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Managerial Influence on Simulation Driven Product Development

A study on simulation technologies and the role of management

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Abstract

The intensifying global competition and technological advancements are forcing companies to change their organizational structures and redevelop their product development processes. In many cases, simulation technologies possess the capabilities to provide managers with an increased competitiveness if utilized successfully. However, managers must ensure new technologies fit with the organizational structure and process to ensure a smooth organizational change. Management also have an increasingly important role in influencing employees' attitudes towards new technologies such as simulation technologies. Therefore, the purpose of this research was to understand in what capacities managers can influence the utilization with simulation technologies and become more competitive in the marketplace as well as understanding the organizational benefits and challenges associated with simulation technologies. This was investigated through a qualitative research by interviewing eight managers who have an extensive knowledge of applying simulation technologies in product development, thus taking the managerial perspective on the matter. The findings were then analyzed through a thematic analysis to identify common themes in the role of management as well as organizational benefits and challenges. Three main findings were established with various support in the literature. Firstly, it was found that speed of development and cost efficiencies were the main organizational benefits from applying simulation technologies in product development. Secondly, relating to organizational challenges it was found that change management and the increasing knowledge requirement were challenging for the organizations when applying simulation technologies. Thirdly, when it comes to managerial influence over simulation utilization in product development results indicated that the factors are to some extent are organization dependent. Nevertheless, it was found managers have a crucial role in auditing the organizations abilities to utilize simulation and based on this set a long-term plan of integrating simulation technologies. Moreover, managers have an important role in continuously working with the employee's mindset during the organizational change to lower the resistance towards new technologies. In conclusion to reach the desired outcome when applying simulation technologies in product development managers have a long journey ahead which includes ensuring the right capabilities and competences exist to utilize simulation technologies. Therefore, managers are in a crucial position to influence the development and utilization of simulation technologies within the future product development process.

Keywords: *Simulation Technologies, Product Development, Managerial Influence, Achieving Simulation Driven Product Development, Organizational Benefits, Organizational Challenges.*

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1. Introduction

This chapter will introduce the reader to the research topic by describing the background and problem discussion. Moreover, the purpose and research questions as well as the limitation of the research will be presented. Lastly, the disposition of the paper will be presented.

1.1 Background

The intensifying global competition and technological advancements are two major factors in the business environment which are creating new challenges for organizations to secure future growth in the global economy (White & Bruton, 2010). These challenges are forcing organizations to adapt and innovate their organizational routines to maintain their capabilities of introducing new products and in some cases even improve their manufacturing processes (Becker, Lazaric, Nelson & Winter, 2005a). Moreover, organizations are feeling an increased pressure to develop innovative approaches aimed at shortening the product development process to cope with the faster paced business world (Tohidi & Jabbari, 2011; Patuwo & Hu, 1998). However, despite the increase of technological advancement organizations cannot just introduce a new technology. The organization must ensure there are strategies and processes that allows the technology to fit with both the organizational structure and employees, otherwise it will become complex to maintain a successful utilization of the technology (White & Bruton, 2010). Therefore, managers have an important task in finding and extracting value from emerging technologies such as simulation technologies which can provide sustainable competitive advantages (Krishna & Kumar, 2015; Gartner, 2019).

Simulation has existed for many decades and has primarily been used in simplistic models for calculation of basic events (Maria, 1997). However, in pace with the development of computer technology, the possibilities of applying simulation technologies for highly advanced calculations and simulations have increased. Research has found that if simulation tools are implemented successfully, they can become an organizational accomplishment rather than a technical challenge for management (Becker, Salvatore & Zirpoli, 2005b). This indicates that simulation technologies are providing organizations with innovative options to establish competitive advantages in increasingly unstable market conditions (Becker et al., 2005b, da Costa & de Lima, 2007). Thus, as indicated by research, simulation technologies can provide innovative solutions to future product development issues. However, challenges still exist for management such as how they influence the application of simulation technologies in product development.

"Modeling and simulation are emerging as key technologies to support manufacturing in the 21st century" (Hosseinpour & Hajihosseini, 2009, p. 261)

"Virtual simulation tools now play a very important role in new product development" (Becker et al., 2005b, p.1305)

Despite its complexity, simulation technologies have gone from an underutilized tool to an accepted tool in the product development setting. The quotes above provide an illustration of how simulation technologies are becoming more valid and important for managers seeking innovative solutions to predict behavior and patterns in the product development to match the global competition. In terms of future utilization, Gartner (2019) argues that simulation technologies are trending upwards in industrial usage and have the potential of disrupting an entire industry. Simulation technologies are becoming an increasingly important building block in the smart manufacturing era, and Cognizant (2018) predict that up to 50% of the Global 2000 companies will depend on digitally enhanced products by 2020. This indicates the important role managers have in leading the utilization of simulation technologies which have the potential of reshaping the whole organizations (Hindsbo, 2018)

1.2 Problem Discussion

Organizations have realized that simulation technologies can bring many benefits to the product development and have therefore expanded the development of such technologies. As predicted by technology consultancy companies, this increased utilization will continue during the coming decades (Gartner, 2019; Cognizant, 2018). However, organizations cannot fully obtain the benefits from new technologies unless they are fully integrated in the organization with employees accepting the change (Davis, Bagozzi & Warshaw, 1989; Venkatesh, Morris, Davis & Davis, 2003). Based on this, management are in an important position to find technologies which provide visible value and competitive advantages to the organization but also match the processes in the organizations (White & Bruton, 2010). Management also have an important role in influencing employees' attitudes towards changes in the organization (Fichman, 2000; Patuwo & Hu, 1998; Lewis & Boyer, 2002). So, keeping in mind that simulation technologies are predicted to increase in usage over the coming years managers will have an influential role when it comes to strategic decisions as well as influencing the utilization of simulation technologies.

However, there are uncertainties regarding how managers can successfully influence the utilization of simulation technologies. Although simulation technologies are already used in several industries, the manufacturing industry is undergoing increased pressure from global economy to lower costs and speed up the product development process (Tohidi & Jabbari, 2011). Many manufacturing organizations are therefore increasingly applying simulation technologies in the product development process to increase competitiveness (Chung, 1996; Voss, 1988; McLean & Leong, 2001). Therefore, fully understanding how managers influence the utilization of simulation technologies can help organizations redirect resources towards managerial factors which are highly influential for unlocking the organizational benefits and avoiding the organizational challenges associated with simulation technologies.

1.3 Purpose

Based on the problem discussion, the purpose of the thesis is to explore managers perception on how they can influence the utilization of simulation technologies in the product development setting. Because the role of management in simulation technologies is a relatively unknown area of research, interviewing managers will provide deeper insights into managerial influence on simulation usage based on the managers perception. However, to fully comprehend the managerial influence the organizational benefits and challenges associated with simulation technologies in product development will also be investigated. By understanding the organizational benefits and challenges associated with simulation technologies the managerial influence can be connected with different outcomes establishing a deeper understanding of their influence. Given that several types of simulation technologies and software programs exist, this research will take a general approach by investigating the overall influence on such technologies. The practical contribution will be broader understanding of how managers perceive they can successfully utilize simulation technologies in product development as well as insights on the organizational benefits and challenges associated with simulation technologies.

1.4 Research Question

The main research question of the master thesis is:

- *How can managers influence the utilization of simulation technologies in the product development process?*

Two sub-questions have been developed to facilitate in answering the main research question:

- *What are the main benefits of utilizing simulation technologies in the product development process?*

- *What are the main challenges of utilizing simulation technologies in the product development process?*

1.5 Delimitations

There are some limitations which have set the boundaries for this research, which will be explained below.

1. Simulation technologies are applied in a variety of industries; however, this research will only cover respondents connected to manufacturing organizations.

2. The research focus on the product development process of manufacturing companies, since simulation is primarily used for design and development.

3. The research does not aim to compare traditional product development with simulation-based product development. However, it aims to understand how managers lead and develop the utilization of simulation technologies in product development.

4. The report does not aim at giving recommendations on how to implement simulation technologies. Rather the report will provide an understanding on what managerial factors influence the utilization and give managers an insight into this area.

5. Lastly, the report will focus specifically on simulation technologies. Currently manufacturing organizations apply many different types of technologies, however they will be excluded from the research.

1.6 Disposition

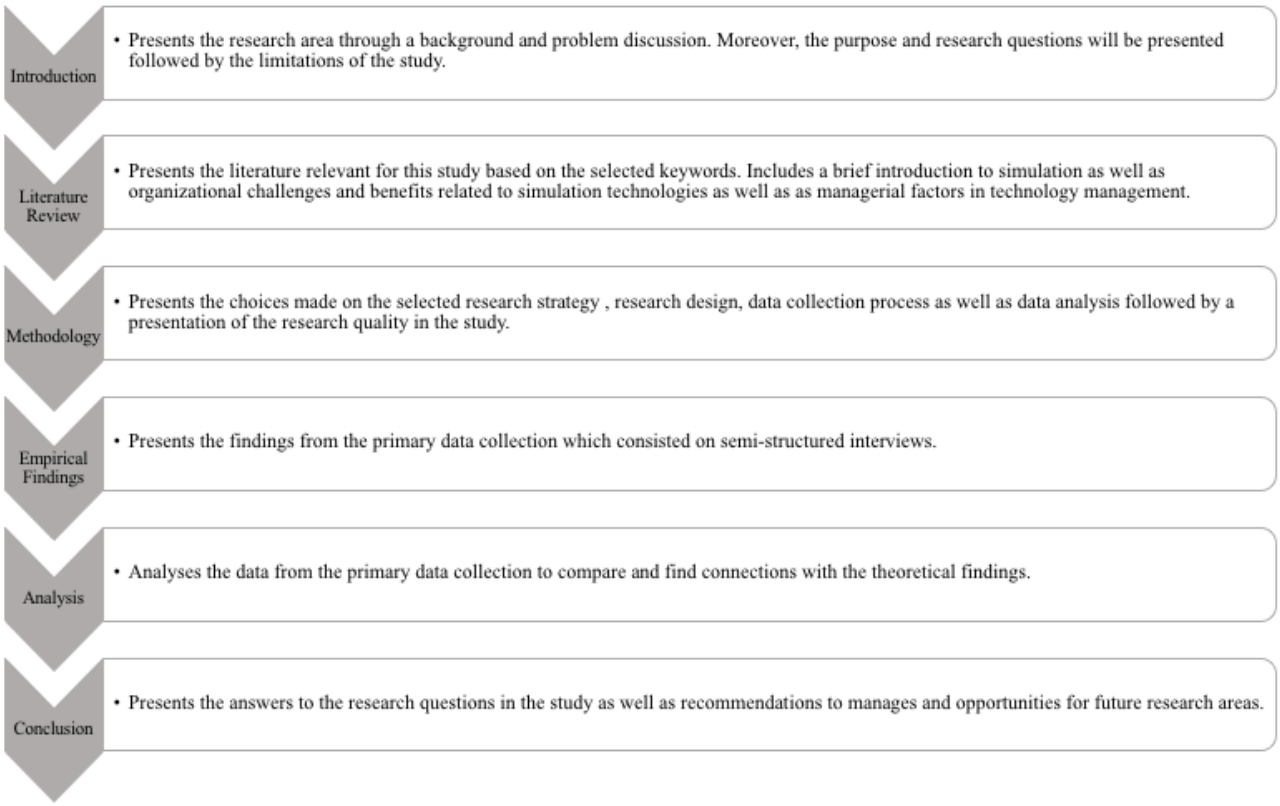

Figure 1 - Disposition

2. Literature Review

This chapter will present the literature used as a foundation for this research paper. Firstly, it will present an introduction to modelling and simulation and a brief history background. After this the main organizational benefits and challenges with simulation technologies in product development will be presented. Lastly, the role of management associated with technological innovation and utilization will be presented.

2.1 Introduction to Modelling and Simulation

To fully understand how simulation is applied in product development, there is a need to understand the basic modelling and simulation functions. The basic idea of modelling is the representation of a real event, process or system through a model designed by engineers, and most often models are used by organizations as an approximation of a real process or system to achieve a comprehensive understanding of the system. Generally, models intended for advanced simulations are able to use advanced mathematical calculations through computer and simulation software's (Maria, 1997; Banks 1999; Banks, 2005). Simulation on the other hand, is the applied methodology used to explain the effects on the system through advanced mathematical calculations and models (Sokolowski & Banks, 2011; Maria 1997). Most researchers have agreed on what simulation is and how organizations use simulation technologies and drawing from this a general definition used in this report follows:

Simulation is the imitation of a real system or process over a selected time.

Modelling and simulation can be used for a variety of instances but generally it only takes two different forms; discrete event simulation and continuous simulation modelling. Discrete event simulation is mainly concerned with problems where the variables change in discrete times and through discrete steps while continuous simulation modelling is suitable and used for systems with continuously changing variables (Banks, 1999; Maria, 1997; Banks, 2005). Thus, for management the main difference between the two types of simulations is related to time management and order of sequence. A general understanding of a simulation processes is described by Maria (1997) in Figure 2 and as seen simulation gives the managers a conclusion based on the experiment and can help adjust a system to optimal design. The rapid development in computer hardware and software during the last decades has led to new advanced manufacturing technologies enabling engineers to visualize features and application of systems, such as studying *what if* scenarios (Chryssolouris, Mavrikios, Papakostas, Michalos & Georgoulias, 2008). As part of the development several technologies such as Computer Aided Manufacturing (CAM), Computer Aided Drafting (CAD), Computer Aided Engineering (CAE), Robotics as well as advanced simulation technologies (AMT:s) have been introduced to the manufacturing market (Mourtzis, Doukas & Bernidaki, 2014). In today's manufacturing industry several such technologies are integrated and used simultaneously by organizations however the focus in this report will be simulation software's used for design and experimentation in product development.

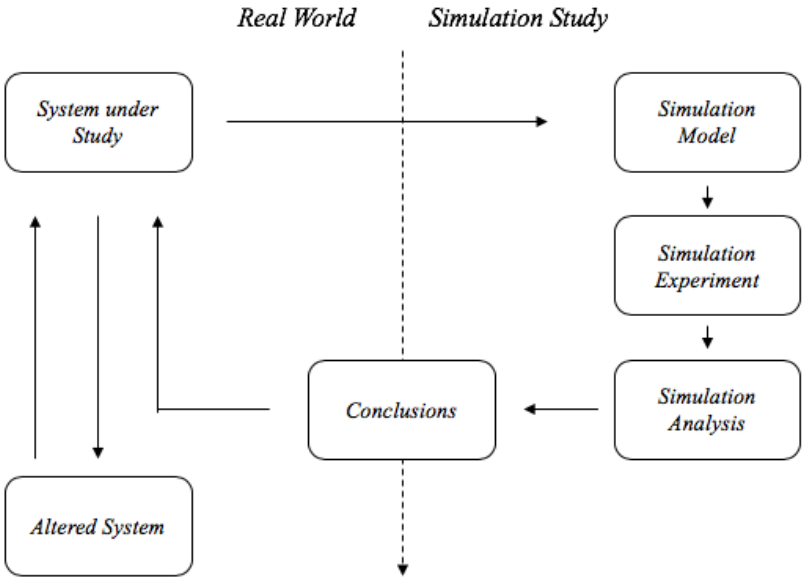

Figure 2 - Simulation Study Schematic (Maria, 1997)

2.2 Organizational Benefits with Simulation in Product Development

Simulation technologies have the potential capabilities to help managers improve their product development processes and navigate the global competition (Lewis & Boyer, 2002; McLean & Leong, 2001; Becker et al., 2005b). Moreover, applying simulation technologies can bring benefits to the organizations, of which the most common ones will be presented below.

