



**Aalto University
School of Business**

Challenges in Adopting a Devops Approach to Software Development and IT Operations

DRAFT

Master's Thesis
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14 April 2016
Information and Service
Economy

Approved in the Department of Information and Service Economy

___ / ___ / 20___ and awarded the grade

Author Joonas Hamunen

Title of thesis Challenges in Adopting a Devops Approach to Software Development and IT Operations

Degree Master of Science in Economics and Business Administration

Degree programme Information and Service Economy

Thesis advisor(s) Advisors

Year of approval yyyy

Number of pages 79

Language English

Abstract

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Keywords keyword, keyword, keyword

Acknowledgements

I thank all my interviewees for their availability and open attitude towards my research as well as my friend Edward Ford for opening some doors for me.

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1 Introduction

This section will give the reader a background overview of the topic, as well as the motivation for the research. It will shed light on the existing research gap in Devops research and also define the research questions the thesis will base itself on. Finally, there is a section defining the key terms used in this thesis.

1.1 Background

In the age of high-availability monolithic IT systems and increasing demands springing from competition and business, there is a pressure of developing new features at an accelerating pace. In addition to rapid development, the systems require zero downtime and error-free operation at any given time. While technological advancement has been rapid, the quality of application development process has been lagging behind. (Menzel 2015)

Staying ahead of competition puts an increasing pressure on software developers to churn out new features at an increasing speed. New software development practices such as Agile Software Development encourage small, incremental changes which means developers need to deliver code changes often - sometimes several times in one day!

On the other hand, operations personnel are in charge of taking these new features and improvements, deploying them into production and keeping them running indefinitely -- at the same time making sure there are no system failures or outages caused by these deployments. Operations tend to naturally resist deployments since they know changes to the systems are a major cause of outages. In other words, developers want to release software more frequently; operations professionals want to protect the stability of the infrastructure. (Hussaini 2014)

If and when problems occur, IT Operations might not necessarily have enough knowledge about the inner workings of the deployment to see what's wrong and on the other side. Development might not have paid much attention to the performance of the developed feature in an actual production system when designing it. This leads to software performance issues being overcompensated by expensive hardware kits that are ultimately never used (Humble & Molesky 2011).

This results in a "Wall of Confusion" between development and operations personnel which manifests in throwing blame around, much to the irritation of management and the business, which obfuscates their ability to predict when releases are coming out and delivering business value as expected and required (Humble & Molesky 2011). In addition, this results in stiffer competition, de-motivated teams and excessive time overruns of delivering changes. (Hussaini 2014) This leads to rising costs in both application development and deployment. As Patrick Debois, one of the fathers of Devops puts it, "Delivering a project to production still feels like going to war". (Debois, 2011)

Devops is an answer to these challenges. The word is an acronym for "development" + "operations" = "Devops". Devops is an umbrella concept that refers to a wide array of tools and practices to smooth out interaction between development and operations. Despite the term being loosely defined, the ideas behind the concept, however, run much deeper than that. From a slightly different point of view, Devops can also be seen as a collision between a trend of "Agile System Administration" or "Agile Infrastructure" and the aforementioned collaboration between Development and Operations throughout the entire application lifecycle (Agile Admin 2011).

The main idea is to bring down the Wall of Confusion to get developers and operations professionals to work together. What started out as a collaboration effort has manifested into a new kind of work profile: a Devops expert that can handle both the development of a function and the deployment and running of it. (Earnshaw, 2013)

From the business side, Devops is a business strategy that seeks to create an environment where the development and operations lanes are merged and cross-pollinated in order to maximize the outcomes of investments and to ensure that customers continuously get increased service quality and features in a manner that satisfies their needs. Additionally, it aims to reduce risk of IT deployments with tools that maximize predictability, visibility and flexibility. (Capgemini 2015)

Devops is not merely a philosophy but also demands an array of tools to automate processes and help facilitate collaborative change and integration. The principles are not entirely new. Many parts of Devops have been around long before the term 'Devops' was coined. (Eficode) The main components of this toolkit are release management and deployment tools (Azoff, 2011). Since Devops is not standardized to any given toolset, individual setups might vary considerably across organizations.

1.2 Motivation

This section outlines why it is useful to study Devops.

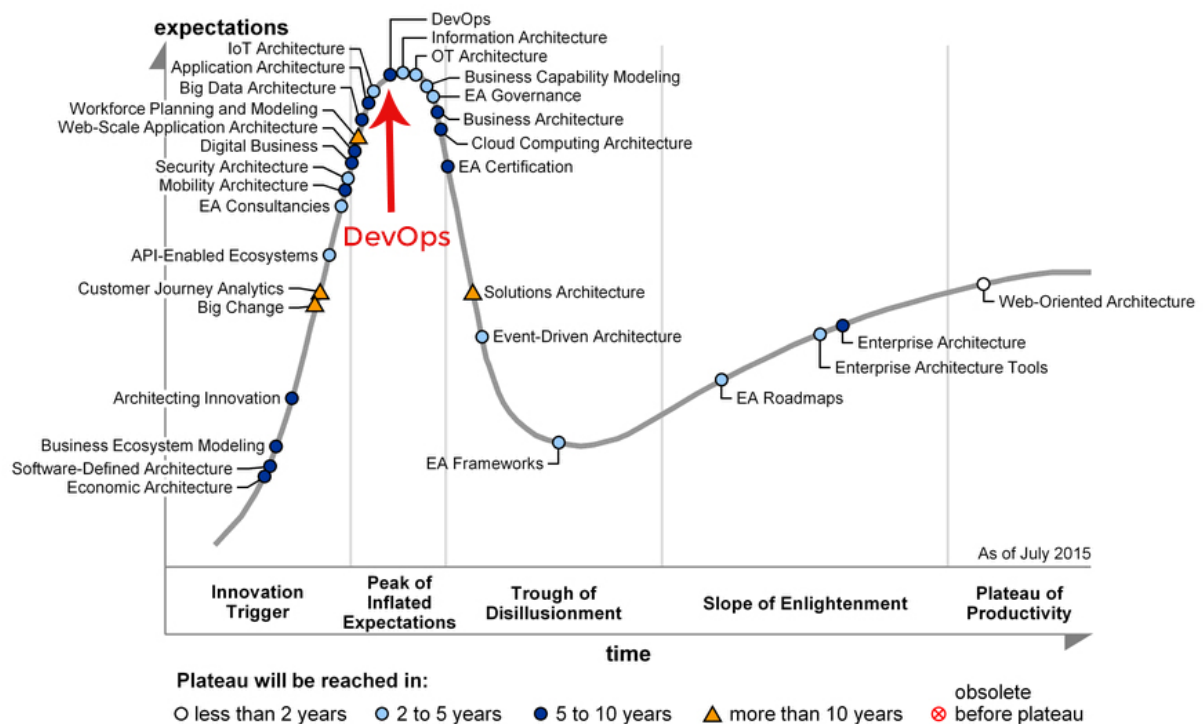
1.2.1 New Trend

Devops is a relatively new term that first appeared in 2009. Many people argue that while the term is new, the concepts have been around for quite some time. While there is no clear-cut specification or standardization of Devops practices, the emerging philosophy has been noted as one of the rising tech trends in the first half of the decade.

On the 2015 Gartner Hype Cycle of Enterprise Architecture, Devops appears to be right on the top of the curve. The Cycle is a map that shows the adoption and expectations of emerging technology trends in enterprises. It is divided into five steps: Innovation Trigger, Peak of Inflated Expectations, Trough of Disillusionment, Slope of Enlightenment and Plateau of Productivity. In essence, emerging trends go through the hype cycle, gaining momentum and expectations as they go up the curve and hitting the peak point where it is thought that this trend will solve many, if not all, your problems. Investments are made. Next, when investments are not showing nearly as much return as expected, the trend comes down the curve and hits the Trough of Disillusionment. Only after expectations have settled to a realistic level and the organizations have been starting to learn how to apply the trend in their own specific contexts, the trend moves onward towards the real productivity gains. (Gartner)

A recent study by Rackspace shows 55% of the 700 IT decision makers had already adopted Devops and are looking for enhancement, while 31% of them plan to adopt Devops in the next 2 years. This adoption is among the largest in the side of technology for the initial implementation of tools. (Rackspace 2014)

Because Devops is now on the peak of inflated expectations, I find it very important to study the real-world implications and challenges of Devops to perhaps clarify some of the expectations and realities behind the approach.



Devops search trend from Google Trends

1.2.2 A remarkable market for Devops tools

As stated above, Devops is not only a philosophy but it requires a certain degree of tools and practices to work efficiently. These tools, for example Continuous Integration tools, Continuous Deployment and Release Management tools, Configuration Automation tools, Infrastructure as Code tools etc, are also evolving because of Devops. This creates a remarkable market for these tools and a lucrative market to enter as an enterprise application developer. These tools are specifically designed and built with out-of-the-box functionality to support Devops characteristics and traits. Many of these tools have existed as a part of the regular toolset of IT development and operations already before Devops came about but the emphasis

in support of Devops currently has started to transform how these tools are positioned and perceived in the marketplace. ()

1.2.3 Benefits

There are many benefits in embracing Devops in an organization. According to a recent Techinsights research, organizations were able to reduce their development and maintenance costs by 18% after shifting to a Devops-style development lifecycle. (lisää siitä)

Also, Devops was found to be the key reason behind increases in revenue and number of new clients. This translates to a 20% increase in business!

