enough || More time consuming in PSED – building machines requires re-building replicas of current versions of the machine which needs extra space and time after testing || Orders and building parts can take time || Not more complicated but more time consuming – how long depends on company engagement and project structure
6	Challenge if the company has a lot of businesspeople above (regardless of PSED or software) – businesspeople need to also be product owners || Restrictions occur when businesspeople and developers are split up and not kept aligned
7	Fear of the impression that control of the product and project is lost || In agile, teams should have all knowledge to deliver a product including business people || Managers may feel degraded if they are placed in self-managing teams whereas engineers will feel upgraded if they are taught business skills || Managers may feel like they would lose control and even their job || Owners may have to fire half their staff before implementing self-managing teams
8	N/A
9	If a team has all necessary knowledge to replicate a physical product, test and deliver then no other processes are needed || Technology will overcome processes || Initial structure started with the company also has influence
10	N/A

(by Researchers)

Summarised Interview Protocol Consultant 6

Date: 23/04/2020
Current Role: Founder
Previous: Background in hardware

Table 11: Interview protocol consultant 6

Question	Response
1	Typically, long lead times || More difficult to manage change as you are starting to build an integrated system || Specifications and solutions may have to be adjusted based on changing requirements – essentially, redesigning parts of the system || Traditional systems want linear progress and changing requirements are one step back || Negative for morale to have to go back and re-do things
2	Must think differently from traditional product architecture in order to manage regular deliveries || Modularisation allows parts to be changed and configured differently – products are not traditionally designed to allow this
3	Traditional development begins with linear structure before integrating at project management level || The limitation is breaking down into sub-systems and integrating at a later stage || Agile processes involve always integrating a product while constantlyy discussion during daily stand-ups || Required mindset shift
4	Optimise product development || Do the minimum, whilst fulfilling requirements
5	Physical products are more challenging when breaking down and creating the minimum viable product to give to customers || This is due to the need of showing the whole product to the customer as technically, there is no product before that || Product management is a restriction – how to define customer offerings, which must be done differently to deliver smaller batches || System engineering is a restriction – how to work with the system and architecture of a product
6	Businesspeople are torn between being close to customer or close to engineers || Should be both || Tradition for engineers to sit in the basement with businesspeople on the top floor – organisational issues
7	Tradition is a lack of understanding of each other's role and the knowledge/competence of the engineers unless collaboration starts || Need to meet often and gain trust with each other || Fear of "let-go" from management more than anything else || Self-managing teams must be given mandate to be efficient in management and decision making on a daily basis
8	Should organise company to have all competencies as close together as possible || More about tradition than anything else || Sometimes, managers fail to see the value in face-to-face cooperation
9	Communication tools to aid long distance || VR Models || 3D printing || Digitalisation helps software features to evolve in physical products
10	Video systems || MS whiteboard || Tools such as Jira to help teams manage work, create transparency and allow management to see pace of progress

(by Researchers)

Summarised Interview Protocol Peter Stevens

Date: 07/04/2020
Current Role: Author
Previous: Background in software

Table 12: Interview protocol Peter Stevens

Question	Response
1	Changing requirements have same impact everywhere and changing enough means you do not have a product || Product development is often a long step-by-step process with a lot of re-start points triggered by stakeholders || Impact root causes are the interactions between leadership and operation
2	Frequent deliveries allow real feedback from stakeholders || Designing and iterating rapidly is a success criteria – problematic if engineering practices do not support this || Extreme manufacturing – optimise and change design/product every week reflecting best understanding || Cannot always change when having to amortise costs || How to make physical products changeable is the key question
3	In software, integration is hard, so the temptation is to do it less frequently || The better answer is to take what is hard to do and get better at it, in order to do it faster and faster || All about reducing turnabout times and cycles
4	Maximising work not done is an argument for simplicity of design and focusing on essentials || Every product feature costs to develop – should focus efforts on only the ones that bring value
5	Outsourcing is a problem – being dependant on external suppliers and their cycle times limits speed at which you can develop a product || Speed to innovate is important for innovative markets || Organisational and structural issues are main hindering factors || Extreme manufacturing suggests designing organisation after and around the product design, so teams can work as effectively as possible
6	Mindset issue – doing things how they have always been done || Case of separate communities of business, finance, developers etc., without interactions || Must fight human nature to have cross-functional teams with a common purpose
7	Human factors || No difference between software and PSED || Must think about how to structure teams and correct skill sets || Need to go to a collaborative approach – many leaders lack the skills, tools and vocabulary to succeed here
8	No difference between software and PSED || Restrictions are structural, and institutions are difficult to change || Having a supplier or manufacturer in Asia makes cooperation difficult || Organisational problems are human problems
9	Most problems are human related, not process || Extreme manufacturing – strongest change was designing testing before product development || Having a clear understanding of the problem before solving it
10	Organisation is about people and not technology || All about getting design and production close to each other || Robot technology