2.2.1 Simplified Product Development

The utilization of simulation technologies can assist in experimenting with unknown or new situations as well as test a system or product before it is produced, and thus reduce the chances of not meeting the specifications. Therefore, the usage of simulation technologies rather than physical experiments will aid in optimizing the system performance and simplify product development (Maria, 1997; Klingstam & Gullander, 1999). Moreover, simulation tools enable organizations to run almost infinite iterations of the same experiment and isolate single parameters in different runs to control different variables. These factors would be impossible in physical experimentation but are enabled through simulation technologies where engineers can observe phenomena's which are less observable in physical experiments (Becker et al., 2005b).

According to Kuhn (2006) as well as Mourtzis et al., (2014) the key to successful digital manufacturing is simulation tools, because it allows organizations to experiment digitally rather than physically in attempts to simplify product development. A digital factory is an approach where simulation is integrated with traditional product development tools, to enhance product and production processes through planning and optimization of product development, which all will be controllable through programmable machinery (Lewis & Boyer, 2002; Thomas, Barton & John, 2008). Thus, the usage of simulation tools such as CAD and CAE will

reduce the set-up time, increase the flexibility to meet schedule changes and allow for digital experimentation to find improved solutions for a simplified product development process (Patuwo & Hu, 1998; Klingstam & Gullander, 1999).

2.2.2 Speed of Product Development

For organizations, managing the product development process successfully is immensely important for the future growth of the business (Brown & Eisenhardt, 1995; Tzokas, Hultink & Hart, 2004; White & Bruton, 2010). The traditional approach in product development has lost its touch due to increasing globalized competition for organizations. Instead, the modern product development process has shifted towards a faster paced, agile and more competitive environment which is pushing new requirements on organizations and management (Brown & Eisenhard, 1995; Cooper & Kleinschmidt, 1994; Chen, Damanpour & Reilly, 2010). Therefore, for organizations the ability to quickly match changes in the marketplace as well as increase profitability is becoming more important and this can be enabled through technologies (White & Burton, 2010). More specifically, simulation technologies can speed up the product development process in comparison to physical testing in traditional product development which can be time-consuming. Instead simulation technologies run digital and virtual imitations of real systems at a faster pace meaning the organization can access results from product development tests at a significantly faster pace, if applied correctly, than traditional product development (Thomke, 1998; McLean & Leong, 2001; Becker et al., 2005b). Beyond this, an improved speed in the product development process can help managers quicker select the right specifications and design for the product as well as avoid product development processes which will not produce a viable product (Thomke, 1998; Hindsbo, 2018).

2.2.3 Reduced Errors in Product Development

Simulation technologies through digitally run software programs can help organizations reduce the errors in product development. During each simulation cycle errors will digitally be detected and removed from future simulations. So, the more simulations run in a product development, the more errors can be detected and removed which will decrease future issues with the product (Thomke, 1998). Therefore, simulations can be highly beneficial for organizations where managers through the collected data can predict the outcome of the product through various tests in comparison to physical product development where errors can go undetected (Thomke, 1998; Choi & Cheung, 2008; Mani, Johansson, Lyons, Sriram & Ameta, 2013). For organizations, human errors are extremely costly in terms of waste, safety and equipment failure. According to Patuwo and Hu (1998) improved quality comes from the automation of product development which simplifies the diagnosis of problems and minimizes human errors. By utilizing simulation technologies, problems such as safety and equipment failure can be detected before they become an issue in the development phase or reach manufacturing. Moreover, simulation tools can minimize human involvement in the product development process and drastically reduce human errors in the process (Hosseinpour & Hajihosseini, 2009; Klingstam & Gullander, 1999; Patuwo & Hu, 1998).

2.2.4 Improved Decision-Making

Simulation technologies can help organizations with an improved decision-making process based on a data collected from simulation cycles (Klingstam & Gullander, 1999; Thomke, 1998). Leveraging on data collected from simulations in product development organizations can allow for a faster and more effective decision-making process as well as an improved predictability based on scenarios generated (Nilsson & Darley, 2006; Robertsson & Perera, 2002). Robertson and Perera (2002) compared this to the process of manually collecting data for the model building process, which is a time-consuming effort for the organization, and which is dependent on human capabilities and knowledge. Moreover, Kroll et al., (2016) established that AMT:s have the capabilities of enhancing product performance and improved decision-making in the organization because managers can rely on data collected from the simulation which are not affected by human errors. Despite this there are challenges for organizations associated with the collection of data and this will be elaborated on later in the paper.

2.2.5 Cost Efficiencies

In traditional product development, experiments are physically conducted and measured, taking up to several months for certain products. This leads to massive costs which are not compatible for managers maintaining a cost-effective organization (Becker et al., 2005b). This together, with the increased pressure on organizations to reduce the time-to-market as well as mass-produce products, has forced organizations towards a higher use of computer and simulation technology in production and development (Patuwo & Hu, 1998; Thomke, 1998; Becker et al., 2005b). Boyer and Pagell (2000) emphasize that design based ATM:s such as CAD can reduce the design cycle times, and thus reduce the costs associated with design. Thomke (1998) further argues that simulation technologies not only have the capabilities of lowering the cost and time of a design but can also increase the depth and quality of the experimental analysis. In the long run this will lead to more effective learning and better design solutions.

Cost efficiencies are closely related to a simplified product development process and reduced errors in product development. By reducing errors in the product development process and decrease the manufacturing lead time organizations can increase effectiveness of their costs (Patuwo & Hu, 1998; McLean & Leong, 2001). An interesting point regarding cost efficiencies is the possibilities of using simulation technologies to determine the most effective material, design and utility of a product which can lower costs of input into the product. In the long-term this leads to major possibilities of cost efficiencies in the product development by applying simulation technologies to predict material usage, avoiding over or under usage of materials in the design (McLean & Leong, 2001; Greasley, 2017). Moreover, the prediction of over and underutilization of material through simulation technologies opens up new opportunities within sustainability for organizations.

2.2.6 Sustainability

In the past, many organizations did not have access to the tools for a sustainable product development including a sustainable selection and handling management of materials. However, today the development of advanced simulation and manufacturing technologies has enabled organizations to control among others energy consumption and carbon emission of their products (Jin et al., 2017; Mani et al., 2013). McLean and Leong (2001) as well as Moon (2015) emphasize that simulation technologies can determine production and material handling as well as material management indicating that organizations now have the possibilities of more extensive control over material used in product development. Moreover, many organizations have discovered the opportunities within the sustainable movement to invest in technologies to both decrease costs but also improve their brand image towards customers. However, in many cases there are in fact strong regulations from the political environment forcing companies to become increasingly sustainable in the product and production processes and simulation technologies have the capabilities of achieving this (Kroll et al., 2016).

2.2.7 Innovation

The utilization of simulation tools gives organizations the opportunities to create representations of systems for experimentation and evaluation (Maria, 1997). Therefore, simulation is often used for experimenting with design, time and materials among many factors, and as such simulation tools are promoting innovative product development solutions (Hindsbo, 2018). Moreover, utilizing simulation also helps the organizations explore new situations or try other alternatives without risking the objective of the product development (Maria, 1997; Klingstam & Gullander, 1999). According to Kroll et al., (2016) the utilization of advanced simulation and manufacturing technologies leads to a higher share of introduced new products in the marketplace in comparison to companies which do not employ similar technologies. Other aspects which show during the usage of simulation technologies is the possibilities of using new materials in the product which leads to new functionalities as well as testing and validating new product design (McLean & Leong, 2001; Kroll et al., 2016). Thus, as argued by Schilling and Hill (1998) the shifting market requirements are pressuring firms to innovate and find new products which satisfy the market needs, and simulation tools can be applied for innovative capabilities reasons.

2.2.8 Competitive Advantage

Although, there are no guarantees in the business world because of rapidly changing business environments, organizations should strive for a sustainable competitive advantage which is performing an activity better than their competitors and ensure customers value this activity (White & Bruton, 2010). According to Cooper and Kleinschmidt (1994) competitive advantages are related to speed in the decision-making process. Moreover, the prime motivation for top management to utilize simulation and other advanced manufacturing tools should be to increase their competitiveness in the marketplace (Voss, 1988). When it comes to simulation technologies there many potential areas where the technology can bring a competitive advantage to the organization. As indicated previously simulation technologies can

aid in reducing errors in product development as well as simplify the product development process (Patuwo & Hu, 1998; Klingstam & Gullander, 1999) and create cost efficiencies (Greasley, 2017). Moreover, simulation has the potential to speed up the product development process and improve the managerial decision-making through less physical testing (Thomke, 1998; McLean & Leong, 2001) and therefore establish a competitive advantage (Singh, Garg, Deshmukh & Kumar, 2007; Cho & Eppinger, 2001; Brettel, Friederichsen, Keller, & Rosenberg, 2014). In some cases, it might even become a necessity for the organization to use simulation technologies to keep up with competition or because of regulations within sustainability (Singh et al., 2007; Kroll et al., 2016).

2.3 Organizational Challenges with Simulation in Product Development

As presented above there are several benefits for organizations that successfully incorporate simulation technologies in the product development process. As with most technical applications several challenges also arise for the organization. To extract maximum value from simulation, organizations and management need to overcome certain obstacles and challenges (Lewis & Boyer, 2002; Singh et al., 2007; McLean & Leong, 2001). Below the most relevant common organizational challenges will be presented.

2.3.1 Integration of New Technology

da Costa and de Lima (2009) argue that for organizations to remain in business they cannot ignore investments in technology, rather management's choice is what type of technology fits the business. However, the actual benefits from simulation technologies will only be obtained if the processes and organizational structure are compatible new technology. Thus, managers have an important role to ensure the selection and integration of technologies fit with both the organization and employees, which can be achieved through training the employees on said technologies (White & Bruton, 2010; Singh et al., 2007; da Costa & de Lima, 2009). The successful digital manufacturing relies on the ability to apply simulation tools during the stages of planning. Moreover, to achieve full optimization in the digital factory the organizations must integrate the virtual and real factory successfully, and the key factor to the integration is simulation tools (Kuhn, 2006; Brettel et al., 2014; Davis, Edgar, Porter, Bernanden & Sarli, 2012). The challenge for organizations is the integration between the new digital factory and the real factory, as well as the time-consuming process of building simulation models from scratch (McLean & Leong, 2001). For management the failure to integrate the various aspects of simulation used in the digital factory will inevitably mean all success factors cannot be reaped (Kuhn, 2006).

2.3.2 Cost of Integration

Simulation technologies are traditionally associated with high costs of integration through the purchasing of hardware as well as licenses which often needs renewals every year, indicating that whether simulation technologies are affordable depends on the user (Gupta & Alemeen, 2017). Because of this, many organizations are reluctant to invest in simulation technologies

because of the extensive capital investments required in software and hardware (Klingstam & Gullander, 1999; Thomas et al., 2008). Moreover, there are high costs associated with the acquisition, integration and maintenance cost, hindering widespread usage of simulation (McLean & Leong, 2001; Brettel et al., 2014). Davis et al., (2012) found that the manufacturing industry would benefit is SME:s could afford and have access to modelling and advanced simulation technologies given that they could shift towards a digital manufacturing leading to lowered manufacturing costs and improved production times. McLean and Leong (2001) argued that simulation technologies were underutilized by the manufacturing industry which could be explained by the high costs of integration. According to McLean and Leong (2001) a lack of strategy for standardizing technologies in the organization can lead to a complex data interface problem which becomes a time-consuming process. Therefore, by fully integrating new technologies directly through a standardized process several costs can be avoided for the organization.

2.3.3 Data Management

According to Sargent (2010) simulation models are increasingly used to solve problems and help managers in decision-making. As simulation models are statistical models based on the input of data, decision makers will use the information and results provided by models, and individuals affected by these results often challenge whether a model and following results are "correct" (Maria, 1997; Banks, 1999; Sargent, 2010). Therefore, many organizations face challenges in the collection of correct data, the input of correct data as well as the capabilities of analyzing the output correctly. Hence, simulation models are a powerful tool for predicting future direction, but they rely on the input of accurate data and information (Becker et al., 2005b; Klingstam & Gullander, 1999; Maria, 1997; Banks, 1999). So, there is a challenge in ensuring the input of data into the simulation model is correct and reliable, especially in the case where the simulation involves a new system or process and historical data is not available for comparison or verification (McLean & Leong, 2001). This also indicates the importance for organization to establish structured routines for verifying and validating the input in simulation models to ensure its results and implementation are correct (Sargent, 2010).

2.3.4 Change Management

Organizational changes, regardless of size and focus, can results in difficulties tasks management as they need to redirect focus on new strategic objectives (Becker et al., 2005a; Hosseinpour & Hajihosseini, 2009; White & Bruton, 2010). Todnem By (2005) argues that successful management of organizational change is crucial for surviving in the business environment. Despite this, there are differing views on how to best develop, validate and use simulation models in practice leaving organization with challenges in the utilization. According to Kroll et al., (2016) one of the main barriers for management implementing new technologies is having to redirect focus towards convincing employees who are resisting any initiatives to change. This is also discussed in a report by Buvat et al., (2017) where results showed that a significant cap existed between employees and management in terms of how digital an organization actually was indicating that management are forced to spend significant time convincing employees of the benefits with a technology.

Moreover, failure during the process of integrating new technologies often comes from the lack and improper attention of the human factors in the organization (Chung, 1996; Patuwo & Hu, 1998). Furthermore, the timely positioning and management of human resources are an important key to compete successfully in the business world. Thus, for organizations it is important to ensure employees are a part of the integration process such as adjusting human resources towards training and preparation to ensure the resistance to change is minimal (da Costa & de Lima, 2009; Patuwo & Hu, 1998; White & Bruton, 2010).

2.4 The Role of Management

In academia there is a consensus that management have an important task in managing innovation and technology as well as influencing employee attitudes towards new technological innovations (White & Bruton, 2010; Fichman, 2000; Patuwo & Hu, 1998). The following section will investigate the role of management and what is important to consider from a managerial perspective when utilizing technologies. Since, simulation tools are computer run programs based on software (Maria, 1997; Klingstam & Gullander, 1999) this review will include management of information technology (IT), which will be utilized to create an extensive understanding of how the managerial influence in a simulation technology context.

2.4.1 Organizational Strategy and Planning

The long-term outlook and planning can be a deal-breaker for a successful implementation and usage of a technological innovation (White & Bruton, 2010). Top management should explicitly be involved, support and designate key personnel and resources towards the project to ensure employees feel supported and motivated (Patuwo & Hu, 1998). Despite this the diffusion of new technology is a continuous and slow process because top management have to weigh the benefits of a new technology against the costs of the investment (Hall & Khan, 2003; Fichman, 2000). The slow process is driving a gap between leadership and employees where managers are ignoring the voice of the employee. This leads to a perception gap where employees do not share the same perception as management meaning there will exist a clash between management and employees (Buvat et al., 2017; Duarte, Staley & Sethi, 2018). Therefore, management need a clear organizational strategy as well as a strong integrated digital culture supporting employees adapting to new technologies to capture the full benefits in the long term (Chen & Small, 1996; Hall & Khan, 2003; Buvat et al., 2017). Because of this management commitment is a vital factor when implementing new processes and systems in the organization (White & Bruton, 2010). The successful utilization also depends on the employee's perception of the organization's strategic objectives and goals with the project. So, for management a clear strategic objective with organizational planning involving employee's perception can significantly simplify the process of convincing employees (Patuwo & Hu, 1998).