A State of Devops report recently quoted that failure rates have been cut in half in their surveyed organizations. The same source also reported considerably faster release times: surveyed organizations were releasing code 30x more frequently and 8000 times faster than before shifting to Devops.

In light of these figures it can be clearly seen that there exists real value in managing the development lifecycle in this manner.

1.3 Research Gap

There has been relatively little academic research on Devops considering the amount of Devops-related investments. () Current literature is mainly based on describing the phenomenon and sharing best practices that are based on more or less subjective experiences of the authors. Moreover, the method is maintained by the community and can best be characterized as a set of best practices. The academic articles on the subject are extremely scarce, and the field lacks a common framework and even a quotable definition. Research circles around trying to describe the phenomenon. The solutions can be viewed through different perspectives and therefore can result in different implementations. According to a survey by Eficode, 66% of Finnish IT decision-makers see Devops as an interesting project for their company.

In light of these motivations, the key question of this research is

What are the main challenges organizations face with Devops?

Additionally, the research tries to answer the following sub-question:

What are the ways to overcome these challenges?

1.4 Definition of Key Terms

Devops

Development

Operations

Lead time

Continuous Integration

Continuous Development

Pull request

Microservices

2 Overview of Development and Operations

This chapter will give an overview of what is meant by Development and Operations respectively.

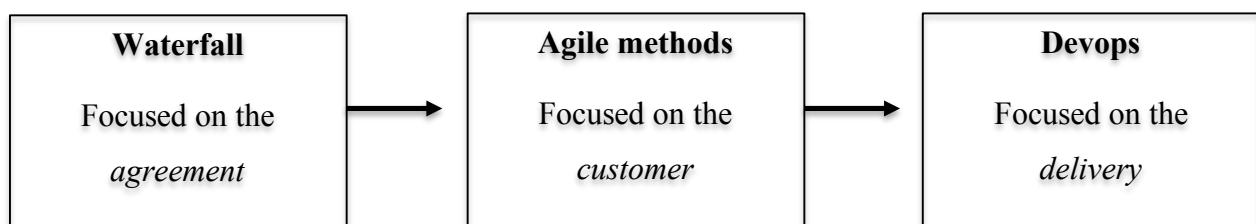
2.1 Software Development Lifecycle

This chapter gives an overview of different software development methods that have been employed throughout the short history of the field.

A software development lifecycle (SDLC) adheres to important phases that are essential for developers, such as planning, analysis, design and implementation. Since software has become a key component in almost all aspects in life, the risks have grown considerably. To mitigate this risk and to bring some structure to development process in order to produce only anticipated outcomes, a number of software development models have been created: waterfall, spiral, V-model, rapid prototyping, incremental, stabilize and agile.

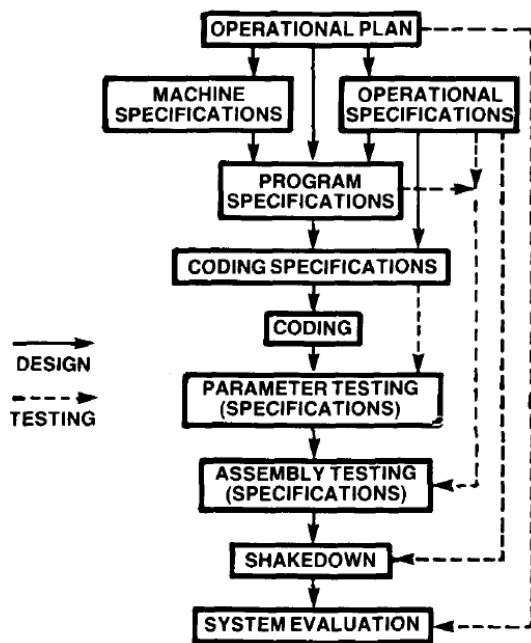
The Waterfall model is also known as the Sequential development model. Waterfall model is the oldest of the group, while Agile software development presents the modern trend of development.

Devops can be seen as the most recent addition in a continuum presented in Figure x. Some call Devops the 3rd generation software development method, a continuation from the 2nd generation agile practices (Eficode).



The next sections will focus on each end of the spectrum, first going over the traditional waterfall model continuing to Lean and Agile which are especially relevant from a Devops point of view. "Some consider Devops picking up where "traditional agile" left off. After all, software doesn't bring value unless it is deployed in production; otherwise it's just inventory." (Debois 2011)

2.1.1 Traditional Software Development: Waterfall method



The Waterfall model is a sequential design process and is recognized as the oldest standardized way of doing software development. The first ideas were presented by Benington (1956) who identified 9 stages for software development that can be seen in figure x.

The idea behind the model is that in order to make a functioning application, a carefully planned and documented application is easier to code error-free than an application that has constantly changing specifications and requirements. This tedious "code-it, fix-it, code-it-some-more-until-it's-quickly-not-maintainable" pattern was not acceptable. (Leffingwell 2007). Each of these stages are meant to be executed sequentially in contrast to a certain degree of parallelism present in modern development. Benington (1956) gives an example where the first 4 specification steps take 53% of engineering manpower, actual coding takes only 7,7% and testing takes the rest. The actual waterfall model is usually credited to Winston Royce (1970), rather ironically, as he stated that "it has never worked on large software development efforts." Surprisingly, the model was widely accepted to use.

The waterfall model is very strict about project scope. Once the specifications are made, the model is prohibitive about changing anything. This results in the model being poor at responding to change. The foundation of the projects is based on a fixed scope, and the costs and schedule are estimated and fixed thereafter. This results in what is called an "Iron Triangle Trap" (Leffingwell 2007). This meant delivering software of either poor quality, or finally either schedule and/or costs getting out of hand.

The sequential nature of Waterfall also meant that the application had to be completed in terms of code before even a single test could be run. (Kee 2006) In a complex application that has a lot of dependencies, tracing errors in this manner could prove to be very difficult.

2.1.2 Lean Software Development

The Lean way of thinking evolved from trends that started in manufacturing, such as Toyota Production System and Total Quality Management. Lean is designed to reduce waste and improve operational efficiency. This applies especially to eliminating repetitive tasks that have no added value in the value chain. The Lean mindset can be applied also to Software Development and IT Operations -- this is especially important from the Devops point of view -- and has also played a major part in the theoretical groundwork of Agile Software Development discussed in the next section.

Mary and Tom Poppendieck have formulated a set of principles that apply to Lean thinking in software development. Eliminating waste is the first principle. As defined by Poppendieck, is "anything that does not add value to a product". Furthermore, the value is as perceived by the customer. This might mean excess documentation, excess features that are not explicitly asked by a customer, and handing off development from one group to another. The key is delivering exactly what customers want. Excess development time is also considered waste. (Poppendieck & Poppendieck, 2003)

The second and third principles are Amplifying learning and Deciding as late as possible. In a software development context, this means not iterative cycles of getting the product just right. Learning is amplified by constant assessment and improvement. Deciding as late as possible is an options-based approach and is effective especially in situations that involve a level of uncertainty. In a dynamic market, better decisions are made based on facts rather than assumptions. In software terms, systems should include capabilities for change. (Poppendieck & Poppendieck, 2003).

Deliver as fast as possible is the fourth principle. Traditionally, a mistake-free approach has been favored over rapid development. However, Womack et al. (1990) argue that speed isn't a cost factor. Swift delivery has a faster feedback loop and is better equipped to improve the product. This is one of the key components of Devops.

The fifth and sixth principles are Empowering the team and Building integrity in. Technical decisions should involve the people that are responsible for the execution of the plans. Because decisions are deferred to the last possible minute, there is no time for higher authorities to

orchestrate the activities of workers. Integrity in software translates to reliable architecture, high usability and fitness for purpose, among maintainability, adaptability and extensibility. (Poppendieck & Poppendieck, 2003)

The final principle is seeing the whole. Integrity in complex systems requires a deep expertise in many diverse areas. From a Devops perspective, Development and Operations traditionally have siloed thinking that leads them to optimize only their respective ends of the development cycle rather than overall performance. This results in suboptimal end product or service. ()

The problems with the waterfall model and their solution with agile development is exhibited in table x.

Problem with the waterfall model	Agile Development Solution
Software is planned like buildings: before any actual work is done. Changing plans later is expensive or impossible.	Software is developed in small iterations and in cooperation with the customer throughout the project
Projects often have a fixed agreement with regard to price and requirements. Negotiations are slow and based on guesswork.	The agreement made at the beginning of the project concerns common procedures and a prioritized list of requirements, not the final product.
Software is developed in stages where testing starts after the development is "ready".	Software is developed in small, independent iterations, the contents of which can be altered before an iteration begins.
Visibility into the development process is poor.	The customer sees the actual status of the project at regular intervals.
Changes that occur during the development process are not prepared for.	Changes are welcome and they are prioritized as parts of the future iterations.
The system is only tested at the end of the execution phase when making changes is expensive. Some of the necessary fixes may even be impossible to implement.	The functionality of the system is already tested during the execution phase to ensure that the requirements selected for an iteration may all be done from start to finish during the iteration.

Both Devops and Agile Software Development have been majorly influenced by Lean thinking. Next, Agile is described in more detail.

2.1.3 Agile Software Development

Agile Software Development springs from the so-called "Agile methods" which are a reaction to traditional ways of developing software, for example the Waterfall method. In response to heavyweight, documentation-driven development processes, Agile methods have

increased in popularity since the beginning of the new millennium. (Beck et al., 2001) Developers found that designing a software from a complete set "locked-in" requirements and documentation lead to frustration (Highsmith, 2002). According to Highsmith (2013) requirements "change at rates that swamp traditional methods". Customers and business owners were unable to state the full requirements of a system that was only going to be in production 2-3 years after the tedious and often lengthy process of "locking" the requirements down. This led to people coming up with their own methods to respond to the traditional way of doing things.