(by Researchers)

Summarised Interview Protocol Arne Åhlander

Date: 08/04/2020
Current Role: Agile Trainer
Previous: Background in hardware

Table 13: Interview protocol Arne Åhlander

Question	Response
1	Risk of starting from the beginning || May need to re-work and throw away things that have already been created
2	Agile perspective teaches to try and add value as early as possible || May not be possible for PSED – e.g. cannot easily do frequent delivery of a car as you need all the parts together || May not be able to deliver but you can learn as you develop the product so the final product is more useful for customers
3	No restrictions || May learn to have a higher sustainable pace after a while but finding a sustainable development pace is not a problem for PSED
4	Maximising work not done is about doing as much as necessary and no more than that || No direct consequences for PSED compared to software || Based upon how you construct something – i.e., good enough still needs to be safe enough
5	Type of product may restrict possibility to deliver early || If you cannot deliver early, it is unlikely you can deliver continuously || Modularisation may be a solution – WIKISPEED's end goal was reached faster due to modularisation
6	Nothing in particular for PSED || People being in different geographical locations
7	Nothing in particular for PSED
8	Nothing in particular for PSED || There are some situations where people need to be in a plant or lab, but face-to-face collaboration is still possible || More about organisational/cultural aspects
9	Possibility to build prototypes with 3D printing || Building models in virtual reality || Agile is about shortening feedback loops – technological advancements should be used to aid this
10	Ability to collaborate more or less when geographically distributed can be achieved through remote calling || Google docs allows you to work in the same document from different parts of the world || Communication and collaboration tools

(by Researchers)

Summarised Interview Protocol Joe Justice

Date: 13/04/2020
Current Role: Pioneer
Previous: Background in software

Table 14: Interview protocol Joe Justice

Question	Response
1	Plans are usually created and approved before funding – change after funding would require regression to re-planning and re-evaluation to funding || Leads to context switching costs || Loss in morale || Agility allows for quick customer input whereas traditional management includes this a whole phase – less real time
2	Impossible in traditional management until the deployment phase || Agile practices involve a release at least every couple month
3	Milestones with phases without releasable products at the end of each phase means zero impact until deployment is complete || Same for agile, but agile is split into tiny projects which are small enough to not be affected by disruptions || Agile cycles are also based on weeks rather than years
4	Large projects are driven by phases and customers are aware they will receive something only every few years meaning organisations receive even more requirements || Must build on what you need right now || Must build simple and elegant projects || Value stream mapping
5	Traditional supply chain prioritises cost over time || Speed of reaction is critical || Mandatory phases are biggest slowdowns – e.g., companies who have 3-month test cycles || Agile teams use the concept of "definition of done," which is the fastest way to meet requirements rather than being tied to a timeframe
6	Barrier to cooperation is lack of shared knowledge, whereas agile disciplines are based around coordination, cross-functionality, learning from someone next to you and teaching them something you know || In agile – business people are the engineers who are cross-trained to make business decisions
7	Barrier seems to be the idea that people make more money based on how many people report to them || Most companies are split by expertise rather than smaller, cross-functional teams || Sub-units must be able to conduct a full value stream map and permission to not abide by phase gate requirements
8	Cultural restriction – people do not want to leave their office which prevents face-to-face interaction || If physical components are involved, you need to move to the point of work – put physical machinery on wheels || WIKISPEED connected teams across 23 countries via Zoom to achieve face to face collaboration
9	Additive manufacturing || 3D printing decreases lead times waiting for parts, meaning downtime processes are eliminated || Does not count as done until testing
10	Jira and collaboration tools allow everyone to see company health || Slack and visualisation tools helps the goal to become visible

(by Researchers)