2.4.2 Managerial Control

Fichman (1992) argues that individuals rarely have the freedom regarding the adoption over workplace innovations. Rather management control and influence the adoption process by controlling the necessary IT and human infrastructures, needed for an implementation (Fichman, 1992; Leonard-Deschamps, 1988). According to Fichman (1992) the adoption can be encouraged by management explicitly through expressed preferences (Leonard-Barton & Deschamps, 1988; Moore & Benbasat, 1991) or implicitly through rewards (Leonard-Barton, 1987). With regards to the explicit encouragement of adoption, Fichman (1992) found a major difference where it can be encouraged (Leonard-Barton & Deschamps, 1988) or even mandated by management (Moore & Benbasat, 1991).

When it comes to control, managers can through training and consulting prepare and encourage employees of the organization to utilize new technologies (Fichman, 1992). Leonard-Barton and Deschamps (1988) found that the managerial influence is not always perceived equally by all members of an organization, but rather that context-specific characteristics mediate the managerial influence. They found significant evidence that employees with low innovativeness, subjective importance of the task being computerized was low and whose task-related skills were low reacted positively to management encourage to adopt new technologies. On the other hand, high performing employees with a high degree of innovativeness were more inclined towards managerial influence, proving this to be an important aspect for management to consider when implementing new technologies. Becker et al., (2005b) found that simulation technologies has a two-folded approach in product development were they both increase standardization but also allow for more experimentation and possibilities. Thus, managers can control the innovation strategies as well as the design process in the organization indicating that they can push the incentives in one strategic direction or the another. According to Becker et al., (2005b) this implies that in firms with an innovative approach and strategy, managers will tend to apply simulation for a more non-conventional solutions, further indicating that managers can control the utilization of simulation technologies.

2.4.3 Team Structure and Training

When implementing new technologies many managers fail to pay attention to the human aspects of the implementation process. In many cases the failure of implementing AMT:s occur because of the shortage of competent personnel within the organization (Patuwo & Hu, 1998). Moreover, according to research management need to pay more attention towards the human aspects of skills, knowledge and attitude through training and education to reduce resistance towards new technologies. Beyond this, managers need to ensure that human resources are continuous and long-term oriented so that management and personnel can keep updated on the latest technological advancements to avoid human errors in the product development (Chung, 1996; Patuwo & Hu, 1998; White & Bruton, 2010). Greasley (2017) explains that as simulation technologies have developed and moved from being specialist tools towards a mainstream tool used for business management techniques. Thus, today simulation modelling elements is included in many business and management degrees at varying levels. Moreover, according to Greasley (2017) many younger students and engineers entering the workforce therefore have

some experience of simulation modelling elements from their education, and often as a tool assisting decision-making.

When it comes to team structure Ferraro (1988) argued that an increased degree of integration in technology means higher demands are being placed on the organization to work in an integrated manner. Thus, management have a great responsibility to ensure this mismatch in the organization is avoided by ensuring team members have backgrounds from all departments within the organizations through cross-functional teams (Patuwo & Hu, 1998; White & Bruton, 2010). Management that build these types of project teams can avoid the failure in terms on unrealistic expectations on members from different functions and departments in the organization. Lastly, an important aspect to consider for management teams when utilizing new technologies is the team leadership. To ensure necessary resources for a successful application for a new technology exist, the team leader should come from top management, be a "doer" and be respected throughout the organization (Ferraro, 1988; Patuwo & Hu, 1998).

2.4.4 Technical Knowledge

To contrast the classical view that diffusion of innovation is solely based on information flows, Attewell (1992) focused on the role of know-how and organizational learning as barriers to the adoption of innovations. He argued that firms will delay the adoption rate of technological innovations because they lack the necessary technical know-how to implement the technologies successfully. In terms of the knowledge barriers, as the organizations learn more about the innovation and develop new institutions, the barriers will progressively decrease, and adoption will be simplified without possessing extensive in-house expertise. Thus, Attewell (1992) proposed the technological diffusion largely depends on the organizational learning and knowledge barriers rather than solely on the communication flows in the business ecosystem. Cooper & Zmud (1990) argue that organizations must understand and manage the implementation process smoothly yet concerns often occur when management fail to recognize and resolve critical issues during the process. As discussed by Ferraro (1988) mismatches in the organization happen at all levels of the organization. These mismatches often occur because manufacturing managers possess expertise in operations but lack the strategic knowledge, and conversely management teams have significant knowledge on strategic processes but lack full understanding of the operations. Thus, to ensure a successful utilization of AMT:s it is important top management possess relevant knowledge of operations.

2.4.5 Employee Resistance

Computers and information technology related investments have drastically increased over the years, but as argued by many scholars to establish an increased productivity and organizational performance these investments must be accepted and used by employees in the organization (Davis et al., 1989; Venkatesh et al., 2003; Venkatesh & Davis, 2000). Despite heavy investments into technology improvements the problem of underutilized systems still exists because of employees refusing to adopt a system or improvement. The reason employees resist new technology is the inherent risk of failure rate and compatibility with organization as well as the risk of feeling abundant to the organization. The low usage of installed improvement has

become a “productivity paradox” regarding the returns on the investments in IT related technologies (Venkatesh & Davis, 2000; Sichel, 1997).

Davis et al., (1989) investigated individuals acceptance rate of IT systems and found that employee resistance will primarily be influenced by two factors. The two factors which will determine an individual’s acceptance rate consists of *perceived usefulness and perceived ease of use. Perceived usefulness* consists of whether the user perceives the technological advancement will be useful for their work while *perceived ease of use* relates to the simplicity in using the technological advancement (Davis et al., 1989; Venkatesh & Davis, 2000). Moreover, other external variables such as system characteristics, development process and training of indentation can be used to mediate the perceived *usefulness and perceived ease of use.* Because of this Davis et al., (1989) predicted that the *perceived usefulness* is highly influenced by the *perceived ease of use* because, all other things equal in the system, the easier the system is to use the *perceived usefulness* of the technological investment will increase for the users. So, in the long term the *perceived usefulness* and *perceived ease of use* will affect the individual’s attitude and intentions towards the technological investments and improvements which in the long-term will determine the usage and adoption of the system. Therefore, managers attempting to influence the usage of technology systems, should focus on the attitude of the individuals as well as the human factors to ensure a successful organization implementation of a technology (Chung, 1996; Patuwo & Hu, 1998).

2.4.6 Business Network

A thought lifted by Fichman (1992) is the influence the industry and business network have on the adoption rate of a technological adoption. In an environment where network effects exist, the benefits of adopting a technology will grow as more users adopt said technology (Choi, Kim & Lee, 2010). So, organizations which are closer and tighter connected to existing users of an innovation, will learn about it because of network effects, and thus adopt the innovation at a quicker pace compared to firms at the periphery of the network. Tidd (2010) argues that barriers to the widespread adoption of innovations are economic, behavioral, organizational, and structural barriers. Economic barriers relate to personal costs versus social benefits, access to information and insufficient incentives. Behavioral relates to priorities, motivation, rationality and the propensity for change of risk. Organizational relates to the goals, routines, power and influence as well as culture and stakeholders. Lastly, the structural barriers refer to infrastructure, sunk cost and governance. Fichman (1992) as well as Leonard-Barton & Deschamps (1988) explain that the dynamics of the community-wide levels of adoption significantly will affect the managers influence on the organizations adoption rate. In other words, managers will to some extent rely on the industry wide conditions in terms of adopting new technological innovations (Fichman, 1992) which raises the question how managers will act when Industry 4.0 and digitalization expands.

3. Methodology

This chapter will present the chosen research strategy and research design as well as an explanation to why they were selected. Thereafter, the secondary and primary data collection process will be presented including a review of the semi-structured interview process applied in this study. Following this, the data analysis process will be presented as well as data quality measures applied in the research.

3.1 Research Strategy

A qualitative research strategy was selected for this thesis. A quantitative approach usually emphasizes quantification in the collection of data while a qualitative study tends to emphasize words and thoughts of the respondents rather than quantifiable data in the collection of data (Bryman & Bell, 2015; Saunders, Lewis & Thornhill, 2012). The aim of the research was to fully capture and understand how managers influence the usage of simulation technologies in the product development process. Therefore, selecting a qualitative approach was convenient as it would help collect insights, through words and opinions that the respondents emphasized as important based on their experience (Bryman & Bell, 2015; Saunders et al., 2012). This in turn, would give different perspectives on the managerial influence on successfully utilizing simulation technologies.

Regarding the relationship between theory and research, there is generally two approaches. An inductive approach, which is often used in qualitative research, is conducted with the aim of establishing new theories. While in a deductive approach the research develops a hypothesis based on existing theory. In this study, an inductive approach was suitable, as it would allow the researcher to explore a phenomenon as well as identify themes and patterns while generating new thoughts (Bryman & Bell, 2015; Saunders et al., 2012). The inductive approach suits this thesis since it allows the researchers to utilize theories on technology management within the field of simulation technologies. This enables the researcher to explore and generate knowledge on managerial influence on the utilization simulation technologies from generalizing the collected data.

3.2 Research Design

The selected research design for this study was a comparative design. The reason for selecting a comparative design was because the purpose of the research was to compare and contrast managerial influence and gain a deeper understanding of how organizations utilize simulation technologies. The comparative design enables the study of two or more contrasting cases, in which it is implied that a social phenomenon can be understood when two or more cases can be compared to find meaningful contrasts (Bryman & Bell, 2015; Saunders el al., 2012). As mentioned by Bryman and Bell (2015) when applying a comparative design in a qualitative context it takes the form of a multiple case study. In line with the comparative design when comparing multiple cases, it improves theory building as well as possibilities of suggesting concepts that are relevant for an emerging theory. Thus, the comparative design enabled a

comparison in multiple cases, which in this study was managers with experience from simulation technologies. The focus of the research was on the individual respondents feeling and thoughts, rather than the compiling an organizational comparison.

3.3 Research Method

In this study both secondary and primary data collection processes occurred. Firstly, secondary data was collected during the literature review based on criteria relevant for this research. Secondly, through semi-structured interviews with relevant respondent's the primary data was collected for the empirical findings.

3.3.1 Secondary Data Collection

Literature Review

When the research question and purpose were established, a systematic literature review was conducted. The systematic literature review ensured a critical review of published sources within a specific area (Bryman & Bell, 2015). For this study, it helped create an extensive overview and evaluation of relevant sources and themes relating to the utilization of simulation technologies and the role of management. Moreover, as the systematic review was conducted before the primary data collection, it helped create a foundation on the topic as well as guide the interview questions. In this study, to ensure that the right material was collected in the review a systematic approach was used with relevant search words, to minimize potential biases of the researcher and increase the legitimacy of the review (Bryman & Bell, 2015; Saunders et al., 2012). The keywords were used in relevant databases such as Supersearch, Emerald and Google Scholar through an organized and systematic manner to obtain as much relevant material as possible. Firstly, number of citations were looked at, but the heading and abstracts were also examined for articles which could be of interest for this research. The systematic review was split into two main concepts relevant for the thesis. Firstly, the review looked at usage of simulation technologies in terms of drivers, benefits and challenges, and secondly the review looked in the role of management in connection to simulation technologies. Both of these sections will be further discussed below in terms of keywords and search words.

Simulation Technologies

The literature review on simulation technologies was conducted through the databases mentioned above. Below the relevant keywords and search words are presented for the review on simulation technologies:

Keywords: Simulation Technologies, Usage of Simulation Technologies, Simulation in Product Development.
Search words: Simulation Technologies, Simulation Driven Product Development, Organizational Benefits Simulation Technologies, Organizational Challenges Simulation Technologies, Product Development Technologies.

The table below presents the relevant inclusion and exclusion criteria used for the review. Simulation as a statistical modelling has been used for centuries, but it is only in the last couple of decades simulation has involved into a tool used in product development, and the reason for this is the heavy development of computer software and hardware. Thus, in the review on simulation technologies articles before 1990 were excluded to ensure a relevant search. Moreover, as simulation technologies are primarily used in the product development setting by manufacturing companies, literature on other industries or functions in the organization were excluded. Lastly, all relevant literature was kept to Swedish and English sources to ensure the author would fully grasp the context.

Literature Review	
Inclusion Criteria	*Peer reviewed journal articles* *Books and articles published after 1990* *Articles concerning organizational incentives, benefits and challenges with simulation* *Articles concerning simulation technologies in manufacturing product development*
Exclusion Criteria	*Articles not written in Swedish or English* *Articles and books written before 1990*

Table 1 - Inclusion and Exclusion Criteria Simulation Technologies

Role of Management

Similar to above, the review of the role of management used the mentioned databases. Below the relevant keywords and search words used in the review will be presented:

Keywords: Managerial Influence, Implementation New Technology, Utilization Technologies Key Factors, Utilization Simulation Technologies, Challenges New Technology.
Search Words: Technological Adoption, Successful Implementation, Simulation Technologies, Planning, Managerial Control, Employee Resistance, Information Technology Diffusion, Utilization Simulation Technologies.

Different to the review of simulation technologies, this review looked into the role of management when utilizing new technologies. Therefore, the review looked at implementation and utilization of technologies including information technology (IT) related technologies. As IT had a major breakthrough in the 1980s it was argued relevant to use some of these sources to understand the managerial influence in the process. Because of this, the review on the role of management was limited to 1980s in terms of articles and books. Secondly, the review was limited to management utilization of new technologies, and articles discussing general project

management were excluded. Moreover, beyond peer-reviewed literature, a few selected articles from leading management consulting firms were included to capture an extensive understanding of managerial influence of new technologies. Similar to the review on simulation technologies the review was limited to articles in Swedish and English.

Literature Review	
Inclusion Criteria	*Articles and books published after 1980* *Selected articles from respected non-peer reviews publishers* *Articles concerning managerial influence on implementation and utilization of new technologies* *Articles on IT management*
Exclusion Criteria	*Articles published before 1980* *Articles concerning general project management* *Articles concerning other factors than the managerial perspective* *Articles not written in Swedish or English*

Table 2 - Inclusion and Exclusion Criteria Role of Management

3.3.2 Primary Data Collection

For this research the primary data was collected through semi-structured interviews with managers working with advanced simulation technologies in product development. Thus, the researcher asked open questions following a structure, which was prepared beforehand in an interview guide. By using semi-structured interviews there was still significant freedom and leeway for the respondents to freely discuss their thoughts and opinions on the topic. The flexibility that came with semi-structured interviews was important for the research when extracting expertise, knowledge and experience of advanced simulation technologies to cover a wide enough scope of information. Furthermore, applying semi-structured interviews enabled a clear focus in the data collection through the topics outlined in the interview guide. In summary the semi-structured interviews were seen as a suitable option because the structure and comparability enabled a comparison of the interviews, but still left room for flexible interviews which fitted well with the comparative design selected in this study (Bryman & Bell, 2015; Saunders et al., 2012).

Selection of Respondents

For this research, purposive sampling was applied indicating that the respondents were selected based on their relevance to the outcome of the study. According to Bryman and Bell (2015) most qualitative research entails some form of purposive sampling where respondents are

selected in a strategic way. The purposive sampling ensured that, based on a set of criteria, the selected respondents were relevant for the study. The key criteria were selecting managers with a long experience of working with and utilizing simulation technologies in the product development process of the organization. Keeping the research purpose in mind, together with the external supervisor at EDR&Medeso eight highly experienced managers working with simulation technologies were selected. The reason for selecting managers was to obtain their perspective on their influence over simulation utilization as well as getting a comprehensive picture of managerial experience with simulation technologies. Moreover, by interviewing experienced managers, it opened for the possibilities of extracting as much valuable information of simulation driven product development as possible. Respondents fulfilling the requirements for participating in this study, were contacted through email with a description of the study as well as an invitation to participate through a semi-structured interview (See Appendix A). The selected respondents were also working in different countries, which for this research was argued would not drastically inflict the outcome, nor was the goal to generalize over populations in different countries. Instead the sampling of managers in different countries was simply due to reasons of their managerial experience working with simulation technologies.