Many of the ideas were already conceived as early as the 70's - Agile Methods were partly based on Iterative Enhancement that was introduced by Basili and Turner (1975). Before Agile, the Waterfall model had evolved into Incremental techniques that broke the Waterfall model down into smaller pieces but still maintaining the basic idea behind it, namely allowing several functionalities to be worked on at once across the project. This brought some reductions to the development time but requirements were still frozen during the whole development cycle. (Boehm, 1988). Iterative development and the subsequent Spiral Model also started to introduce managing changing requirements and risk to the development process but failed to cut down on planning time and the need to heavily document everything.

Finally, the capability of quick change was recognized. Schwaber, the developer of Scrum, realized that rather than stressing predictability, development needs to accept change in order to be Agile. Also, what was necessary was stressing the importance of creativity in managing complex software development problems rather than heavy documentation (Highsmith & Cockburn, 2001) and techniques that would allow responding to change as quickly as it arose (Turk et al., 2002). These ideas, coupled with Lean Manufacturing discussed earlier eventually led to the Agile Manifesto.

The Agile Manifesto is an agreement made by seventeen representatives of the alternative software development movement that came together in 2001 to discuss new ways of doing development. The manifesto concentrates on individualism and interaction, working software over extensive documentation, collaboration and responsive change. (Beck et al., 2001) The emphasis on individualism was based on the fact that the development was too caught up in its emphasis on process. Working software was embraced since it was the final product rather than large tomes of documentation that was never maintained. Collaboration was valued over contract negotiation since business value is delivered instantaneously after the project has been started (Abrahamsson et al. 2002) Finally responding to change was highlighted because

"Requirement change was one of the most common causes of project failure". (Glass, 2001). The Agile way prioritizes features constantly in response to changing demands and even released features can be modified.

The aim of Agile in practice is to develop and release application functionalities in small proportional batches instead of releasing the finalized product all at once. According to Ambler (2002), there is no requirement for excessive planning ahead or documentation. Instead Agile strives to keep the development as simple and planning as adaptive as possible, focusing on continuous improvement and communication between people. People are the primary source of creativity and value. (Highsmith & Cockburn 2001).

Highsmith & Cockburn (2001) note that software is tested throughout the development cycle (in contrast to a separate testing phase later in the cycle). Customer participation also plays a key part in validating the constantly-released features. Concurrent testing and customer participation keeps the feedback loop tight and allows the teams to be better focused and spot errors in the software sooner.

Agile software development is a philosophy rather than a standard set of practices. There are several detailed processes that apply agile methods, the most popular of them being Scrum and Kanban.

The main idea of Scrum is based on sprint-oriented thinking. Sprints are development periods lasting that typically last 1-4 weeks, however no longer than one month. During these sprints, the features are coded, tested and integrated into the existing product. Daily sessions or "scrums" are held to track progress and create a plan for the next 24 hours. The items that scrum teams work on are arranged into a backlog of items or "stories" that are prioritized according to their perceived value at each point of time. Stories in Scrum refer to descriptions of features how they are perceived by the customer. (Scrum Guide, Mayer 2009)

At the start of the Scrum process, the Product Owner gathers input from customers and other stakeholders. These features are arranged into the product backlog. The Scrum team decides how much work is needed per feature and decides how much work it can do in the next sprint. Once the sprint is started, requirements and items in the sprint cannot be changed. The progress of the sprint is monitored closely with burndown charts and no changes can be introduced during an ongoing sprint. The teams have special Scrum Master whose job is to facilitate the work of the team and to remove any obstacles in the way of their work. Scrum teams have a very low hierarchy by design and the whole team is responsible in delivering the predefined

outcome by the end of the sprint which may mean sudden reallocation of tasks at an individual level if its beneficial to the team. (Mayer, 2009) Scrum has been seen to increase productivity, induce higher quality and reduce lead-times. (Schwaber, 2004)

Kanban was developed in Japan by Taiichi Ohno after World War II for manufacturing purposes while working at Toyota. The main goals of Kanban were to keep up a high level of production and to continuously improve the process. (Ohno, 1988; Gross & McInnis, 2003). Kanban was first used in a Software Development process by David Anderson in 2006.

Kanban highlights incremental change rather than radical change. Respecting the current process and the elements worth preserving in addition to embracing current roles, responsibilities and titles minimizes change resistance. Concurrently, agreeing to strive for continuous improvement constantly changes the process towards a more efficient one but takes a slow and gentle approach. (Anderson, 2010)

Kanban focuses on the flexibility of planning. The development team focuses only on one item at a time: the one that is prioritized first in the product backlog. This ensures that the team is providing maximum value back to the business. The product manager is free to re-prioritize work in the backlog if it's not currently actively worked on. There is no need for fixed-length iterations such as sprints used in Scrum. The key is to concentrate on the constant "flow" of value rather than fixed delivery dates. (Atlassian).

Firstly, Kanban visualizes workflow. At the very basic level, items of work are represented by cards. These cards are attached to a board with different columns for different stages of the process (the word kanban stands for "signal board" in Japanese). Typically, these columns are labeled Pending, Analysis, Development, Test, Deploy or something similar. Visualizing work in this manner makes it more tangible and therefore easier to focus on and prioritize. (Anderson 2010)

Work-in-progress is limited to a set amount of items at a time. This utilizes the Theory of Constraints where a bottleneck is found and protected with buffers (Goldratt 1990; Goldratt & Cox 2004). In Kanban, the buffers are the artificial card limits per each column. Even though items in other columns upstream might be finished, they cannot "pull in" new work from previous steps before some of their items are pulled forward. This highlights bottlenecks in the process and makes workers at other stages idle, allowing them to help completing the tasks at the bottleneck station. (Kanban blog). Measuring the outputs of a process before making changes and mirroring the results to the ones measured after the change makes it easier to see

how the process is evolving. Keeping the steps small and the feedback loop tight is essential for continuous improvement. It is essential, however, for the whole team to understand the process in the same way before changes can be made, highlighting the necessity of open communication. (Everyday Kanban).

Kanban is known to reduce lead-times and velocity of development, since focus is always crystal clear. Limiting work in progress, according to Little's Law, leads to decreased lead-times, affecting the number of software defects such as bugs in code and therefore improving the quality of the product.()

2.2 IT Operations

IT Operations is the area of IT responsible for managing the IT infrastructure of an organization. Gartner defines IT operations as "the people and management processes associated with IT service management to deliver the right set of services at the right quality and at competitive costs for customers." (Gartner IT Glossary) Furthermore, IT Operations Management is split into different components by the Information Technology Infrastructure Library (ITIL). According to the ITIL Service Operation, IT Operations are "IT operations management executes the daily operational activities needed to manage IT services and the supporting IT infrastructure" (Steinberg 2011). In other words, IT Operations performs a defined sequence of daily activities in order to keep IT going. A traditional operations role is measured by its ability to provide a reliable, optimized infrastructure. In effect, that means ensuring as little change as possible in order to guarantee that network resources are available so users can be more productive.

The main areas of IT Operations are Console Management, Job Scheduling, Backup and restore, Print and output and Maintenance Activities. Console Management refers to monitoring the IT infrastructure through various logging tools, reporting engines and IT controls. Job scheduling still plays an important role in IT organizations, where integrations, cleaning operations and other batch jobs have to be triggered manually at scheduled times. Backup and restore remains a key operation event though IT has been moving to central server control and management through various virtualization solutions and backup is therefore easier to perform. (Steinberg 2011). The role of printing and output has been shifting away from IT Operations to various print management solutions maintenance, but there are still plenty of IT Ops organizations that maintain printers and other output devices.

Infrastructure maintenance activities requested by the two functions Application and Technical management. This means provisioning new servers, migrating them and deploying applications to them. Operations is usually organized to work in shifts, so it can perform assigned after-hours tasks.

Facilities management is in charge of the physical sites where the infrastructure is located: server rooms, data centers and disaster recovery sites. This involves cooling, power, humidity, etc. as well as actual network infrastructure and servers.

Depending on the size of the organization, IT Operations are usually organized in three ways. It can either be a department or a sector in large organizations. In mid-sized IT organizations, it can be a virtual team that consists of also Application and Technical management team members. Finally, in small-size IT organizations, Service Desk operators can perform IT Operations tasks during their normal shifts. More complex tasks are escalated to on-call engineers or technical account managers.

3 What is Devops?

This section will detail Devops at a more in-depth level. First, I'll cover the history of Devops and the main principles behind the philosophy. Then, I'll take a more practical approach in describing the methodologies behind Devops. Finally, there is a section about the discovered benefits of the approach following a short note about the process of shifting into Devops practice. The main goal of this section is to give an overview to support the succeeding research.

3.1 History of Devops

The Devops movement is so widespread that it's surprising to think that it is only a few years old. Devops has formed out of a fundamental need and it is based on a simple yet powerful philosophy: Business works best when efforts are coordinated and when they are based on collaboration. As a result, its growth has been rapid.

Before the current evolution of Devops, there was no direct connection between development and operations. One of the early influencers of Devops was a Belgian consultant named Patrick Debois. Debois had assumed several IT roles in large organizations. In 2008, at an Agile Conference in Toronto he brought up the problems associated with the segregation of dev and ops and the fact that projects were assumed to be always late and the final product underperforming. (Rapaport 2014) This talk lead to the forming of the Agile Systems Administration Group (Paul 2014).