Interview Guide

An interview guide was created to assist the semi-structured interviews with structure and comparability as well as acting as a frame of reference during the interviews (See Appendix B). To design an interview guide Bryman and Bell (2015) recommends keeping the research questions in mind and considering what answers and questions are needed to fully answer the research questions. Thus, only questions which were relevant and contributed to the research question were included in the interview guide. In order to ensure the respondents would not misinterpret or not fully understand the questions, they were designed in a simple way to avoid confusion (Bryman & Bell, 2015; Saunders et al., 2012). As seen in the interview guide, the interviews started with an introduction of the interviewer and the subject, to ensure the respondents understood the purpose of the research. This followed with a few introductory questions regarding the respondent's position as well as experience and history of simulation technologies, to create an understanding of their position towards simulation technologies. Thereafter, the interviews continued with questions regarding the incentives, challenges and benefits of using simulation technologies in the product development had on the organization. After this the interview guide changed focus towards the managerial level to capture the role of management when it comes to simulation technologies. Thus, the interview guide was split into two themes with the first one concerning the organizational level and the latter focusing on the managerial level. As mentioned above the interview guide was purposefully used as a guidance around the topic, and space was left to ensure a discussion and follow up questions regarding interesting thoughts lifted by the respondents. After the interview guide was designed is was reviewed by the supervisor at the host company as well as the university supervisor to ensure it was complete and relevant for the outcome of the study.

Conducting the Interviews

Before the interview, an email was sent out with a brief description of the themes covered in the interview to ensure the respondents would be comfortable and give them an opportunity to think and prepare their answers (See Appendix C). Preferably the interviews would have been conducted face-to-face to capture a deeper understanding of their role as a manager in simulation projects, but due to geographical reasons all the interview were conducted online. A majority of the interviews were conducted in English, with one exception in which the interview was conducted in Swedish. The choice of conducting the interviews in English was because this was the common language between the interviewer and the respondents as well as being the professional language used by many respondents in their daily work. All of the interviews were also intended to be recorded to help with the natural limitation of the human memory as well as a more thorough examination of the respondent's answers after the interview (Bryman & Bell, 2015; Saunders et al., 2012). So, before each interview the respondents were asked for permission to be recorded where one of the respondents declined. Thus, in this case extensive note taking occurred during the interview replacing recording. All recorded interviews were transcribed, and summaries were sent out to the respondents to allow for feedback and confirmation giving credibility and trustworthiness to the findings (Bryman & Bell, 2015; Saunders et al., 2012). Since most of the interviews were conducted in English the transcriptions did not need translation with the one exception which was transcribed in Swedish and later translated into English.

Upon the request from some of the respondents, the decision was made to keep all the respondents anonymous. The decision was made because the respondents' identities were not seen as relevant for the outcome of the study. Moreover, some respondents wanted the organization to remain anonymous as well, and thus the choice was made to only publish the position of the respondents. Since the point was to find similarities and differences in how management influence the usage of simulation technologies rather than focus on one organization, the decision to not mention the respondent's organizations helped taking away the focus from respective organization.

Respondent (R)	***Position***	***Date***	***Time***	***Interview Type***
Respondent 1	*Senior Specialist CFD*	*2020-03-17*	*60 min*	*Online Interview*
Respondent 2	*Head of Mechanics & Material*	*2020-03-18*	*35 min*	*Online Interview*
Respondent 3	*Director Powertrain Strategy*	*2020-03-18*	*50 min*	*Online Interview*
Respondent 4	*Head of Structural Science*	*2020-03-19*	*40 min*	*Online Interview*
Respondent 5	*Improvements & Development Programs Manager*	*2020-03-23*	*40 min*	*Online Interview*
Respondent 6	*Director Technology Development*	*2020-03-25*	*40 min*	*Online Interview*
Respondent 7	*Director Powertrain Engineering*	*2020-03-25*	*45 min*	*Online Interview*
Respondent 8	*Senior Research Engineer*	*2020-04-06*	*45 min*	*Online Interview*

Table 3 - Information about Interviews

3.4 Data Analysis

Thematic analysis is one of the most common approaches for analyzing qualitative research data (Bryman & Bell, 2015). Moreover, through a thematic analysis it was possible to identify common themes and patterns as well as conclusions based on the collected data. Therefore, this method was considered appropriate in this study for contributing with new insights on the role of managers in the usage of simulation technologies, and how organization can successfully use them. The analysis process started with the transcription of the interviews and the process was conducted along the interview process. Transcribing the interviews was an ongoing process and allowed for a greater understanding throughout the data collection, which is beneficial for utilizing emerging themes in latter interviews (Bryman & Bell, 2015, Saunders et al., 2012). As part of the thematic analysis the transcripts from the interviews were color coded into commonly mentioned categories, and the same method was used for the interview which was not recorded where color coding occurred on the notes. Given that the interviews were split into two major categories the collected data was color coded in two separate parts, with the first being related to benefit and the challenges with simulation and the second part relating to the role of management. After the color coding was finalized, the categories were scanned and bundled into similar overarching themes which were then used as the basis for the empirical findings.

3.5 Research Quality

In terms of research quality, it is argued that the concepts of reliability and validity are closer to quantitative research. Instead the criteria of quality for qualitative research is related to trustworthiness and guidelines set for achieving this trustworthiness. Bryman and Bell (2015) discussed and presented four alternative ways originally developed by Lincoln and Guba (1985) related to trustworthiness and authenticity. The four different factors for evaluating qualitative research are; *Credibility*, *Transferability*, *Dependability*, *Confirmability*.

3.5.1 Credibility

Credibility is related to the trustworthiness and accuracy of the research and there are certain actions researchers can use to ensure the accuracy and credibility of their research (Bryman & Bell, 2015; Lincoln & Guba, 1985). To ensure credibility in this research, *respondent's validation* was used, where the coding of the interviews occurred directly after the interviews and summaries were sent to the respondents to give them the possibility to confirm the transcripts. Secondly, the research was carried out in good faith and practice were the researcher took an objective view to the matter and maintained a neutral point-of-view when interviewing managers in the selected organizations. The most inherent risk towards the credibility of this research was that the respondents were not aware how simulation technologies were utilized in the product development process as well as overestimating their decision-making process on the usage of simulation technologies. However, in this research the selected respondents were individuals possessing high knowledge and expertise on the usage of simulation technologies lowering this risk. Moreover, to minimize the risk of the respondents discussing wrong topics in the interview an introductory email with the themes of the interview was sent out beforehand, giving the respondents time to prepare their answers.

3.5.2 Transferability

Transferability in a research implies that the findings can be applied in other contexts, and thus is generalizable (Bryman & Bell, 2015; Lincoln & Guba, 1985). In this study semi-structured interviews were used to ensure a higher transferability compared to single in-depth case interviews. The research itself focused on managerial influence on simulation technologies in product development process, specifically in the manufacturing industry implying that the results might not be transferable to other industries which the researcher of the study was aware of. However, in an attempt to ensure transferability, the primary data collection was comprehensively described opening up for transferability to other industries using simulation technologies in the product development process.

3.5.3 Dependability

The dependability is seen as a parallel to reliability in quantitative research, and to establish this criterion in a qualitative research, the researcher should take an auditing approach (Bryman & Bell, 2015; Lincoln & Guba, 1985). In an attempt to ensure dependability in this research the primary data collection as well as the research process has been comprehensively described in the report.

3.5.4 Confirmability

Confirmability is related to the subjective values and opinions of the researcher, and a high confirmability is ensured through less subjectivity in the research. Thus, it concerns the researcher's ability to exclude personal values and opinions as well as acting in good faith and not allow their own personal values inflict or influence the research (Bryman & Bell, 2015; Lincoln & Guba, 1985). The researcher was aware of the consequences of personal bias, acted in good faith and evaluated the results from an objective perspective. The interview guide was built upon the literature review, and the questions were formulated in an open and objective way to avoid the personal opinions of the researcher. Moreover, all empirical material was grounded in the transcripts from the interviews ensuring the material presented reflects the opinions of the respondents.

4. Empirical Findings

This chapter will present the empirical findings from the interviews. Firstly, the organizational benefits with using simulation technologies in product development will be presented followed by the organizational challenges with simulation technologies. Lastly, the empirical findings connected to the role of management will be presented.

4.1 Organizational Benefits with Simulation in Product Development

In this section the empirical findings relating to organizational benefits with simulation technologies in product development will be presented. The section will present the mentioned themes during the interviews in following order with the most mentioned theme first. There were also other themes mentioned during the interviews, however they were discussed by less than three respondents and will therefore not be presented in the empirical findings.

Respondent	***R1***	***R2***	***R3***	***R4***	***R5***	***R6***	***R7***	***R8***
Cost Efficiencies	✓	✓	✓	✓	✓	✓		✓
Speed of Product Development	✓	✓	✓	✓		✓	✓	✓
Product Performance		✓	✓	✓	✓	✓		✓
Risk Mitigation	✓		✓		✓	✓	✓	✓
Competitiveness		✓	✓			✓		

Table 4 - Overview of Organizational Benefits

4.1.1 Cost Efficiencies

Almost all respondents agreed that simulation has an organizational benefit in cost savings and efficiencies. R2 mentions that the organization has three strategic initiatives relating to simulation technologies including cheaper and more cost-efficient product development. R1 explains that simulation technologies facilitate cost savings for the organization. Moreover, the organization conducts internal business improvement projects aimed at developing new methods and tools for cost savings. R3, R4, R5 and R6 all argue that organizations must apply virtual testing and simulation methods because of the costs associated with long development times in physical testing. Moreover, R4 and R5 mention that cost optimization in terms of material quantity and other features can be achieved in the product development through simulation.

"Cost question as laboratory tests come with a relatively high cost in time and of course money needed to be invested in physical testing"

R6

R6 discussed another aspect related to costs which is the sales side where the organization can benefit from both lower costs and faster sales using simulation technologies. R1 also mentioned an interesting trade-off organization are faced with when determining whether to apply simulation technologies. In some cases, more simulation might cost so much extra that managers are confronted with the decision whether that extra simulation is worth it to lower the risk a fraction. Similarly, R7 points out that for organizations to achieve cost efficiencies they must achieve the right level of simulation and identify areas where it can be applied.

4.1.2 Speed of Product Development

R1, R2 and R8 explain that applying simulation tools can speed up the product development process through shorter processes in ordering physical prototypes and avoiding redesign loops which leads to products reaching the market faster. R3 and R4 explain that the speed of product development are important drivers for utilizing simulation technologies. R3 explains that organizations often want to shorten the product development cycle because physical product development takes significant time and results in a longer time-to-market process. Thus, integrating simulation tools early in the product development and applying physical testing as verification will speed up the process as well as give management early status updates. R4 on the other hand, although agreeing that simulation leads to a quicker product development, also points out that time-to-market is not as important in their business. According to R6 the organizations utilization of simulation tools has increased because it massively contributes to increasing speed of development projects. Further, R6 argues there is an incentive to develop product faster and lower the time-to-market as sales will occur at a higher pace.

"Speeding up the process and getting faster with new projects"
R1

4.1.3 Product Performance

R5 explains that simulation can provide organizations with early confirmations on expected product performance helping the organization ensure they fulfill industry standards. R4 and R6 mentions that finding reliable and optimized products is a major incentive for applying simulation tools. R6 further expands by explaining that as the quality of the product development improves the more simulation methods and tools will be applied. R2 explains that one benefit from using simulation is finding better solutions with higher performance in terms of quality, product performance and level of innovation. R3 points out that simulation can help the organization select the right specification for products, and thus reach a higher performance. Thus, overall using simulation to enhance product performance seems to be a common incentive but also benefit for the organizations as seen in the quote by R3 below.

"Primarily about reducing development time and meeting better in the use of features"
R3

4.1.4 Risk Mitigation

R1 explains that by applying simulation tools the organization can increase the maturity of product design which lowers the risk of developing a faulty product and therefore increases the confidence in the design. R3 expands and argues that simulation can provide managers with a status early in the projects in comparison to physical product testing. This managerial advantage will provide them with credibility as well as confidence in the development and higher probability of finalizing the project. Furthermore, R5 and R8 explain the importance of upfront validation on product performance which can help predict consequences of failure as well as explore other design variations and select the best possible option. R7 describes the importance of simulation models being validated in reality so that the organization know where they can apply simulation on an appropriate level. More, R7 explains that with simulation you can understand matters which are impossible to understand without physical testing and thus cannot be measured with physical measurements. Therefore, one of the major benefits is understanding more about the products, but also the opportunities to make variance assessments with time and gain more confidence in the product development work.

"Confidence in that we are selecting the rights parts and mitigating risks in the design"
R8

4.1.5 Competitiveness

Competitiveness was discussed by several respondents as a form of overarching benefit from using simulation technologies. R2 explains that their competitiveness rests on the high performance from their products and achieving a high performance is impossible without applying the best engineering methodologies. R3 and R6 on the other hand discuss simulation tools as on option for becoming more competitive in the market, whereby applying simulation you could reach the market with products before your competitors. Thus, as argued by all three respondent's competitiveness may not be the major incentive for utilizing simulation tools, but from a benefit perspective, lower costs and a faster product development process will lead to better competitiveness.

"Big part of competitiveness is performance of products, therefore highest performance, standard and efficiency is important"
R2

4.2 Organizational Challenges with Simulation in Product Development

In this section the empirical findings relating to the organizational challenges with the utilization of simulation technologies in product development will be presented. It will follow the same reasoning as the section of the empirical findings above where the most mentioned challenges will be presented first. Similarly, as with the benefits there were organizational challenges which were mentioned by less than three respondents and are therefore not included into the empirical findings.

Respondent	***R1***	***R2***	***R3***	***R4***	***R5***	***R6***	***R7***	***R8***
Change Management	✓	✓	✓	✓	✓	✓	✓	
Knowledge Requirement	✓	✓	✓	✓		✓	✓	✓
Specialist Tools	✓			✓	✓	✓	✓	✓
Data Management		✓	✓		✓	✓		✓
IT Infrastructure		✓			✓	✓	✓	

Table 5 - Overview of Organizational Challenges

4.2.1 Change Management

Change management was discussed in relation to the challenges of shifting an organization's product development towards a primarily simulation-based product development. R7 highlights that employees prefer working with tools they are experienced with, and some employees will resist new tools and methods because of the fear of becoming irrelevant in the organization. R7 also points out that other employees will be curious and have no doubts in trying new tools and methods, and most likely an organization will have all types of employees. R3, R4, R5 and R6 follow the same line, arguing that challenges with change management will exists in organizations especially relating to technological changes. R5 mentions that a lot of change management challenges can be managed by extensive work with the mindset of employees who do not grasp the full potential of a digital change.

R2 takes a deeper discussion on change management and explains that for an established organization there is often a traditional work culture, which itself leads to challenges with change management when an innovative new way of working is introduced. R1 mentions similar ideas that change management becomes a challenge for organizations because there will always be a resistance to change. So, when implementing new ways of working such as initiating a more integrated systems engineering you need employees to agree with it.