Next year, the first Devops speech was given by Flickr employees titled "10+ Deploys per Day: Dev and Ops Cooperation at Flickr". This helped IT professionals look at the problem from a different point of view and showed the world what can be achieved with a highly transparent and integrated development-operations collaboration. Debois and a few interested professionals are inspired to organize a conference called Devopsdays. Simultaneously the name of the movement is coined to the portmanteau "Devops". Devopsdays soon become a regular global series of community-organized conferences and a major force driving the Devops community forward. The twitter hashtag #Devops becomes an essential source of information. (Rapaport 2014)

In 2011, beginning with Vagrant, a tool to create and configure virtual deployment environments, the Devops community starts building open-source tools to facilitate the philosophy.

Two years after, Devops had started to formulate from a bunch of ideas and buzz to a more coherent, standardized practice. A plethora of seminal literature is released such as "What is Devops?" by Mike Loukides (2013), "Implementing Lean Software Development" (Poppendiek & Poppendiek, 2013) and even a business fiction novel called "The Phoenix Project" (Kim et al., 2013) that highlights the problems of current IT organizations and the benefits of making the shift to Devops in an engaging and inspiring way.

What was first thought to be a simplistic thought of fixing up a communications channel between developers and IT, has been expanding to include the whole development lifecycle. This includes "automation from the beginning of the process through the deployment of the solution in a system of incremental builds" (Dodson 2013).

Currently, organizations have started reaping the benefits of this new approach, with several well-known organizations such as Netflix, Amazon and Target (Null 2015).

3.2 Trends Behind the Evolution of Devops

There are several trends that have contributed to and enforced the rise of the Devops paradigm. In this section I will describe each paradigm in detail.

3.2.1 Consumerization of IT

Consumerization of IT stands for describing the cycle of IT first emerging in the consumer market and then spreading to a business or government environment. This is largely due to employees using consumer market technology and devices at home and then bringing them to the workplace. (Webopedia)

The field in consumer IT is changing quickly. For instance, Apple and Google need to keep pushing out new features in all their services, mobile operating systems and hardware. From yearly big updates to quarterly smaller ones, consumers are accustomed to expect these releases. Bug fixes and other critical improvements are made even more quickly and deployed at once to millions upon millions of devices and software. If the providers are unable to keep up with this pace, consumers are quick to react and switch to competitors. Marketing process is also changing from driving consumer behavior to one responding to it. (Sussna 2013).

In business IT, these consumer expectations are also "consumerized" and they apply to software as well. This also requires the software development and application delivery process

to be consumerized as well. However, with enterprise IT, there is so much more complexity, moving parts and integrations involved which prevent lead times from improving naturally. This calls for embracing Devops practices. (Elgan 2013)

3.2.2 Lean & Agile

Lean principles have had a major impact in the way Devops software development is made. The principle of reducing lead times is facilitated by Agile, while reducing waste, such as manual repetitive tasks is a key principle of Lean methodologies (Poppendieck & Poppendieck 2013).

3.2.3 The evolution of IT infrastructure to cloud-based services

IT infrastructure is described as the foundation of shared IT capabilities. This foundation provides the base for other business systems. These capabilities consist of internal technical expertise such as equipment, software, cabling and managerial expertise that are required to provide reliable services (McKay & Broadway 1989)

Traditionally, IT infrastructure has been viewed as a significant barrier or enabler in the practical options available to planning and changing business processes. (Grover et al. 1993) IT infrastructure and related issues have consistently been identified as a key concern of Information Systems Management. (Niederman et al. 1991, CSC Index 1994)

Furthermore, Grossman and Packer (1989) argue that IT infrastructure differs from applications in its purposes as a foundation for also future applications rather than current business functionality, and in the way in which it must cope with the uncertainty of future needs. Therefore, the financing of IT infrastructure has traditionally been different from applications and their benefits have been difficult to quantify, requiring board-level or executive management approval (Weill 1993). According to a research, about 55% of the total IT budget goes towards technology, processes and human resources that comprises IT infrastructure. (Weill 1991)

Major IT infrastructure components include hardware platforms, base software platforms, communications technology, client-server technology and other software components, common handling mechanisms for different data types and methods, standards and tools (Turnbull 1991; Darnton & Giacoletto 1992). These capabilities can be provided either in-house by the corporate IT function (Weill & Broadbent 1994) or by an outsourced service provider. (PE International 1995).

Finally, providing the IT components as a service to business and application stakeholders requires a human infrastructure that has the knowledge and experience to provide the policies, architectures, planning, design, construction and operations capability necessary for a viable IT infrastructure. (McKay and Brockway 1989; Keen 1995) The elements of IT infrastructure are visualized in Figure x.

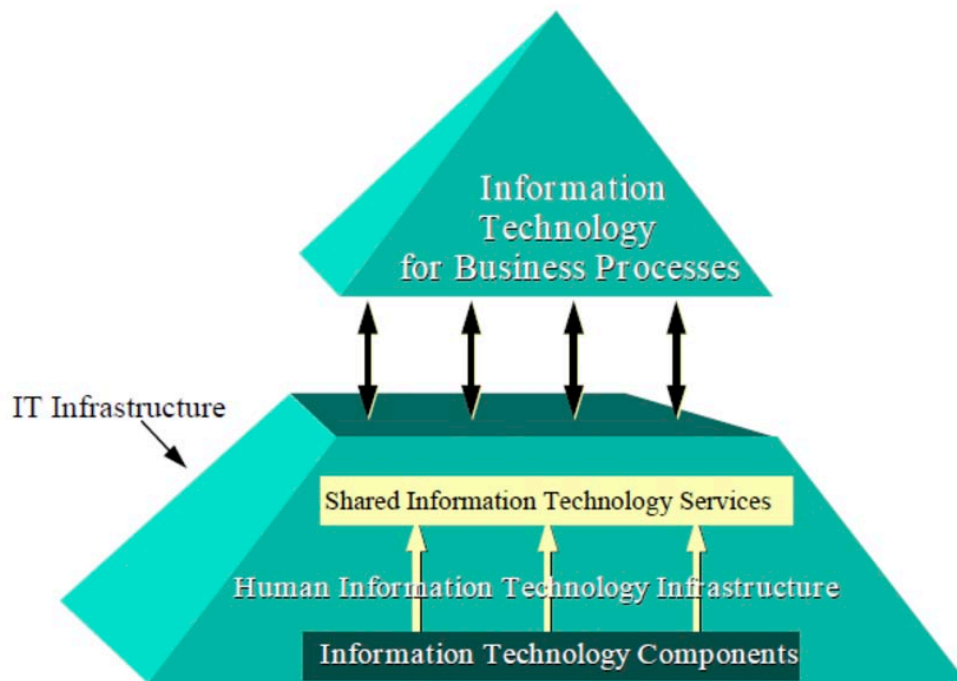


Figure 1. The Elements of IT Infrastructure

McKay and Broadway 1989, Weill and Broadbent 1994

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Cloud computing is not prerequisite of Devops but it is a major part of most Devops undertakings. "Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." (NIST 2011)

This enables servers to be accessed from anywhere over the Internet. Cloud infrastructure is ubiquitous by definition which means many providers introduce multi-location redundancy in case of site failures. This translates to a faster and more reliable service. (Buyya et al., 2009)

This enables operations to spin up new servers in a matter of minutes. This brings about agility and flexibility since traditionally server hardware needed to be purchased, set up in a physical location and configured separately. Traditionally, hardware needed to be purchased to accommodate peak times which resulted in servers being idle most of the time and it is impossible to use this extra capacity for other workloads. (Cervone 2010)

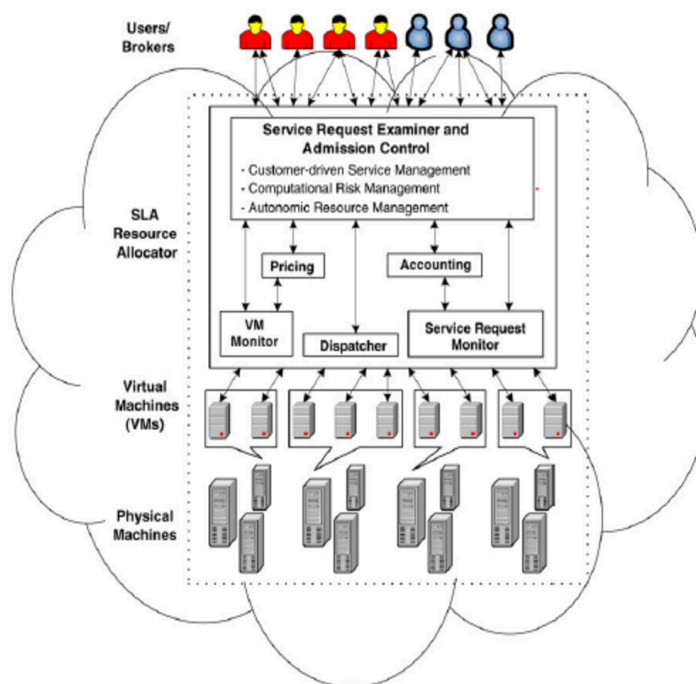
Cloud computing is also much cheaper than traditional hardware resources. Smaller and newer organizations with simple needs often get the most dramatic and immediate results from public cloud services. That's because they have no "sunken costs" in existing infrastructure and fewer internal applications to integrate with cloud platforms.

The emergence of cloud computing is related to service economy. In service economy the nature of software has changed from being customer-operated products to vendor-operated services. Furthermore, payment is based on consumption and utility rather than one-off purchases. (Buyya et al., 2009)

The main services cloud computing can offer are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). These are levels of abstraction, going from a more low-level approach where a service provider provides vanilla servers to pre-configured servers that are meant to run applications of a specific type finally to software that has all server-side implications abstracted. Cloud vendors are playing an increasing role within Enterprise IT, freeing up internal IT to focus on value added services. (Sussna, 2013)

Cloud is a direct response to the need of agility discussed earlier.

R. Buyya et al. / Future Generation Computer Systems 25 (2009) 599–616



Buyya

3.2.4 Virtual servers

Server virtualization is a major component of cloud computing. Rather than offering a physical server for each deployment, the resources of one physical machine can be split up into multiple "virtual server" operating systems running simultaneously on the host. This brings about economies of scale in addition to better utilization of resources. Services seldom require even the most minimum amount of resources that a physical machine purchased nowadays can provide.

In addition to better utilization of resources, virtual servers are "sandboxed" which means that their configuration has no effect on other virtual servers running on that instance or even the host, for that matter. Virtual server images can also be migrated to other physical instances in order to scale up, prevent failure if the physical machine goes down or to ensure continuous deployment. The physicality of virtual servers is diminished so that no one needs to know the exact location of the machine running the software any more. (Cervone 2010) Virtual servers is a key component of the automated delivery process used in Devops.

3.2.5 Deployment automation

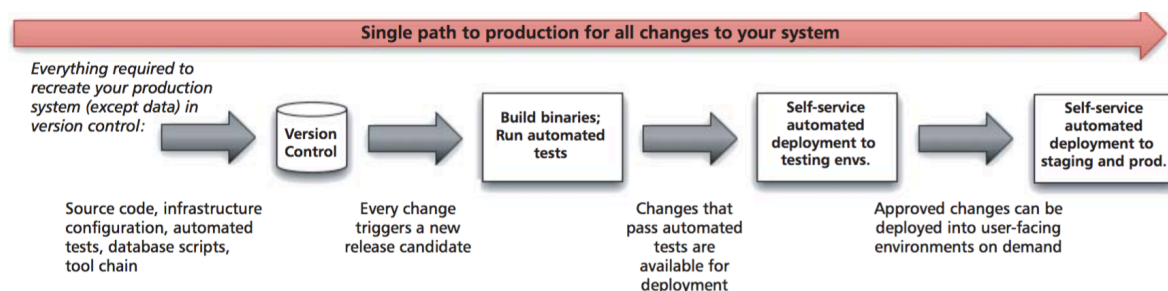


Figure 2 — The deployment pipeline.

Deployment automation is one of the key elements of Devops. Changes to a system pass through a pre-defined deployment pipeline involving a complex framework of different tools ranging from version control through automated testing frameworks to configuration management tools. (Humble & Molesky, 2011). The idea behind deployment automation is to reduce user errors in each of the phases and to increase deployment speed and visibility. Everyone who has access to the pipeline can immediately see in which step a release is currently on. The feedback loop is very tight: the developer is immediately notified when the deployment passes through each phase or if there's problems with the build.

3.2.6 Automated testing

Automated testing is essential to releasing quality software in rapid increments. First of all, test automation reduces the need for manual testing and speeds up the testing process significantly. Secondly, it ensures testing is carried out exactly the same way every time, minimizing the risk of user errors and oversights.

3.2.7 Infrastructure as Code

Infrastructure as Code (IaC) is a method for managing IT infrastructure following the same principles as software development. This involves version control, testing, small deployments etc.

Infrastructure as Code automates the provision and configuration of application servers and middleware using pre-defined automation logic. IaC automations are expected to be repeatable by design, so that the infrastructure can be brought up to a desired state from any arbitrary state. (Hummer et al., 2013) This process is facilitated by IaC tools such as Chef and Puppet. The key notion of IaC is idempotence, which means tasks can be executed multiple times always yielding the same results. IaC removes human error and makes sure that all machines in an infrastructure are configured how they are intended and all scripts are executed in the

same exact order, every time. This differs from infrastructure automation which just involves replicating steps on multiple servers.

IaC is easy to write and debug: similar environments can be brought up even on the laptop of the developer. Version control allows tracking changes to configuration over time with the possibility to rollback quickly to last working configuration. The caveats of IaC are extended amount of time needed to plan the configuration, bad configurations are duplicated everywhere once they are executed and finally the requirement that all configurations made to an environment must be present on the configuration template, otherwise the environments will differ and produce unexpected results. (Sitakange, 2014)

3.3 Challenges that Devops attempts to overcome

Devops came into existence because of certain problems in the traditional way of managing development and operations. This section will give an overview of the main challenges that sparked the evolution of Devops.

Michael Hüttermann, the author of the seminal "Devops for Developers" (2012) book, categorize the challenges into categories: Traditional Project settings, Organizational and cultural barriers, Misalignment of goals and incentives, "Blame game" and Operations as Bottleneck.

3.3.1 Traditional project settings

In traditional project settings, Hüttermann describes the following characteristics as problematic in a project setting: Hero cult, Emphasis on titles, Shadow responsibilities, favoring plan over planning. In an IT-project it is not unheard of to have an individual or individuals who fail to document and share their code and decisions with the rest of the team. In doing so, this "hero" is the only one who knows how to make a software work and to apply changes to it. Emphasis on titles in a project context is also dubbed problematic by Hüttermann, since titles usually correspond to a team members' duration working for a company. Seniority does not correlate with development skills, let alone interpersonal skills. Shadow responsibilities, such as tending to pet projects and other ambiguous areas, manifest as a mismatch between role descriptions and what is actually done resulting in problems with planning and coordination. Finally, favoring plan over planning isolates the intended results from the project goals. Alterations to the original plan are rarely made or even authorized since the goal has changed to following

the plan rather than delivering value-adding software in a timely manner. This holds especially true in the Waterfall model discussed earlier. (Hüttermann 2012)

3.3.2 Organizational and cultural barriers

Organizational and cultural barriers are one of the most definitive challenges Devops hopes to address. Having development and operations siloed in their respective teams or "some loosely coupled working groups" is a major impediment in achieving a unified goal of releasing value-added software quickly.

In addition to separate teams, dev and ops might not share a common language in communicating their ideas and challenges. This leads to misunderstandings, confusion and extra work on either sides as well as on the business side. The final barrier is fear: negative attitudes toward sharing knowledge and a common goal coincides with old habits and fear of losing power, reputation or influence. (Hüttermann 2012)

3.3.3 The misalignment of goals and incentives

Several researchers mention the misalignment of goals and incentives as one of the predicaments of Devops (Hüttermann 2012; Humble & Molesky 2011; Hussaini 2014). While Agile methodologies have done a lot to increase collaboration and transparency within the development group and quality assurance, operations are traditionally still left out of this equation.

Agile teams have goals of delivering an increasing number of features at an increasing speed. Business depends on them to respond to fast changing business and/or technology needs. Because of this intimate relationship, Development is often expected to bring in as much change as possible. (Hussaini 2014) On the other hand, operations is tasked with delivering these features into production with additional nonfunctional requirements of service stability. These requirements often conflict with delivery requirements. (Hüttermann 2012)

Stability is defined as "a resilient system that keeps processing transactions, even if transient impulses (rapid shocks to the system), persistent stresses (force applied to the system over an extended period), or component failures disrupt normal processing (Nygard, 2007).

It is the responsibility of Operations to ensure software availability in production. Its success is often measured with metrics that calculate server uptimes, software availability, security measures, capacity and response times. Together these attribute to Service Level Agreements

(SLA's) that express the users' expectations that all of the software features are fully available. (Hüttermann 2012).

It is established that changes to production systems are the main cause of system failures (Humble & Molesky 2011; Hussaini 2014). When downtime is experienced, operations are blamed for the outage directly, resulting in operations shying away from changes to the production system. The main goal of operations is stable and working software with high availability. Therefore, SLAs and delivery requirements have traditionally had a tendency to conflict. (Hüttermann 2012)

3.3.4 The "Blame game"

Another issue described in this context is described as the "Blame game" (Hüttermann 2012), or "A Toxic Blame Storm" (Turnbull 2010) a mistrust and juxtaposition between development and operations. The conflicts are often due to time pressures and they manifest in several ways.

A common scenario goes as follows: developers hand in a release that worked well in an isolated test environment, however failing to run in production. Operations blame developers for bad design and developers blame operations poor implementation and out-of-date infrastructure. (Turnbull 2010) This cycle goes on until the root cause is found out to be a mismatch between configurations or some minor detail that neither party knew about (Hüttermann 2012).

The reason behind this conflict lies in the fact that developers never have to run the systems and therefore do not understand the tradeoffs in scalability, reliability, performance and quality. Due to a lack of influence over the design of the application, operations tend to overcompensate the aforementioned by acquiring more expensive hardware that ultimately is never used. (Humble & Molesky 2011)

3.3.5 Operations as a bottleneck

As mentioned before, Agile Software Development embraces frequent and small deployments. Furthermore, Agile promotes collaboration but this does not normally extend to the operations people. Frequent deployment puts pressure on the operations side, widening the gap even more. (Debois 2011). The advantages of Agile processes are often "nullified because of the obstacles to collaboration, processes, and tools that are built up in front of operations". Software is released only in test environments and the releases queuing to production grows.