"If you want to introduce new technologies you have to have people on board buying in otherwise it will become a challenge"
R1

4.2.2 Knowledge Requirement

Several respondents mention that the knowledge requirements on the employees is becoming an organizational as well as a managerial challenge in product development. R1 mentions that simulation tools still require significant mathematics and physics background to fully understand the complexity while R2 talks about the simulation bringing engineering technical challenges to the organization. R4 follows the same reasoning and explains that people risk not understanding simulation unless they have the correct educational and practical background. R7 mentions that some simulation methods are complicated in nature and those specific tools should be used by employees possessing the practical background as well as understanding the physics and simplifications made in the model. R6 and R8 follow the same reasoning and mention that challenges exist when employees without the technical knowledge attempt to use simulations models and risk using the wrong information which can lead to issues with interpreting the results. R8 explains further that the challenge with technical knowledge is not surrounding the actual simulation of models but are connected to the analysis of the models.

"Usually the software runs and gives you results, but you need the competence to get the right input as well as the interpretation of results correctly"
R8

R3 agrees that one would usually need to have a correct educational background, especially when the calculations techniques in the tools can be complicated mathematically. However, the respondent also points out that most simulation programs are often pre-programmed meaning employees learn quickly and that at university level simulation basics are often included in the education.

4.2.3 Specialist Tools

Closely connected to the knowledge requirements all respondents but two mention that simulation technologies to some extent are becoming specialist tools which is a challenge for the organizations. R8 talks about the tools being used in highly complex physics situations with small margins in design which can lead to trust issues in the results. Similarly, R1 and R4 point out that simulation tools are specialists' tools requiring a lot of knowledge from the engineers using the simulation, turning them into specialists. R6 mentions that when applying simulation tools, the engineers set the boundary conditions for the simulations meaning they need to know potential flaws in the set-up as this in turn influences the outcome and results. This is turning some simulation tools into specialist tools are it requires specialist knowledge to understand potential flaws. R7 talks about similar challenges where the organizations need to make sure the tools are on a level where you get relevant physics modelled so that the engineer cannot manipulate the physics in the wrong direction. The respondent expands on this thought by explaining that for simpler tools it is possible but for more advanced tools the user will always

be able to add adaption factors since they calibrate the tools, and there is a risk that the results then get misinterpreted. This itself is turning the tools into specialist tools which requires specialists.

"In the future for a lot of simulations, we need to have specialists doing nothing else than using these tools all day"
R7

4.2.4 Data Management

R2 explains that in some instances when simulating a certain product type there is lack of capacity or previous simulations on similar products. This leads to a lot of groundwork for the engineers in terms of building the right model with correct data and input validated in physical testing. R5 mentions that working in an industry which mostly uses tailor-made products in their projects has certain challenges in product development. For new projects, although to some extent re-engineering can be applied, you need to build a new analysis again considering shifting conditions, meaning that a lot of groundwork re-occurs. Similarly, R8 explains that when the organization wants to study a new phenomenon or product, physical testing is used coupled together with simulation models to calibrate and ensure the simulations model represents the real world.

"It takes time to ramp up the simulation technology, and then it evolves so that simulation can be used more frequent and results can be more trusted"
R8

R3 also discussed data management mentioning that a lot of structure in the organization is required to be able to reuse previous simulation models. The respondent expands on this thought by explaining that working with simulations is very much concerned with processing data and providing answers to simulations. Therefore, there needs to be a clear way of categorizing and processing data to simplify application of data in future models.

4.2.5 IT Infrastructure

Building on the challenge of data management some respondents also explained the importance of having a solid IT infrastructure within the organization. R2 mentions that challenges exist in ensuring the organization has the right underlying IT infrastructure ranging from hardware to software including licenses. This challenge is primarily relevant for organizations currently looking at utilizing simulation technologies in product development according to R2.

"Essentially a journey for organizations which are not simulation driven from the beginning and want to shift their priorities there"
R2

R6 discusses the challenges of computer power where some simulations can be run by a single laptop while other simulations require a cluster of high-performance computers. The

respondents expand this thought and explains that the challenge itself lies in scaling up the hardware for variations in capacity needs of simulations. Similarly, R5 agrees that when hardware improves, the simulation tools to perform analysis also improve leading to more complex handling of models because of expanded boundary conditions. This can lead to problems in execution due to it becoming a large time-consuming model, but also means that organizations constantly need to keep their IT infrastructure updated. R7 points out that some simulation tools require a huge investment in hardware and software, and that as manager you are obliged to create and find budget for these IT investments through an assessment process of relevant choices.

4.3 The Role of Management

In this section the empirical findings on role of management in terms of influence and work with simulation technologies in product development are presented. This section will present material firstly from how management work with simulation and then material from sub-categories will be presented. This section will differ from above and will not be presented based on most mentioned category first, but instead all managerial factors will be presented.

4.3.1 Managerial Work with Simulation

When discussing potential managerial benefits, it was found that in many cases they were similar and corresponded with the organizational benefits. R5 expands on the thought of managerial benefits and argued that simulation gives managers an upfront capture of potential problems in projects, meaning potential reworking of products can occur early in the process. R7 points out that managerial benefits simply depend on what you want to achieve as a manager. Still, you need to have a sound understanding of where different simulation tools and methods could be applied in the product development to reap both organizational and managerial benefits. R1 explains that management have drafted overall strategies for digitalization, virtual verification and certification as well as including simulation and digitalization into the organization chart through governance for different programs. Further, R1 addresses that previously managerial work with simulation has been chaotic with less overall structure, but now management have shifted priorities and organized the utilization of simulation. R2 agrees and points out that priorities have shifted over the years as previous middle managers have moved up into top management positions, initiating a management supported strategic initiative on simulation.

"Taking simulation from supporting development to being in the core of development and used in all stages of design"
R2

R6 mentions that management see and value simulation highly, pointing out that the product development process is often started through concept development where simulation is applied nowadays. Still, it can become a challenge for management to prioritize which part of a project simulation experts should focus on. R5 explains that in the past simulation was predominantly

used in the end of the design phase as a verification mode. Today, the organization has an integrated design approach where simulation works hand-in-hand with design, highlighting the importance of using simulation.

"The importance has become more highlighted within the organization"
R5

4.3.2 Education and Training

The subject of education and training of employees was discussed in connection to the challenge of shifting knowledge requirement as well as simulation tools to some extent becoming specialist tools. R2 and R6 specifically mention the frequent use of third-party vendors as part of their technical training. R2 expends on this and argues that the technical training is the easy part, while the challenging part for the managers is changing the mindset of the employees which is primarily done through internal training programs with both managers and employees. R6 also mentions the use of informal internal training but does not mention it in the context of changing the mindset of the employees.

"We also have the gurus in the organization which spread and disseminate their knowledge to colleagues"
R6

R4 and R5 both mention that training exists for less experienced employees to develop as well as for experienced employees to keep up to speed with the latest development within simulation technologies. R8 explains that they have introduced templates of automated workflows giving design engineers the support needed for simulation tools. However, management have noticed that these automated workflow templates should be designed as simple as possible. R3 explains that the simulation tools used in the organization are often pre-programmed meaning you can learn quickly. Thus, the education does not concern the technical aspect of the tools but rather how the organization applies and utilizes the tools. The respondent still highlights that the knowledge requirements are important as inserting wrong data into a model will yield inadequate analysis and results.

"Rather education consists of how we work in teams and how our models work but it is still important to understand the background to simulation"
R3

4.3.3 Team Structure

The importance of team structure for a successful usage of simulation in product development was mentioned by a few respondents. Moreover, the communication between team members but also between the different business departments was discussed by some respondents. R3 explained that management need to consider all testing and production aspects as well as ensuring cooperation between testing, production and simulation to be successful. R6 mentions that simulation licenses are often location locked meaning that all licenses cannot be run by all

members of the organization, and thus when investing heavily into licenses you would preferably want to structure the organization to achieve the highest possible utilization and return on investment. R8 mentions that almost all their simulation and physical testing is done in-house which simplifies the communication process between teams compared to having some departments outsourced which could lead to more complex communication and feedback loop. Moreover, internally R8 saw challenges with having separate teams of simulation experts and design engineers. According to R8 finding the best practice is important, which is mixing employees backgrounds in teams leading to simpler and quicker processes but also an internal exchange of information and roles among employees.

"(...) if they work in the same team, they can learn from each other"
R8

R7 points out that when the organization is using more specialists it is important that they are mixed into teams containing employees with knowledge on the physical problems of the product. Managers need to ensure employees understand each other since they will often want to solve the problem in a way they are experienced with, which can lead to struggles for management applying simulation technologies in development processes.

"Communication is always the hardest, and bringing the teams together is the most crucial"
R7

4.3.4 Top Management Support

Several respondents mention top management support and the importance of managers possessing the knowledge on simulation technologies. R5 explains there are requirements on middle managers to considerer all factors in product development and how it can be improved. Further, if top management have a background within simulation it becomes significantly easier to push simulation into a higher level of integration in product development. R5, R6, R7 and R8 explain that challenges can exist when demonstrating the visibility and convincing top management to invest in simulation technologies. However, according to the respondents starting with simpler ideas and scale them up during the process is a strategy to convince top management and gain their trust. According to R8 resistance has occurred from management because they do not trust the simulation models because there are so many parameters which can be manipulated resulting in outcomes favorable for the simulation. Therefore, it is important to keep top management up to date with the latest results to gain confidence and which creates top management support. Moreover, R7 points out that top management support could potentially be difficult because normally top management would not understand the advantages of simulation tools because the methods are often of a specialist level which top management do not necessarily understand. Therefore, is it crucial to establish trust in the levels between top management and the specialist. R6 can also understand the challenge of convincing top management because it can be difficult on an organizational level to measure the speed of product development making it even more important to clarify the benefits for management as costs are rising.

"The problem is that license costs are constantly increasing meaning you need to see more and more benefits"
R6

On the other hand, most respondents work in organizations which are successful at utilizing simulation technologies and thus none have any major issues in convincing top management, rather top management are in the position to decide which technologies is best to invest in. Both R2, R4 and R6 mention that managers in their organization are very open towards integrating simulation and new technology which can benefit the organization. Although R4 points out that initiatives can come from any level in the organization through an idea pool, R2 mentions that their organization primarily focuses on a top down approach in terms of strategy and planning. Despite this both respondents where clear that their respective organization are open for new initiatives and have strong top management support.

"Management are very open to new technologies in simulation"
R4

4.3.5 Business Network

Several respondents (R2, R4, R5 and R8) could to some extent see the external influences as a reason that simulation utilization is expanding. R4 states that they are currently the leading organization in their industry but that their network through internal and external communication influences the utilization. R8 explains that in some project's customers are requesting analysis in troubleshooting which itself requires the usage of simulation tools and methods as it usually is impossible for them to do any physical testing in these scenarios. R2 argues that it is spreading in their ecosystem with both upstream and downstream requests on simulation incoming before the product development has started. Similarly, R5 explains that they are increasingly integrating suppliers into the design process through co-engineering to cut down lead time and reworking.

"Having the input from suppliers at an early stage is very relevant"
R5

R1 could to some extent see an influence were organizations want to speed up and render certifications virtually but also explained that the industry is not there yet in terms of accepting virtual certifications. R3 discussed the internal view of the network effect, where they receive requirements internally and apply simulation tools to prove projects can fulfill the requirements and thus meet the business goals.

4.3.6 Future of Simulation

Several respondents (R1, R2, R4, R5, R7 and R8) agreed that the utilization of simulation technologies would only increase in general and in product development because of Industry 4.0 and digitalization. R1 explains that currently they are at the forefront of simulation development, but more organizations are increasing their usage of simulation indicating that the overall utilization will continue to increase.

"(..) but we are all heading in the same direction in digitalization and simulation in product development"

R1

R2 explains that currently an extensive utilization of simulation technologies is a competitive advantage but to maintain this position managers must focus on continuous development. R5 mentions that the industry is changing, and organizations need to adapt towards new technologies because only so much can be achieved through optimization improvement whereas digitalization is offering more options for organizations. R7 and R8 follow the same logic and predict an increased usage because the tools will become more flexible and therefore easier for employees to apply in product development. Still, R7 points out that physical testing will always exist, but it will shift from development to verification indicating that simulation will be predominantly used in design.

R6 explains from a managerial perspective the requirements will likely remain similar because as a manager you only need to know when and where to apply simulation and increase the confidence in the methods. Similarly, R7 agrees that in the future the requirements on management will not change drastically, however managers will still have to implement and swap out old methods through a continuous assessment regardless of amount of simulation executed. R7 further explains that it is hard to predict which technology will increase or decrease but that depends on the organization's processes. But, in general the methods in simulation will become better over time but how business crucial it will become depends on the technical domain which is assessed together with specialist.

"No manager should go out and say we should apply this method because it is new, that will always be wrong"

R7

5. Analysis

In this chapter, the empirical findings and the literature review will be compared and analyzed. Firstly, the organizational benefits concepts will be analyzed compared to the literature review followed by the organizational challenges. Following this, the role of management in simulation context will be assessed and compared with previous studies on technological management. Lastly, the chapter will be finalized by an assessment and analysis of how managers can influence the utilization of simulation technologies in connection with to the organizational and challenges.

5.1 Organizational Benefits with Simulation in Product Development

In the literature eight organizational benefits related to simulation technologies in product development were identified. In the empirical findings five main organizational benefits were identified while there were some minor benefits only mentioned by one or two respondents as well and therefore were not seen as significant. There were certain similarities between the described organizational benefits from the empirical findings and the theoretical findings indicating a relevant relationship (See Table 6). Moreover, two organizational benefits discussed by respondents, risk-mitigation and product performance, were not identified explicitly in the literature but have other corresponding categories. Thus, there were some differences in the empirical findings and the theoretical findings in terms of organizational benefits. Moreover, there were indications of relationships between the organizational benefits and this will be further analyzed in the follow section.

Empirical findings corresponding to literature	***Yes***	***No***
Cost Efficiencies	✓	
Speed of Product Development	✓	
Product Performance		✓
Risk Mitigation		✓
Competitiveness	✓	

Table 6 - Comparison between Empirical Findings and Literature on Organizational Benefits

Firstly, there exists a pattern between the organizational benefits mentioned in the interviews and the theoretical findings. In the literature there are indications that simulation technologies can bring organizational benefits in reduced costs, improved quality and shorter time-to-market within product development (Maria, 1997; McLean & Leong, 2001; Greasley, 2017). In the empirical findings, the two most commonly mentioned benefits, cost efficiencies and speed of product development, were mentioned by at least seven respondents (See Table 4). Subsequently, these two benefits may be considered a particularly common outcome both in

literature and empirical findings of applying simulation technologies in product development. In fact, since these were mentioned by almost all respondents, covering a variety of products and services, it can be argued they are the most relevant and important organizational benefits which managers should strive for when applying simulation technologies. This follows the logic of the literature where it is argued that simulation technologies can help organizations establish a faster and more agile product development (Becker et al., 2005b; McLean & Leong, 2001). Moreover, from the interviews it was also identified that cost efficiencies and speed of product development from simulation technologies were closely related as most respondents argued that speed of product development largely influences the cost efficiencies of the organization. These two factors should largely influence the competitiveness of the organization, as a faster product development should lower the time-to-market meaning organizations can reach the market before their competitors, as well as increase the sales of products. Reaching the market before your competitors or indeed achieving cost efficiencies through simulation technologies should in the long run lead to a competitive advantage (Voss, 1988; Thomke, 1998)

However, competitiveness as an explicit benefit was only mentioned by a few respondents (See Table 4) but given that the interviewed organizations are highly successful, the increased speed and cost efficiencies from simulation technologies has most likely led to a better competitive position. One explanation for the few confirmations on competitiveness could be that competitiveness is industry specific for some respondents and it might be harder to determine if the organization has obtained a competitive advantage through simulation technologies. However, what is most likely the explanation is that for most organization speed and cost efficiencies in product development has indeed led to a greater competitiveness. But when the respondents have mentioned organizational benefits such as speed of product development and cost efficiencies it might have been implicitly thought this leads to a better competitive advantage and thus therefore not mentioned. Nevertheless, reaching a competitive advantage should be the ultimate goal for an organization utilizing simulation technologies (Voss, 1988) and therefore managers should focus on structuring the organizations so that the crucial factor of speed in the product development is fulfilled. This is an important action as simulation technologies will speed up the product development which is closely related to greater cost efficiencies through quicker sales and less physical testing in the organizations. This indicates a close relationship between speed of product development and cost efficiencies stemming from simulation technologies as well as a increased competitive position compared to the rest of the industry.