Operations are reluctant to deploy in such a pace, often referring to previous bad experiences of hasty deployment. There is often a heavy mismatch between completed functions and planned release dates. This mismatch is also influenced by horizontal optimization where the operations have a higher priority in optimizing the infrastructure than delivering releases more frequently. (Hüttermann 2012).

3.3.6 Lack of a feedback loop

One of the principles of Lean Software Development is eliminating waste. It is a common notion that features that are not directly needed to get the customers' current work done *should not be implemented* (Poppendieck & Poppendieck 2007). Subsequently, the knowledge of whether or not to implement a feature needs a working feedback loop between development and the customer. Humble and Molesky (2011) argue that there is a lack of contemporary feedback to base the feature development decisions on - introducing decisions based on out-of-date or incomplete data. This lack of information is a result of long lead times associated with non-Devops organizations.

3.3.7 Complexity of systems

Finally, the overwhelming complexity of systems makes it difficult to determine what systems are redundant. Decommissioning a system that still plays a part in the inter-related and fragile network of systems can have catastrophic consequences. Therefore, to play it safe, systems are kept running thus increasing the cost of maintaining systems. (Humble & Molesky 2011)

Table x summarizes the problems with agile development and exhibits a Devops solution to them. (Eficode)

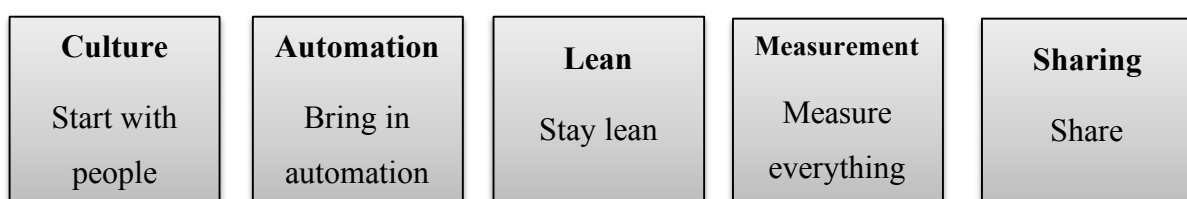
Problem with agile development	Devops solution
Delivery of new features to the customer is often delayed.	Devops tools are used to test and release new features as they are completed.
Completed software components are not compatible with each other.	Open interfaces and test automation make it possible to divide development into independent yet compatible parts.
Quality of the product is not ensured properly prior to release.	Devops tools and practices help automating quality assurance and reduce the need for repetitive manual work.
New features break old functions.	The quality of existing functions is ensured quickly and automatically after each change.

Budget goals and deadlines are missed.	The tools and procedures of Devops increase the transparency and predictability of the development work.
Developer teams and IT operations crews are not cooperating.	Developer teams and IT operations crews agree upon responsibilities together. Their goals are unified.

3.4 The key areas of Devops

This section will detail Devops from two points-of-view. Devops is no longer considered as a trendy subject of those working with the latest development tools. Contemporary thinking goes beyond technology into processes and people, and there are many different approaches to bringing them together. (Riley, 2014) .

Humble and Molesky (2011) purposes that Devops consists of four dimensions: Culture, Automation, Measurement and Sharing. These four dimensions each target the specific problems discussed in the previous section, the main goal being the alignment of incentives of all stakeholders, particularly development, testing and operations personnel. Furthermore, several sources add Lean to the definition as well.(Riley, 2014; van Ommeren et al.) Collectively this has been dubbed as the “CALMS” model: Culture, Automation, Lean, Measurement and Sharing respectively. This model defines the most essential points-of-view of Devops. These areas also describe Devops as a “flow”. (Riley 2014)



3.4.1 Culture

The adoption of Devops approaches begins from culture. While the tangible parts of Devops largely consist of new processes and tools for continuous deployment and integration, “Devops” is merely just another buzzword if the organizational culture doesn’t embrace all the things that comes in the package. (Wilsenach 2015)

An essential part of Devops is changing the organizational culture from a collection of silos into an openly collaborative way of doing things. This entails involving operations personnel

in the design and transition process of an application. (ITIL V3) Furthermore, they should attend necessary planning meetings, retrospectives and showcases of project teams in order to share their insights and knowledge already early on in the process. Also, rotating through operations teams is necessary for the developers and they should be equally available for root cause analysis and remedy in case of incidents in production. (Humble & Molesky, 2011).

Humble & Molesky (2011) suggest shifting from project- and responsibility-oriented teams into product teams. In essence, it means that teams are responsible for the entire life cycle of an application or service. The development team easily becomes disinterested in the operation and maintenance of a system if they employ a strict handover process to another team that will look after the system. Rather than having development that throws a deployable package “over the wall” to the operations team, operating the software becomes the duty of the team. Looking after the system becomes the product team’s pain. (Wilsenach 2015). This will force the team to take interest in optimizing the software code to run as smoothly as possible in production, as well as streamlining the testing and deployment phases of the product eg. through automation and improved monitoring mechanisms. The product team might consist of developers, operators and quality assurance personnel. The often-used dogma “You build it, you run it” applies especially in this context. This involves building quality into the product via automated tests. In addition to shifting the composition of talent in teams the responsibilities also change. The traditional operations team no longer carries the responsibility of keeping all things running: rather it merely provides the necessary infrastructure solutions for teams to run their software on. (Humble 2012).

Co-locating development and operations staff will help them to work together. Handovers and sign-off processes discourage sharing between individuals and also contributes to the “blame game” mentioned earlier. In contrast, viewing system successes (and failures) as a team effort effectively reduces the culture of blame. (Wilsenach 2015). Devops culture blurs the line between the roles of developers and operations staff. In some cases the blurring eliminates the distinction altogether. The extreme manifestation of this paradigm is “NoOps”, a model where the developer role has taken over all operations responsibilities through effective automatization and IaC or PaaS. (CenturyLink 2013)

A common anti-pattern is the introduction of a Devops role or a separate “Devops team”. This kind of approach has an adverse effect on the silos Devops aims to break down as well as the spreading of culture and practices inside the organization. (Humble 2012).

While development and operations talent consolidate to form product teams and new tools are introduced to the workflow of these teams, the need for control is also diminished. In order for the team to perform effectively, it has to be able to make their own decisions without the extra overhead of a convoluted change management process that is common in large enterprises that promote ITIL for instance. Shifting to autonomous teams involves building trust between managers and team executives as well as changing the way risk is managed. (Wilsenach 2015). New tools help facilitate these changes. Introducing version control to infrastructure, for instance, increases transparency and auditability in changes. There is no need to associate changes to infrastructure to change management tickets anymore since every change and the accountable individual is visible in version control.

3.4.2 Automation

In order to build the new kind of culture into an organization, processes need to change. According to Humble & Molesky (2011) this is made possible by various Devops tools and Infrastructure as Code covered in the previous section. The goal behind the automation practices in Devops lies in achieving low lead times and rapid feedback. This entails using a deployment pipeline that covers all changes that are to be made to a system by any team. The pipeline models the entire process of developing, building, testing and deploying a system. This "single path to production" is not just application code, rather it encompasses everything including the infrastructure (as code), different environments, database schemas, reference data and configuration. The pipeline acts as one of the gatekeepers into production - most of the time there is a wide coverage of automated tests that are executed against each change to catch any potential bugs, errors or conflicts in the change. Once the change passes all tests it moves onward to the next stage in the deployment pipeline. When the fitness-for-release has been established, actual deployment is a just a button-push away if automated provision of different environments is enabled. The upside of automated provision is clear: any environment (at any point of time) can be recreated should emergency rollback be necessary. (Humble & Molesky 2011).

Continuous delivery is a method used in Devops to further increase the speed of development and getting the features out through the door. It applies the use of automated deployment through the continuous delivery pipeline discussed earlier.

3.4.3 Lean

As described earlier, Lean methodologies are a major building block of Devops. In a Devops context, many practitioners prefer Kanban over Scrum since Kanban is viewed more flexible. .

3.4.4 Measurement

Humble and Molesky (2011) define measurement in Devops as “monitoring high-level business metrics such as revenue or end-to-end transactions per unit time”. At a lower level, it requires careful choice of key metrics in the delivery process such as lead time and the effect of releases on system stability. Measurement affects the way people work and visualization of these metrics is important so people have a clear view of how well the team is doing at any given point of time. Metrics also have an influence on discovering the bottlenecks in the process – an important step in keeping the process lean.

Another point of view to measurement is application monitoring in production. Traditionally in Waterfall-type of delivery models, application monitoring is only built downstream at the end of the development process, a step that is performed by operations to ensure application stability. A crucial approach in Devops is to build monitoring capabilities in parallel with the application – this is a requirement of the “you build it, you run it” –type of thinking. This might entail building health endpoints for easy status queries of a service etc. As applications are broken up to even smaller units (i.e. microservices), built-in monitoring mechanisms that can be automatically triggered play an ever-increasing role in measuring application stability.

3.4.5 Sharing

The final component of the CALMS model is Sharing. A transparent culture with effective mechanisms of spreading knowledge across teams is essential in bringing down the walls between development and operations. Humble and Molesky (2011) mention celebrating successful releases together and sharing tools and techniques as effective sharing mechanisms. Co-location, and face-to-face meetings with other teams further enhance social aspect of Devops. Finally, giving developers time to experiment with new things fuels the discovery process and encourages people to share these findings with the rest of the organization benefiting the organization as a whole. (Puppet Labs, 2015)

Like most components of the CALMS-model, sharing is also facilitated with new collaboration tools. In addition to improved auditability, introducing version control to everything and

sharing the code repositories across teams helps keeping all teams on track in terms of what techniques and technologies are being used, what code commits are made etc. Patrick Debois, (2011) one of the “fathers” of Devops, also mentions shared workflow as a key element. When an organization has a deployment pipeline that is visible to everybody, all team members know what deployments are in which stages in the workflow. In other tools chat, wikis and newsletters are also mentioned.

Already mentioned in the Culture section of CALMS, shared responsibility is a key element in motivating people to break down silos. Shifting operational responsibility to the developer side and reorganizing teams into product teams fosters collaboration. Previously, the pains of deployment were experienced solely by operations. In Devops, the pain is shared by the whole team and it is in everyone’s interest to make deployments as painless as possible. Instead of just having operations on call in case of emergencies, developers also carry pagers and are alerted if something goes wrong. (Debois 2011) Having a shared monitoring system for all application instances further increases transparency and encourages other teams to review what is going on in the infrastructure as a whole.

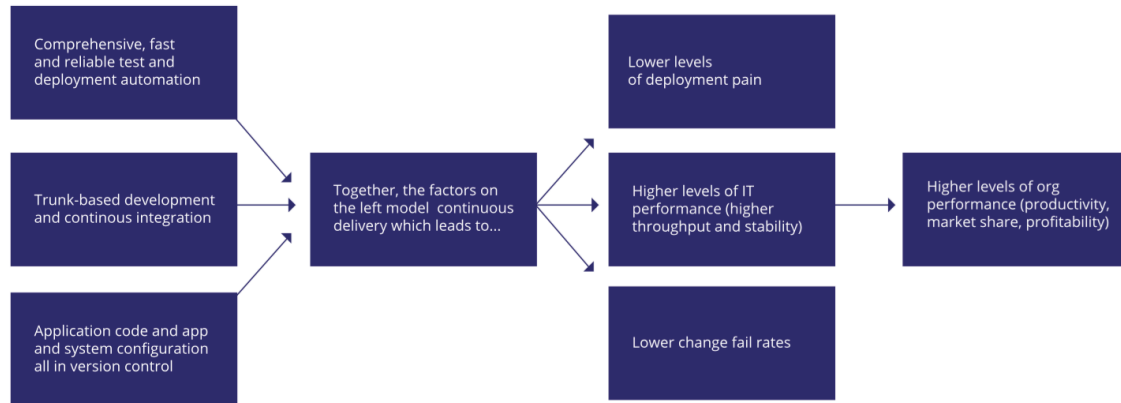
Finally, the introduction of Infrastructure as Code makes it possible to share existing setups with all teams. Having all teams commit to shared practices, unified operating systems and languages makes life easier for everyone. Using Docker as a tool allows the further unification of systems so all server instances can have the same setup without limiting the choice of technology when developing an application.

3.5 Benefits of Devops

There are clear benefits that can be drawn from the different components of Devops. This section will give an outline of the most important aspects of Devops benefits.

Figure 5

Path diagram showing relationships between continuous delivery practices, IT performance, deployment pain, change failure rate, and organizational performance



3.5.1 Reduced lead time and enhanced deployment frequency

Lead time is defined as “Time required for changes to go from “code committed” to code successfully running in production.” Additionally, deployment frequency stands for “How frequently the organization deploys code.” (Puppet Labs 2015) Applying Lean methodologies to cut down batch sizes and the use of automatization in the delivery process are key contributors in these metrics. According to the 2015 State of Devops report (Puppet Labs 2015), high-performing IT organizations have 200 times faster lead time than low-performing organizations. Also, by minimizing the bottlenecks and reducing the pains of deployment, high performing organizations deploy 30 times more frequently than low-performing ones. In this context, high-performing organizations use Devops approaches.

More deploys means faster time-to-market and an enhanced feedback loop. With an enhanced feedback loop, organizations have a better idea of customer reactions to features and consequently, better means of continuous improvement.

3.5.2 Enhanced change success rate

With a well set-up continuous development pipeline in place, organizations have seen a reduction of pains in the deployment phase. Change success rate is defined as the percentage of changes that succeed when rolled out into production. The 2015 State of Devops research states high-performing organizations have 60 times higher rate of success in deployments than low-performing ones. (Puppet Labs 2015).

The key to realizing this benefit is the use of version control, infrastructure as code, automated testing and common build mechanisms for different environments to prevent errors in code and differences in configuration. A high change success rate attributes to employee satisfaction as well as a lower level of burnouts in staff when unplanned, meaningless work and related stress decreases.

3.5.3 Enhanced stability

Stability in this context stands for error-free operation of a system and the ability to keep processing requests. Enhanced stability is realized by building quality into the system by utilizing automated tests, building applications with testability and deployability in mind and creating a culture for continuous improvement.

Stability is often measured with availability. As an example of enhanced stability, Fonecta's systems went from 95 % availability to 99.95% availability after adopting Devops approaches (Halkosaari 2016).

3.5.4 Enhanced Mean Time to Recover

3.5.5 Increased productivity

3.5.6 Reduction of costs

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4 Research Design

The chapter will detail how the research is designed. First, the overall research strategy and approaches taken in the study are explained. The second part describes how data collection was carried out and the reasons for selecting the approach. Finally, in the last subsection the quality of the research is discussed.

4.1 Research Strategy

This research is an empirical study of a relatively new approach to software development and delivery in the field of IT. Uusitalo (1991) states that an empirical study has to focus on a real world phenomenon and information has to be acquired with a systematic method. Due to a scarce amount of prior research in the field, the empirical data collection for this thesis was carried out by a systemic qualitative method. The thesis consists of rich insights to the topic with an aim to describe and explain the phenomenon. This supports the view of Miles and Huberman (1994). Further, the aim of qualitative research is to describe a phenomenon or an event with the goal to understand a certain activity or give a theoretically meaningful interpretation to a phenomenon (Eskola and Suoranta 1996).

The sampling data is chosen by judgement sampling. According to Hirsjärvi et al. (2009), using judgement sampling data is an important feature in qualitative research. By hand-picking the suitable interviewees, the best understanding of the phenomenon can be reached and the challenging areas of Devops uncovered. One of the contributions of qualitative study is the ability to describe a phenomenon in depth rather than making broad, generalized assumptions based on statistical analysis of data (Koskinen et al., 2005). Therefore, based on the amount of the available data, the thesis favors this research strategy.

Theme interviews were chosen as the method of data collection for this research. In order to zoom in to potential challenges in the Devops approach without making any assumptions beforehand, the data collection method needed to be flexible. According to Tuomi and Sarajärvi (2006), interviews are the recommended method of data acquisition where flexibility is important.

Additionally, the value of interviews also lie in the ability to ask for clarification and to find out more about specific issues mentioned. This holds especially true for themes that haven't been previously explored. (Hirsjärvi et al., 2009).

Theme interviews are adaptive in the sense they support making follow-up questions and modifications if an interesting topic comes up. The aim of this research was to find out and understand potential challenges in the field of Devops. Therefore, targeting questions and predefined discussion topics were decided with the overall aim of the research in mind (Tuomi & Sarajärvi, 2006).

Finally, an abductive approach was chosen to carry out the interviews. According to Dubois & Gadde (2002), abductive approach stands for first exploring and analyzing the existing theory followed by the empirical phase of the research. This method creates “fruitful cross fertilization” between theory and reality. The abductive approach was necessary for this study to first find out the main components Devops so all necessary areas could be covered in the interviews.

4.2 Data Collection

The data collection was carried out by semi-structured theme interviews with nine Finnish IT-professionals with previous in-depth experience of Devops initiatives. The interviews were structured by the CALMS-model described in the theory part of this thesis. Each section of CALMS was supported by targeting questions. However, conversations were allowed to develop freely in any direction in order to learn more about the different aspects of Devops as well as to uncover new sources of challenges and points-of-view.

4.2.1 Interviews

The study consists of nine semi-structured theme interviews with industry experts. The experts mainly come from organizations that have seen a Devops-transition and many of these interviewees were key sponsors of these transitions. Additionally, two of the experts come from companies that work with Devops transitions as a business. While the number of interviewees is low, they have extensive knowledge on the subject and some of them can be considered key players in the field of Devops in Finland. Gomm et al. (2009) state that the statistical significance does not influence the quality of the study. Taking a deep scope, rather than scratching the surface, allows to concentrate on the reasons and the ways to overcome challenges in Devops implementations, as supported by Dubois and Gadde (2002).

The data collection interviews were carried out between February 19th and March 8th of 2016. The interviewees were contacted through LinkedIn and e-mail and they were carried out at company premises or their nearby restaurants. On two occasions, two people were

interviewed simultaneously. The length of the interviews varied between 51 minutes and 1 hour 7 minutes. The average length of the interviews was 1 hour 1 minute. The interviews were held in Finnish and were recorded on the permission of the interviewees. The interview questions were based on the key areas of Devops, aiming to guide the interview. Most of the questions asked to describe a Devops transition process while a minority of them asked specifically to name challenges in related areas.

A summary of the interviews is displayed on table x.

The interviews were transcribed on March 14-March 20. The transcribed content was analyzed and given a title based on the topics mentioned in the interviews. The categories were coded thematically using Microsoft Excel. Further, the findings were grouped and categorized by axial coding into separate categories based on their similarity. The table of the categories is displayed in chapter six. The individual nuances are not included in the table due to space limitations. However, most of them emerge in the analysis section.