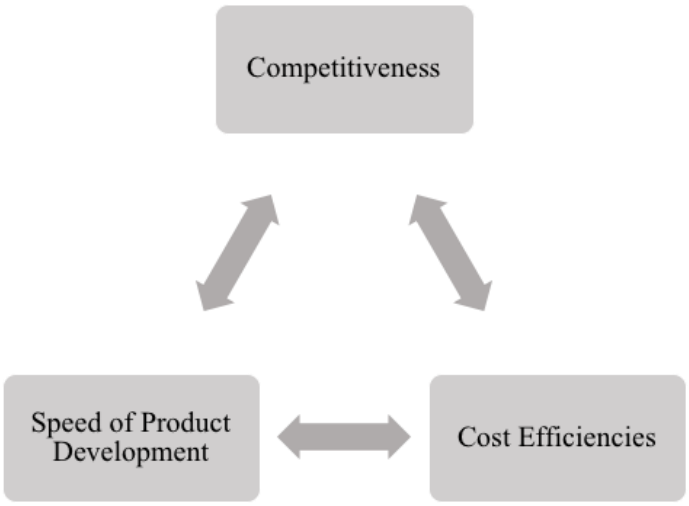

Figure 3 - Overview of Main Relationship between Organizational Benefits

A second relationship was identified between risk mitigation and product performance during the interview, however none of them were explicitly mentioned during the theoretical findings. Theory (Klingstam & Gullander, 1999; Thomke, 1998) states that simulation technologies can establish an improved decision-making process within the organization based on data collected from simulations. During the interviews risk mitigation were mentioned by several respondents indicating the importance for managers to decrease the risk in product development with simulation technologies. Risk-mitigation does to some extent correspond with the theory on an improved decision-making process from the perspective that collected data can form a solid ground for decision-making and provide early indications in a project. Presumably, this will simplify the process for managers regarding decision-making in the product development, but also help managers make objective choices based on simulation results which will lower the risk of developing a faulty design. A perspective which was discussed with the respondents related to the maturity of design and building confidence in simulation models. This corresponds well to the theory by Thomke (1998) who explains that an increased number of simulation cycles will decrease the number of cumulative errors in the product development process. In the interviews, product performance was seen as an important benefit with many respondents mentioning optimized and reliable products as an outcome. Moreover, there were indications that optimized and reliable products obviously can shorten the product development process as organizations can avoid re-development and therefore also lower the costs associated with product development. In fact, in literature it is argued that argued that simulation leads to better quality in products, indicating the importance of utilizing simulation technologies when improving product development processes (Hosseinpour & Hajihosseini, 2009; Patuwo & Hu, 1998) in both literature and empirical findings. However, from a managerial perspective both risk-mitigation and product performance are interrelated and important where risk-mitigation is an important organizational benefit from simulation technologies as they can significantly lower the risks of developing a faulty design (See Figure 4). Thus, simulation technologies have the potential of becoming an important tool for managers in decision-making as it can lower the risk with design and increase the product performance as indicated in the empirical findings.

Figure 4 - Relationship between Risk Mitigation and Product Performance

Both innovation and sustainability through simulation technologies were identified as important organizational benefits in literature, however they were only mentioned by a few respondents and were therefore not included in the empirical findings. However, it indicates that beyond the most common organizational benefits there are many benefits which are organizational specific. Maria (1997) as well as Klingstam and Gullander (1999) explained that simulation technologies can be used by organization to explore new situations and alternatives without risking the objectives of the project. The reason only a few respondents mentioned innovation could be that managers have primarily focused on integrating simulation technologies into the product development and overall business strategies. Thus, the next step for managers could be to increase utilization of simulation within innovation and sustainability when the speed of development and cost efficiencies have been established. Other explanations could be that some benefits are not as relevant for some product development processes. In this case sustainability was seen as a benefit for an organization working with oil and energy products while other respondents were involved with other products. Therefore, as seen in Table 4 some benefits are valid for all organizations while others are more organization specific, indicating that managers must scrutinize their own organizational objectives before utilizing simulation technologies.

5.2 Organizational Challenges with Simulation in Product Development

In the literature four main organizational challenges relating to the utilization of simulation technologies in product development were identified, while in the empirical findings five organizational challenges were identified. As with the benefits of simulation technologies, the challenges in some respects correspond with the literature but there also exist differences (See Table 7). For example, costs of integration were not mentioned explicitly but only mentioned briefly when discussing IT infrastructure. Two themes identified in the empirical findings, knowledge requirement and specialist tools, have no direct comparative in the literature but to some extent fall under resistance to change. Moreover, there were indications of two major relationships between the organizational challenges which will be further explained and analyzed in the section below.

Empirical findings corresponding to literature	*Yes*	*No*
Change Management	✓	
Knowledge Requirement		✓
Specialist Tools		✓
Data Management	✓	
IT Infrastructure		✓

Table 7 - Comparison between Empirical Findings and Literature on Organizational Challenges

Firstly, following the logic applied in the organizational benefits, change management and the increasing knowledge requirement were mentioned by almost all respondents indicating that they are considered the major challenges when utilizing simulation technologies in product development. Overall, most respondents mentioned that change management issues were not always related to simulation technologies, but in general resistance existed with any major technological or organizational change. When undergoing such a change many respondents mentioned that the resistance originates from employees who are afraid of not possessing the necessary skills or knowledge and therefore feel obsolete to the organization. In literature it is argued that implementing changes in an organization can results in a difficult task for management (Hosseinpour & Hajihosseini, 2009; White & Bruton, 2010), while Kroll et al., (2016) claims that one barrier for management when implementing change is having to focus on convincing employees to buy into the change. This was mentioned by a couple of respondents, who pointed out that an effective strategy when facing change is for managers to focus on a small group who are buying into the idea, and then work towards the larger group of employees. This indicates that although technical and organizational changes can be a challenge for the organization, several managers have also identified an effective strategy to deal with the issues and make sure simulation technologies are utilized within product development.

Both specialist tools and an increasing knowledge requirement in product development were identified in the empirical findings and were found to be closely related to change management, however none of the two themes existed explicitly in the theoretical findings. However, both themes can be related to resistance to change which were discussed by several respondents during the interviews. Theory (da Costa & de Lima, 2009; Patuwo & Hu, 1998) explains that for a successful utilization of a technology, management need to ensure employees are integrated by applying training and preparation to increase knowledge. Most of the respondents mention that even though simulation has grown in popularity employees still need a relevant background within mathematics and physics to fully understand the tools, which is becoming an issue as the tools become more specialized. More specialized tools indicated that the knowledge requirement is increasing on the employees because not having a relevant

background to utilize simulation technologies can potentially cause more harm to the project than benefits because of inaccurate analyses and conclusions. This indicated a close relationship where the increasing knowledge requirement and specialist tools are interrelated as simulation technologies in some respects are becoming more technical which is increasing the knowledge requirement which is turning the employees into specialist on the tools. However, a few respondents on the other hand, explained there were no signs of increasing knowledge requirements on simulation tools or simulation technologies turning into specialist tools. Thus, it can be argued that knowledge requirements are dependent on the effect internal and external training programs have on employee as well as the employee's motivation to learn how to utilize simulation tools. Thus, as indicated in the empirical findings there exists a clear relationship between change management and knowledge requirements as well as specialist tools (See Figure 5) and managers should be aware of these factors.

What is interesting with these results is that managers think the knowledge requirements are becoming a real issue for the organization in product development and thus affects the long-term outcome. This clearly contradicts Greasley (2017) who argues that simulation tools have moved from being a specialist tools towards a mainstream tool for business managers. Based on the empirical findings it actually turns out that many managers working directly with R&D and product development explain that simulation tools are moving towards specialist tools, but to some extent also mainstream tools for simple simulation and decision-making. Thus, managers should be aware of the potential issues with increasing knowledge requirements on employees and ensure employees are part of training and knowledge programs to minimize resistance (da Costa & de Lima, 2009; Patuwo & Hu, 1998).

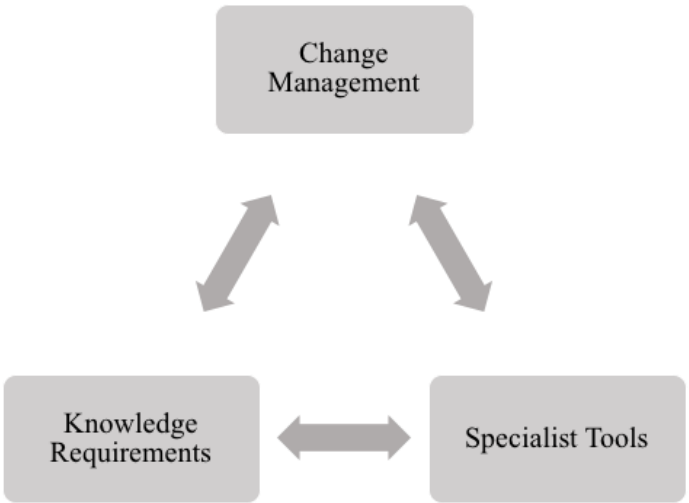

Figure 5 - Overview of Main Relationship between Organizational Challenges

A second relationship as identified among the organizational challenges related to data management and IT infrastructure. Corresponding thoughts were identified in the theoretical findings associated with the high costs of integrating new technology, however IT infrastructure was not explicitly mentioned in the empirical findings. With that said during the discussions on IT infrastructure, costs both for simulation licenses as well as investments into hardware required for simulation technologies were mentioned by respondents but they were

not explicitly mentioned as a challenge itself. When discussing data management respondents referred to this as the process of handling, structuring and building simulation models in terms of validating them in reality. This poses challenges for the organization and managers in terms of building the right knowledge and capabilities to ensure the right input and data goes into the models but also determining when simulation should not be applied. This again indicates the increasing knowledge requirements on both the organizations, managers and the employees which can also be identified in literature. In the literature both Becker et al., (2005b) and Klingstam and Gullander (1999) argue that simulation models are powerful tools, but organizations and managers struggle with the collection, input and analysis of the data.

Closely related to data management, was the establishment of a robust IT infrastructure which is scaled to handle ups and down in the workflow. By establishing a robust IT infrastructure organization can avoid issues with capacity needs or the ability to simulate certain aspects and factors which are crucial for the outcome of the product development. However, establishing an IT infrastructure also requires that managers find adequate resources and budget within the organization, which can be problematic as many technologies share the same IT budget. Thus, management must have a clear process for assessing potential innovation and technological changes as well as being prepared to invest in the organization. Therefore, some respondents argued it was considered crucial to build a strategy for finding the right capacity and handling of data to simplify the process of assessing where IT investments in hardware and software should be utilized. Maria (1997) and Becker et al., (2005b) explain that building simulation models is solely based on getting the input right which can become a struggle for some organizations in terms of IT and knowledge capabilities. As to why this was not mentioned by all organization, the soundest explanation would be that some organizations have established a robust process surrounding how simulation models should be executed and thus have no reported issues. However, all organization are very successful and at the forefront of simulation usage and are experienced with handling simulation technologies and should be able to handle the future increasing demand of simulation driven product development. Moreover, a challenge which will presumably increase in the future is the integration of other technical innovations where managers must establish an IT infrastructure capable of using cloud services to store data but also other manufacturing technologies.

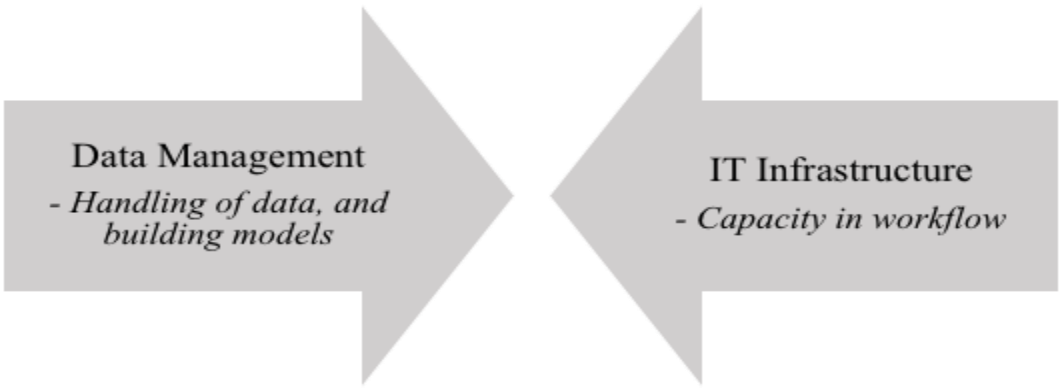

Figure 6 - Relationship between Data Management and IT Infrastructure

5.3 The Role of Management

The empirical findings on the role of management discuss how managers influence the utilization of simulation tools in product development. To some extent the empirical findings correspond to the literature on management of IT and new technologies indicating that there are some overlapping managerial features in IT management and simulation management. An explanation to this overlap could be that in many cases simulation is considered part of the IT infrastructure by management due the purchasing of hardware and software (licenses). Within the literature similar ideas are proposed by Maria (1997) as well as Klingstam and Gullander (1999) explaining that simulations are computer-based software programs indicating that to some extent managing simulation will have similarities to other IT infrastructure related technologies.

5.3.1 Organizational Planning and Strategy

Managing innovation and technology within an organization is a crucial task to survive in a competitive industry (White & Bruton, 2010; Patuwo & Hu, 1998). Moreover, Patuwo and Hu (1998) argue that management should be responsible for supporting and delegating resources through a long-term plan and perspective to secure a successful utilization of simulation technologies. In the empirical findings it is established that simulation technologies are becoming increasingly important for managers to apply in product development because of the organizational benefits such as speed of product development and cost efficiencies. However, it was also found that this successful utilization depends on managers ability to acknowledge the organizational benefits and investigate where simulation can be applied in the organization. Looking at the discussion with the respondents, managers have in some cases moved simulation up in the process and ensured it is part of the core development in design rather than being used for verification and supporting development. So, for managers it is clear that they must internally investigate the organizations and seek opportunities to integrate simulation technologies into the business as well as drafting overall strategies were simulation and digitalization are included. Overall, this means management have to work extensively with the long-term outlook and planning for simulation technologies in order to fully utilize the capabilities within the organization. Moreover, as found in reports by (Buvat el al., 2017; Duarte et al., 2018) the absence of a digital culture will create clashes between management and employees on perception of digitalization indicating the importance of ensuring management and employees are on equal terms. This can be achieved if managers use planning and strategy as a system to integrate the employee's perception and work with factors which are creating perceptions differences.

As the discussion continued several respondents argued that shifting towards simulation-based product development is an ongoing and organizational dependent process which can take significant time and resources from management. Both Fichman (2000) as well as Hall and Kahn (2003) explain that the diffusion of new technologies is a continuous and slow process as top management must analyze and assess investment. As found in the empirical findings the organizations are at different levels in the development of their product development processes,

but most managers are actively working towards integrating simulation technologies in all possible instances. However, as mentioned in both literature and empirical findings this is an ongoing process which takes patience and planning from management as simulation further expands as Industry 4.0 and digitalization.

5.3.2 Managerial Control

According to Fichman (1992) employees rarely influence the adoption process of workplace innovations, but this is management's responsibility as they control the necessary infrastructure such as IT and human capital. The empirical findings indicate that management are now increasingly acknowledging the importance of simulation technologies to their daily work and are therefore taking more control of the technology's development. One respondent stated that the simulation initiative began in middle management but as the organization has shifted priorities, it now engages in a top down approach indicating that management are driving the control of simulation technologies. Therefore, management should control the development, as well as the responsibility for setting goals and strategy for the development of the utilization. Given, that most of the organizations interviewed are at the forefront of simulation driven product development it can be argued that managers early took control over the technologies and decided that simulation technologies were the best choice for the organization. As mentioned above the long-term planning is crucial for success, indicating that management should control the workplace innovations either through a strong "doer" or a person which has respect throughout the organization.

Moreover, other influential reviews found that adoption can be encouraged explicitly through expressed preferences or implicitly through rewards. When it comes to explicit encouragement it can take two forms, either through encouragement or mandated by management (Leonard-Barton & Deschamps, 1988; Moore & Benbasat, 1991). In the empirical findings there were no conclusive answers to which process is the best instead it was found to be a complex process depending on employee's acceptance rate. With that said most of the respondents interviewed work for organizations which are at the forefront of simulation driven product development. In some instances, this means that employees have an internal motivation to apply and work with simulation methodologies. According to some respondents' managers can only push simulation to a certain extent but if the employees lack the internal motivation there will always exist a resistance. This implies to some extent that managers can influence employee motivation, but in some instances manages simply have to be a strong "doer" and continue utilizing simulation if it is successful for the organization, regardless of the employees internal motivation as indicated in literature (Ferraro, 1988; White & Bruton, 2010) and empirical findings. Moreover, the interviewed managers have worked actively with simulation in product development for years and built up strategies where simulation and digitalization are included in comparison to previously. This in turn can contrast towards organizations which are currently looking at integrating simulation technologies in product development and thus are facing challenges related to change management with employees feeling obsolete. Furthermore, Becker et al., (2005) explains managers can control the utilization of simulation technologies by pushing the strategies and design process in desired direction towards more

standardization or more experimentation. Given that innovation was not seen as one major organizational benefit but instead speed of product development and cost efficiencies were the main organizational benefit it can be argued that managers are pushing initially for more standardization in the product development. With that said, as mentioned by several respondents this strategic priority can shift over the years depending on the organizational goals, and managers therefore have an important task in maintaining control over the simulation technologies to ensure they are utilized as intended.

5.3.3 Team Structure and Training

As found in the literature managers have to pay attention to the human aspects such as skills and knowledge when implementing new technologies. Moreover, this should be a long-term oriented training to keep personnel updated with the latest advancements (Chung, 1996; Patuwo & Hu, 1998). During the interviews several respondents highlighted the importance of education and training for employees, through both internal and external training programs. The external training programs were more concerned with technical knowledge, both for beginners but also keeping more senior employees up to date with the latest development. It was common to use third party vendors for this process, and the organizations seem to have acknowledged the importance of keeping employees up to date. In fact, as mentioned previously, the increasing knowledge requirement is becoming a challenge for managers, and thus using training courses is one solution to this issue. The internal training is argued as the most difficult part, and it concerns the mindset of the employees. Having the right mindset is vital when shifting the organization focus towards a simulation-based product development. It is a complex process but as seen in the literature when employees have the wrong mindset or a different perception that management it will lead to a gap which in the long-term will lead to issue in fulfilling all the benefits with the change (Chen & Small, 1996, Hall & Khan, 2003; Buvat et al., 2017).

The process of changing employees' mindset is closely related to change management where Hosseinpour and Hajihosseini (2009) argue that changes in an organization can results in a difficult task for management. Several respondents acknowledged that it had been a significant challenge over the years and that it is an ongoing process of internal training courses. Some respondents mention that internal training would consist of experienced employees having informal sessions with less experienced or employees wanting to update their knowledge. There were also some differing opinions on the knowledge of younger employees whom often possess the right technical knowledge directly from university, which goes in line with Greasley (2017) study. Greasley (2017) argues that younger students entering the workforce often have course within basic simulation and decision-making. Altogether, even if younger employees have a good knowledge base from the beginning most respondents argue that continuous education and training is important because the knowledge requirements are increasing. Having employees with the right mindset is a crucial key to a successful utilization which should be the ultimate goal for managers. Managers are therefore in a position where they can clearly influence the amount of training and education employees can receive and

based on the results from the interviews, managers should focus heavily on working with the mindset of the employees.

When it comes to team structure Ferraro (1988) as well as Patuwo and Hu (1998) explain that management have a great responsibility to ensure that project teams have employees from different background to avoid mismatches in goals and objectives. Managers should involve members from different backgrounds to avoid unrealistic expectations. Theory also states that team leadership is important when it comes to advanced manufacturing technologies and preferably the team leader should come from management and be respected throughout the organization. Finding the best practice for managers is important and one way of establishing a best practice is ensuring the manager has a mixed team with members from different backgrounds and educations. Having teams with different background also helped managers and departments with internal communication, informal education and training as employees could learn from each other. Thus, several respondents have acknowledged the importance of structuring teams to avoid mismatches in objectives but also encourage communications. In fact, especially when it came to the specialist to ensure they are mixed with employees who have the practical experience from the product and not only the knowledge on the tools. Linking this back to the role of managers, to fully utilize simulation technologies it is crucial that the project teams are of mixed education and practical background but also that managers early in the process find the best practice and build on this.

5.3.4 Technical Knowledge

Theory behind technical knowledge proposes that firms will delay the adoption process of technological innovations because managers lack the necessary technical know-how to implement the innovation. Cooper and Zmud (1990) argue that organizations must understand and manage the implementation process smoothly, yet this often causes issues when management fail to recognize problems. In essence, it is important that managers possess the relevant knowledge otherwise management will be a barrier to new innovations, but they must also trust lower level employees to some extent. In the empirical findings technical knowledge was discussed from both the employee and management perspective. Managers are facing challenges with employees having incomplete knowledge because of wrong educational backgrounds as the models are getting more complicated or analyzing the results is becoming more complex. This indicates that various challenges exist with a lack of technical knowledge which can lead to issues for managers as employees lack the know-how of running simulation models. Moreover, as found in the empirical findings there exists cases where top management also lack the technical knowledge. As explained by some respondent's top management do not always have the technical knowledge about new innovations because their role in the organization is to focus on the long-term outlook and thus are not always closely connected to the technology. This itself can lead to issues as lower level employees and middle management set out to convince top management to invest into new technologies. This is a process which more than often starts with simple cases and is further scaled up to ensure management grasp the advantages of investing into simulation. As seen in the theory by Cooper and Zmud (1990) top management need to control the implementation process smoothly and recognize issues to

avoid becoming a barrier to new technology. So, by engaging management and building their confidence in simulation methodologies, the organization can ensure the knowledge barriers are significantly lowered (Attewell, 1992; Cooper & Zmud, 1990).

As for the respondents most of them have no issues today with convincing top management to invest in simulation technologies, but there is still a significant need to clearly highlight the benefits as top management want an extensive return on investment. So, for managers it is important to work with the technical knowledge throughout the whole organization, to ensure the knowledge barriers are lowered and utilization can remain high. However, how to specifically spread the technical knowledge throughout the organization is a complicated process which is dependent on the organization but as mentioned before managers should actively work with the mindset of the employees and utilize informal groups in the organization. Cases where the technical knowledge is incomplete at top management level, could exist because managers are exposed to high expectations and requirements on selecting the right technology. This could lead managers to become cautious and rather delay an adoption until is it seen in an industry wide context, which will be further discussed later.

5.3.5 Employee Resistance

As stated by Hosseinpour and Hajihosseini (2009) change, whether small or big, can result in a difficult task for managers. Especially with technological changes is it important to achieve acceptance among employees to ensure a high utilization and avoid a "productivity paradox". One of the main reasons employees will resist a new technology is the inherent risk of failure rate and compatibility with organization as well as the risk of feeling abundant to the organization (Venkatesh & Davis, 2000; Sichel, 1997). Thus, management have an important role in influencing employees and ensure simulation reaches a high utilization rate in the organization to justify the investments. As found in the empirical findings most of the respondents have encountered employee resistance in their roles as managers but there have also been instances where resistance has occurred from higher ranking employees of the organization. In that case, one respondent explained that resistance has occurred from management because of the possibilities to manipulate the parameters in the simulation models and thus achieve the results needed. Overall, resistance has been more common among lower level employees who to some extent are afraid the competences will not match the new objective in the organization. Given that most organization are now successfully utilizing simulation the resistance level has lowered although some cases still exist. As a manager you can only push for a new technology so far, unless the employee actually has an internal motivation to develop their capabilities some respondents argue that resources should not be used on these employees. For managers, this becomes a case of how much desire they have to utilize simulation technologies, in some cases managers should simply become "doers" and continue utilizing the technology.

Davis et al., (1989) explains that employees acceptance rate is determined by *perceived usefulness* and *perceived ease of use* and thus managers should use these factors to influence employee's resistance to use technology. Moreover, the effects of external variables such as

system characteristics, development process and training of intention to use are mediated by *the perceived usefulness* and *perceived ease of use.* In the interviews, there are clear indications that managers should and have been successful in highlighting *the perceived usefulness* and *perceived ease of use* with simulation technologies to employees. However, as discussed, employees also have to find that internal motivation to understand the usefulness and ease of use with simulation technologies compared to physical testing. Managers should therefore when facing employee resistance or actively working with the mindset of the employees, highlight the benefits simulation technologies bring to product development and the employees' specific position. Simulation technologies do not only bring benefits to the organization but as an engineer there are benefits as well, such as the speed of process where instead of waiting for weeks for a result it can now be produced within days which correlates to *perceived usefulness.* Overall, working with the employee mindset and employee resistance if a major responsibility for management and crucial for the utilization of simulation technologies.

5.3.6 Business Network

Theory states that network effects can affect the adoption rate of technological innovations. According to Choi et al., (2010) the network will influence in the sense that organizations closer to the existing users of an innovation will adopt it earlier compared to firm which are at the periphery of the business network which will be significantly slower at adopting innovations. Tidd (2010) argues that other barriers to widespread adoption are related to economic, behavioral, organizational and structural barriers. Thus, to some extent organizations will rely on industry wide conditions when it comes to adopting new technologies (Fichman, 1992). As found in the empirical findings network effects to some extent existed but primarily in the case where managers can influence external parties to use simulation. Today, many of the organizations are leading the development of simulation within the industry, and thus have large influence over suppliers and customers. In some cases, this influence has led to new expectations from suppliers to include simulation in the product development, and thus is spreading within business network among managers responsible for product development. The barriers mentioned by Tidd (2010) are to some extent relevant as well, because several respondents mentioned that the costs associated with simulation can be extremely high but there also behavioral barriers such as personal motivation from top management and objectives of the business. Looking in the future, most respondents agree that simulation will increase as part of Industry 4.0 and digitization of organizations. Currently, using simulation technologies can be a competitive advantage but as the applications spread in the ecosystem, the competitive advantage will also diminish. However, some respondents explain that even if the applications spread and increases the role of management will remain the same, which is to continuously assess potential new investments and technologies. So, overall the business networks can significantly influence managers utilization of simulation technologies, especially if suppliers and customers are demanding simulation methodologies to be included in product development project. The important role for managers in the future will be to establish strong partnerships and networks especially considering that suppliers are getting more involved in the simulation utilization, and as predicted by several respondents this will increase in the future.

5.4 Summary Managerial Influence

This part of the analysis aims to link the role of management and the managerial influencing factors to the organizational benefits and challenges identified in the study as part of summary of the most important thoughts from the analysis. Firstly, it is important to acknowledge that managers have a crucial role in finding the right technologies that match the processes and goals of the organization while establishing a competitive advantage. As part of this process many organizations go through significant organizational changes such as shifting towards simulation technologies in product development. In this study it has been established that according to managers themselves they can influence the utilization of simulation technologies in product development through many aspects reflecting both the organizational benefits and challenges. Moreover, as indicated in the findings there were some general benefits and challenges as well as managerial factors which were common among the organizations. Most of these common categories had support in the literature indicating their relevance but beyond this there were also indications that minor benefits, challenges and managerial factors were heavily organizational dependent. Thus, it is a complex process for managers governing the utilization of simulation technologies in product development as it involves organizational changes and innovation. It was also found that to some extent how managers influence the process is dependent on organizational and personal factors. However, given that speed of product development and cost efficiencies were the most common organizational benefit there are certain managerial actions which can influence the process of reaching this outcome.

When it comes to the managerial influencing factors in connection to the organizational benefits some factors were identified as more important. Firstly, it is crucial that top management audit the internal organization to establish a clear picture of where simulation technologies can be applied including an overview of IT infrastructure and data management. Based on this internal audit, top management should build their long-term strategy and plan the organizational structure around this to minimize resistance from organizational changes. Through this method, management should have clear objective of how simulation technologies can be utilized in product development and therefore increase their chances of speeding up the product development and achieving cost efficiencies which should be the ultimate goal. After this, management should control the utilization process by involving a respected individual in the organization to handle the organizational change but still have significant trust in employees and utilize their capabilities in simulation technologies. By controlling the utilization process management directly control the development and ensure the goals with simulation technologies in product development are fulfilled such as focusing more on standardization or innovation for example. Lastly, going forward it will also become increasingly important for managers to build partnerships with suppliers, customers and third-party vendors which can help develop the applications of simulation technologies, especially as organizations increase their digitalization. Thus, relating back to the purpose of the thesis, there are many factors where the managers can influence the utilization of simulation technologies in product development to achieve the organizational benefits which are summarized in Figure 7 below.

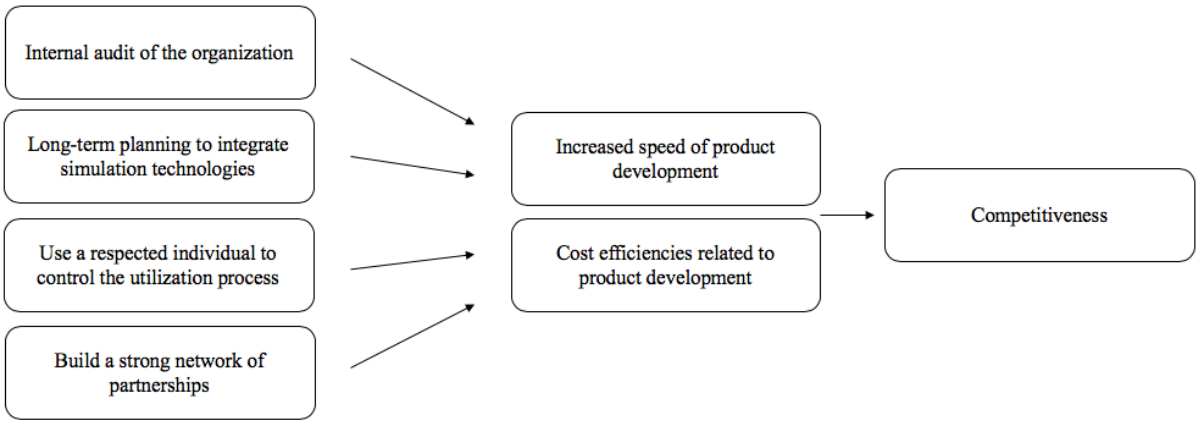

Figure 7 - Managerial Actions to Achieve Organizational Benefits

There also existed several organizational challenges which could be connected to the role of management and their influence over the utilization of simulation technologies. As found in the empirical findings, a major challenge when working with simulation technologies related to change management, and one dominant aspect of change management was working with the employee's mindset. Working with the employee's mindset could arguably be the most influential factor managers have on employees as this could influence and direct the utilization of simulation technologies through managing the employee's knowledge and willingness to participate. Both literature and empirical findings highlight the importance of navigating the change management process as well as working with the mindset of the employees when innovating in organizational structures. Therefore, there are increasing demands that management themselves possess the correct technical knowledge before attempting to manage the change management process associated with simulation driven product development. For managers when it comes to knowledge requirement, finding the right employees with the right knowledge will increase in importance in the future, as well as the process of creating clear organizational and team structures with members from different background. Therefore, it is important that managers continuously work with education (internally and externally), but also set clear objectives, goals and requirements with simulation technology development projects so that employees are aware of which capabilities are needed.

As mentioned, managers are therefore in a crucial position to influence the knowledge capabilities and requirements in the organizations through working with employee's mindset, continuously use the right educations tools within simulation technologies as well as recruiting new employees which have a desire to work and apply simulation technologies. Moreover, for these functions to work seamlessly, it is crucial that managers themselves possess the technical knowledge to ensure the organization are setting the right requirements and capabilities related to simulation. This is also applicable for top management, as they have the final say in most investment there is a need to continuously ensure they possess updated knowledge and information on simulation technologies. Moreover, managers can influence the outcome by ensuring projects are utilizing mixed teams so that mismatches and unrealistic project objectives can be avoided. Finally, as the digitization continues to increase both literature and respondents explained how crucial it is that managers build a strong network and use partners such as third-party vendors with other strong capabilities as part of a knowledge exchange.

Thus, there are many factors where the managers can influence the utilization of simulation technologies in product development to avoid organizational challenges which are summarized in Figure 8 below. In summary there are several factors which managers can influence the utilization of simulation technologies which have been discussed and analyzed in the section above, and it is crucial to point out that these factors are not necessarily applicable in all managerial cases, but keeping them in mind can help managers utilize simulation technologies to a greater extent.

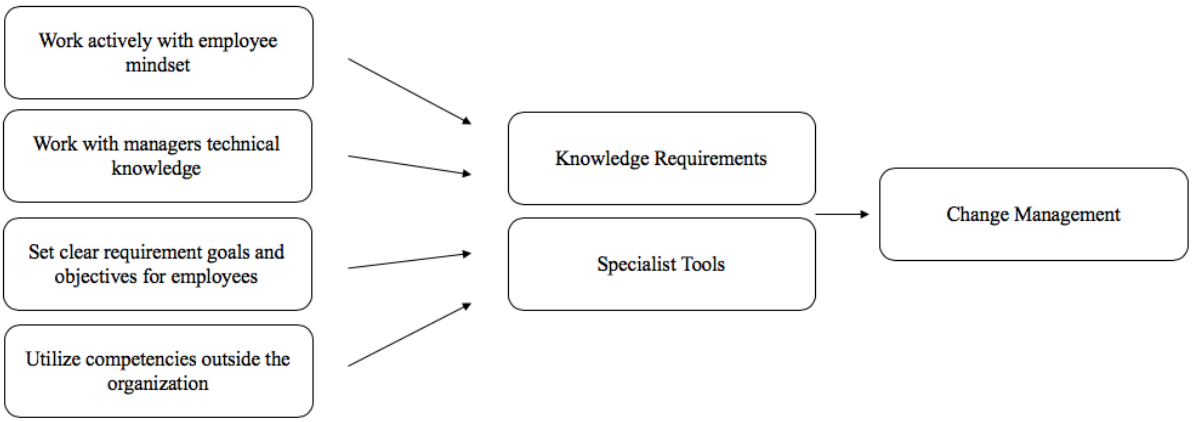

Figure 8 - Managerial Actions to Avoid Organizational Challenges

6. Conclusion

This chapter will present the conclusion to the research. Firstly, the two sub questions will be answered followed by the main research question. After this, the researcher will present recommendations based on the findings. Lastly, suggestions for future research will be presented.

6.1 Background to Research Question

The purpose of the thesis was to explore managers perception on how they can influence the utilization of simulation technologies in product development. Moreover, to gain a comprehensive knowledge on the managerial influence, the research also investigated the organizational benefits and challenges associated to simulation technologies. Based on this the following research question were developed:

- *What are the main benefits of utilizing simulation technologies in the product development process?*

- *What are the main challenges of utilizing simulation technologies in the product development process?*

The main research question in this research was the following:

- *How can managers influence the utilization of simulation technologies in the product development process?*

In today's fast paced business environment organizations are developing new innovative strategies and technologies to shorten the product development process and secure future growth and competitive advantages (Tohidi & Jabbari, 2011; Patuwo & Hu, 1998, White & Bruton, 2010). However, management must find technologies which match the organizations process ensuring a full integration and acceptance by the employees (Davis et al., 1989; White & Bruton, 2010). Simulation technologies on the other hand, has rapidly developed in pace with computer technology and can now provide organizations with innovative options to establish competitive advantages in increasingly unstable market conditions (Becker et al., 2005b, da Costa & de Lima, 2007). Based on this, the researcher interviewed experienced managers in R&D functions related to manufacturing companies heavily utilizing simulation technologies to investigate their perception on managerial influence. The data collected from the interviews was analyzed and compared to other studies in the field on technological utilization to find out how managers influence the utilization of simulation technologies. The final answers to the research questions will now be summarized and presented below.

6.2 Answering the Research Question

6.2.1 Main Organizational Benefits with Simulation in Product Development

The first sub-question related to the main organizational benefits from using simulation technologies in product development. By understanding the organizational benefits, it would support the idea of how managers influence the utilization of simulation technologies in product development. The empirical findings found organizational benefits in product development such as speed of product development, cost efficiency, product performance, risk mitigation and competitiveness. The identified themes are interrelated and share some common themes, such as speed of development and cost efficiencies relation to competitiveness (See Figure 3). This relationship was also identified within literature where it was clearly shown that they all are connected and co-exist within the organization's product development.

Out of the five organizational benefits identified speed of product development and cost efficiencies were identified in seven cases each (See Table 4). When discussing speed of product development, it was found that simulation technologies first and foremost minimize time spent on physical testing. However, it can also shorten the organization's time-to-market process which can be significantly crucial in a fast-paced business environment. Cost efficiencies was clearly found to be related to the speed of product development in the empirical findings. Aspects which were mentioned in cost efficiencies were related to cost saving from avoiding full scale laboratory physical testing but also the sales upside of being first to the market. Moreover, speed of development and cost efficiencies are of huge importance for managers wanting to establish a competitive position in the business environment. So, given that speed of product development and cost efficiencies were mentioned by seven respondents they are considered as the main organizational benefits from utilizing simulation technologies in product development.

6.2.2 Main Organizational Challenges with Simulation in Product Development

The sub-question on main organizational challenges in product development was developed to gain more insight into the managerial influence on the utilization of simulation technologies. In the empirical findings five main organizational challenges were identified; change management, knowledge requirement, specialist tools, data management and IT infrastructure. There was a mixed similarity towards the themes identified in literature, with some themes existing while other such cost of integration was only implicitly mentioned during the interviews. On the other hand, knowledge requirement and specialist tools were not identified explicitly in the literature, but support for it was found in change management. Given that it was discussed by several respondents they were still considered challenging factors, rather than bundled into change management. The two most commonly mentioned challenges in product development were change management and knowledge requirement.

Looking in the literature, change management was identified as a complex challenge while increasing knowledge requirements was mentioned within the overarching challenge of

shifting the organizational focus. In the empirical findings most of the respondents talked about the challenge of shifting the organization towards simulation-based product development, and there were few discrepancies when discussing this challenge. Overall, change management and knowledge requirements were mentioned by seven respondents each and support to some extent was found in the literature. Therefore, they are considered to be the main organizational challenges when using simulation technologies in product development which managers should be aware of.

6.2.3 Managerial Influence on Utilization of Simulation

The purpose of this study was to explore from the management perspective how they think they can influence the utilization of simulation technologies in product development. The results from the study show that managers can influence the utilization in several aspects covering both positive and negative factors (See Figures 7 & 8), however in some cases factors seem to be context dependent and therefore managerial influence can have different effects in different organizations.

With that said shifting towards a simulation-based product development process is a long and continuous journey for organization as identified in literature and empirical findings. In fact, most of the respondents are currently at the forefront of simulation driven product development and have actively been working with the technologies for years. This indicates as found in literature and interviews that long-term planning where managers set the strategy for the future product development and simulation technologies is a crucial managerial aspect. Developing a long-term strategy for technology involvement can be a complex process, which is why managers as found in the results must trust their lower level employees. By creating trust between management and employees the process of utilizing simulation technologies will be simplified as managers can focus on the crucial human factors of the employees.

One aspect which was deemed very important was working with the mindset of the employees during change management. Shifting towards a primary simulation driven product development where simulation is an integrated part of design is not a simple process for any organization. When organizational changes occur, there will always be a need for new capabilities and therefore managers have a crucial role in working with the mindset of the employees. In the empirical findings similar results were found when the organization were integrating simulation technologies into the product development, where in some cases employees with the wrong mindset can significantly complicate the process for managers. This also goes hand-in-hand with the increased knowledge requirements of employees, where managers must ensure internal and external training so simply the process of changing the product development process. Therefore, management have an important role to ensure relevant capabilities and knowledge relating to simulation technologies exist in the organization as well as working with the mindset of the employees.

All in all, according to managers, shifting towards a simulation-based product development is a long and continuous journey, where managers can influence the utilization through several

factors (See Figures 7 & 8). With that said, based on the interviews with experienced managers, some of the managerial factors can be organizational dependent. This itself indicates that there is no single correct way when it comes to managing simulation technologies in product development, rather managers should be aware of the factors identified in this study as they have been identified in organizations which are experienced in utilizing simulation technologies.

6.3 Recommendations

Three recommendations have been developed for managers influencing the utilization and shift towards simulation-based product development. These recommendations are based on that organizations are seeking the most desirable outcome which has been determined to be increasing the speed of product development and gaining cost efficiencies in the product development. Firstly, managers need to examine the organizations needs within product development to examine where simulation technologies could be applicable. This is crucial to ensure simulation is applied in the right context leading to the desired outcomes. Based on the organizational review, management should set up a long-term strategy for integrating simulation technologies and actively work with simulation during this process by highlighting the benefits within the organization.

A second recommendation for managers is to actively work with the mindset of the employees. It has been highlighted by many respondents that working with the mindset of the employees as well as increasing their knowledge it an important aspect when changing the organization towards more utilization of simulation technologies. Therefore, to have a smooth transition towards a simulation-based product development, managers should actively work with the mindset of the employees. Through external and internal training as well as focusing on groups which show a high acceptance rate, managers have opportunities to influence the mindset of employees.

The final recommendation concerns the role of business networks which will become more important in the future because of the digitalization of product development and Industry 4.0. Therefore, it is important that managers establish a network with relevant partners, to continue the development of simulation technologies to find a best practice for the utilization and improve the future product development. Beyond this, managers also have an important role in connecting with suppliers and customers to complement each other's capabilities and from there build a strong network as they integrate simulation in the future product development.

6.4 Future Research

This study aimed at investigating how managers can influence the utilization of simulation technologies in product development in connection to the organizational benefits and challenges. The research itself took the managerial perspective by interviewing experienced managers to gather their thoughts and opinions on the managerial influence on simulation technologies in the product development. Throughout this thesis several interesting thoughts

on future research topics emerged, especially looking into the managerial aspects of simulation technologies which is a relatively unexplored topic in literature. Based on this, two suggestions on future research related to simulation technologies and the role of management were developed.

Firstly, this research as mentioned took the managerial perspective when investigating the managerial influence on simulation technologies in product development. However, in organizations there are naturally other perceptions on how managers act and what factors are considered important to lead the daily work involving simulation technologies. Based on these facts a future research area to investigate could be to interview employees and other stakeholders in the organization to obtain their perspective on the managerial influence. By capturing the viewpoint of other employee's, the future research can build on the findings from this research and build a comprehensive understanding on which managerial factors are considered crucial for the organization to sustain a simulation-based product development.

Secondly, the findings of this research linked managerial influencing factors with outcomes of simulation technologies through interviewing managers in organizations which have a successful involvement with simulation. These findings present a general picture of how managers can have a successful utilization of simulation technologies in product development as well as the common organizational benefits and challenges. However, in the future it could be interesting to investigate less successful cases of simulation technologies in product development to further understand the role of management and their influence on technologies. Moreover, this could give an insight into the product development areas are adjusted and how managers influence this process.

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Appendix

Appendix A - Interview Request Email

Hi,

I am currently studying towards my master's degree in innovation and industrial management at the School of Business, Economics and Law at the University of Gothenburg. At the moment I am writing my master thesis in collaboration with EDR&Medeso office in Gothenburg. I was recommended to reach out and contact you because of your experience in simulation technologies.

The master thesis focuses on the role of management in terms of utilization of simulation tools and technologies in the product development process. Moreover, the thesis will in connection to the role of management also look into the drivers, benefits and challenges with using simulation technologies. Therefore, I would like to get in touch with and interview people with knowledge and insights from a management perspective on the usage of simulation technologies in the product development process. I would be very grateful if you would like to contribute to the report by participating in an interview during March. If you find this interesting, please let me know which day and time would be convenient for you.

Do not hesitate to contact me if you have any questions or are interested in further information regarding the thesis.

Best regards
Mattias

Appendix B - Interview Guide

Introduction

1. Could you please give a short introduction about yourself?
2. Could you please give a short introduction about your experience managing/working with simulation technologies in product development?

Incentives for using simulation technologies

3. Describe the organizations incentives for utilizing simulation technologies in product development?
4. How have the incentives shifted for the organization over the years?

Realized benefits and challenges of using simulation technologies

5. Describe the realized benefits for the organization associated with the utilization of simulation technologies in product development?
6. Describe the challenges in the organization associated with the utilization of simulation technologies in product development?
7. Describe how these benefits/challenges shifted over the years for the organization? And why they are challenging?

Role of Management - Achieving a simulation driven product development

8. Describe how management work with new technologies in the organization?
9. Describe how management work with simulation technologies in product development?
10. What managerial benefits/challenges have occurred when utilizing simulation in product development?
11. Can you identify the most important managerial factors for a successful utilization of simulation technologies?
12. Describe how management work with organization and planning of simulation technologies?
13. Describe how management work with resistance from employees? If any?
14. Describe how management work with the education and training of employees in relation to use simulation technologies?
15. How will the future usage of simulation technologies look like?

Finally, anything you want to add to this research.

Appendix C - Email before the interview

Hi,
Here is some information regarding the interview to allow some preparation beforehand on the topic. The interview itself will be split into two sections, covering both the organizational level as well as the managerial level in relation to the utilization of simulation technologies in product development. Moreover, the interview will be of semi-structured nature meaning I aim of having a discussion rather than a strict interview.

Firstly, the interviews will discuss the incentives of adopting simulation technologies in the product development. Then it will move into the benefits and challenges of simulation technologies in the product development phase post the implementation phase. Thus, this part of the interview will focus more on the organization factors related to the utilization of simulation technologies, and how these factors have shifted over the years.

In the second part of the interview, the focus will shift towards the managerial factors influencing the utilization of simulation technologies in the product development. Questions will relate to how management works with the utilization of simulation technologies in terms of challenges and benefits as well as important success factors. Thus, this part of the interview seeks to understand the role of management in the utilization of simulation technologies within the product development process of the organization.

Looking forward to speaking soon!