4.2.2 Interviewees

A total of nine people were interviewed in the data collection phase. The interviewees were picked by first identifying Devops initiatives in Finland (Commitcom, 2014). Next after getting responses from the first interviewees, I got recommendations from their personal networks for additional people. All interviewees are top professionals in the Finnish Devops-scene and have been deeply involved with Devops transformations in their respective companies.

The remainder of this section will give an overview of the interviewees and their involvement with Devops.

Erno Aapa

Erno Aapa is the founder of Devops Finland, a community of 750+ members attending Devops-related meetups and promoting discussion about the approach. Originally a developer, Aapa has experience in Devops consulting to companies such as Rovio and Elisa. Currently Aapa is working at Sharper Shape with focus on management and team leadership.

Lauri Halkosaari

Lauri Halkosaari is the CTO/CIO of Schibster Media / Tori.fi. With a background in full-stack development, web services and project management, Halkosaari was leading the Devops transformation at Fonecta before going to Schibster.

Pasi Katajainen

Pasi Katajainen is the Head of Technology at Nordcloud, a leading cloud architecture and Devops consultancy company in Finland. Originally a developer, Katajainen has experience at Nokia's HERE-unit in managing its cloud transformation where he got acquainted with challenges of Continuous Integration and Devops generally. Nowadays working closely with Devops-workshop-based solutions.

Marko Klemetti

Marko Klemetti is the CTO of Eficode. Eficode is one of the leading Devops consultancy service providers in Finland. Klemetti has been involved in many Devops implementations starting from the early days of Devops.

Juha Lehtosalo

Juha Lehtosalo is Portfolio Manager at YLE, the Finnish national radio. His area of responsibility is the development of YLE.fi web service. Lehtosalo has played a key role in the Devops transformation at YLE web services.

Joakim Sandström

Sandström is an application architect in Aktia. Aktia is a large bank in Finland. Sandström became involved with Devops through the banking renewal project in Aktia, that aims to renew all basic banking services with the use of 3rd generation software development.

Niilo Ursin

Niilo Ursin is the CTO of Alma Talent / Kauppalehti. With both developer and operations background, his team is responsible for the technology behind digital content. Ursin has been of the key drivers in Devops transformation at Kauppalehti.

Tomi Vainio

Tomi Vainio is Senior Production manager at Alma Talent / Kauppalehti. Before his 14-year career at Alma Talent, Vainio has also worked at Elisa and Sonera. Along with CTO Niilo Ursin, Vainio has driving the Devops initiative at Alma Talent / Kauppalehti.

Kalle Ylä-Anttila

Kalle Ylä-Anttila is Application Architect at YLE, the Finnish national radio. With 9 years of experience at YLE, his responsibilities lie in leading the operations-team and Ylä-Anttila has been deeply involved with the Devops-transformation at YLE.fi.

4.3 Quality of the Research

The quality of the research refers to validity and reliability of the research. Validity describes how well the research is mirroring the claimed research objectives. Reliability is referred to the repeatability of the results in methodology research. Tuomi and Sarajärvi (2006) claim that there are no specified rules to measure validity and reliability. Measuring validity and reliability in quantitative study is considered easier than in qualitative study since all findings are quantified and the research can be repeated using different sets of data. Using numbers to measure validity and reliability makes it easy to test the research (Hirsjärvi et al. 2009; Uusitalo 1991).

Qualitative research complicates the measuring of reliability and validity. According to Hirsjärvi (2009), the reliability and validity should still be addressed in all types of research. In order to increase research reliability and validity, a detailed description of how the research is conducted should be present. Koskinen et al. (2005) also argue that concentrating on a limited number of observations in qualitative research enhances reliability. Taking heed of these points, this research follows the aforementioned guidelines to improve the quality of the study.

5 Analysis

This section analyzes the information derived from the interviews. The thesis uses a data driven analysis for the purpose of creating a theoretic body of the qualitative data that is acquired by means of theoretical research. Data driven analysis can be divided into three phases (Miles & Huberman 1984). This research leans on these three phases in processing the acquired data.

1) Reduction of the data (simplification)

2) Clustering of the data (categorization)

3) Abstraction of the data (creating theoretic concepts)

Definition of challenge

Reduction of data, linking similar stories together

In order to reduce the data into manageable entities, I first identified the broad concepts of different challenges and linked similar stories from different individuals together. Next, I created an Excel-spreadsheet to manage the data and prioritized the challenges according to the frequency they were mentioned in interviews.

Clustering of data

Next, the data was clustered into different categories. There were 16 sub-challenges identified. Further grouping resulted in four general-level challenges that are listed below:

Challenge 1: Lack of Awareness in Devops

Challenge 2: Lack of support for Devops

Challenge 3: Implementing Devops technology correctly

Challenge 4: Adapting organizational processes to Devops

Next, I am going to elaborate on each set of challenges.

5.1 Lack of Awareness in Devops

As anticipated, the lack of clear definition of Devops brings forth confusion. The concept of Devops is not well understood, since the concept has not yet sufficiently matured. Also since Devops is such a hot word currently, a certain amount of resistance to ‘buzzwords’ also was identified in the interviews. The lack of awareness inside an organization creates bottlenecks and people-dependencies.

5.1.1 Maturity of the concept

One of the main challenges in bringing Devops to an organization was found to be the actual concept of Devops. The lack of definition for Devops was found to be confusing in six of nine interviews. This creates problems in getting organizations aboard to start embracing the approach and selling Devops-consultancy services to customers.

According to Ylä-Anttila, a common misconception about Devops is that it is a “product” or a “toolset” that “one can buy straight from IBM and be done with it”. Mentioned both by Ylä-Anttila and Halkosaari, some configuration management software companies seem to be selling their products as a “Devops suite” that further promotes the confusion. As I mentioned earlier, the market for tools that can facilitate the automation part of Devops is growing rapidly and these companies are taking full advantage of the buzzword Devops. Furthermore, Halkosaari mentioned that consulting companies are also trying to capitalize on the buzzword by offering Devops as a package to customers whereas the real advantage of Devops is organizational and process change.

Another common misconception was that Devops is either a “Devops guy or a Devops team” (Katajainen) or a “separate operations team that is doing some coding” (Ylä-Anttila). Neither is it a role or a title (Aapa). The problem is that everybody is using Devops the way they see it and how their organization has been inspired by it. Aapa stated that the usage of the term is also dependent on the size of the organization: for startups Devops might entail radically different things than for large enterprises. For instance, startups are usually born cloud-native and are operating on a pure PaaS infrastructure, for example Heroku¹, which is closer to a NoOps-model where all operations are automated and handled by the service provider. In contrast, large enterprises might operate on a mixture of self-hosted and IaaS infrastructure that requires more configuration management, coding infrastructure and automation. (Halkosaari). As a conclusion, Devops for startups might mean pure development with no operations while Devops for enterprises might mean the whole product development process going even further over the boundaries of both development and operations to involve product owners as well as quality assurance, Katajainen states.

On the other hand, Halkosaari brings forth an alternative point of view: it can also be seen as a great freedom and strength for Devops that it is not centrally directed by any foundation in

¹ Heroku is a leading PaaS (Platform-as-a-Service) provider that offers an automated platform to host applications without the developer having to worry about the underlying infrastructure.

contrast to Scrum foundation or ITIL and the British Military. Devops gets its trends and best practices directly from the community and interested industry professionals – everything is kept lean and therefore true to the approach.

5.1.2 Allergy to buzzwords

There are several interviewees who see a problem with the Devops-buzzword. Partly due to the fact that Devops is currently such a hot word and partly due to its ambiguity and “wild” usage, the value of the word has decreased and Devops is now met with a certain kind of reluctance. Aapa mentions that the “allergy” can be seen in people that are naturally against trend phenomena, people who think “it’s too mainstream, I am against it even though I don’t know what it is really about”. This is important to mention because it affects how to sell the idea and how it is received on the other end.

Many of the interviewees suggest a strategy of dropping the umbrella term ‘Devops’ and talking about reducing lead time and introducing automation instead (Halkosaari, Aapa, Ursin) while others say the “hotness” of Devops actually works to its advantage (Klemetti) or that the reluctance can be used to educate the other party (Katajainen).

5.1.3 Lack of Awareness

Devops is a new concept for many people. As mentioned before, it is a challenge to grasp the whole concept of Devops. For management, it might not be even necessary to understand Devops (Vainio, Halkosaari) but for the people inside the IT organization where the change is taking place, the concept needs to be shared and communicated in order for everyone to work together with the level of collaboration Devops requires for it to work.

The overall lack of awareness about Devops is viewed as a challenge by several interviewees. Even though the majority of the organization might already be Devops-oriented, there are always areas in the organization where Devops has not reached yet. (Sandström). Not limited to the concept of Devops, the components such as Continuous Delivery or Continuous Integration may be unknown.

In an organization that is moving fast with these technologies, training all necessary people can be easily overlooked. (Katajainen). Formal training is not enough. Sponsors for Devops are usually the key people that share knowledge inside and across teams. (Katajainen) Often they do not have higher position in a team and therefore they are a bit more difficult to find. Moreover, managers might not even know that these people are key resources in the teams for

sharing and educating their colleagues. (Klemetti). If the specific knowledge needed to use the tools is not readily available, the people dependencies required to operate them become bottlenecks and risks for continuity. (Aapa)

Finally, sharing and spreading the knowledge of Devops is considered easy in the start when large changes are happening in parts of the organization. Once an equilibrium is reached and business is going as usual, sharing and spreading common practices may easily be forgotten. Implementing a Devops-approach in new teams usually re-ignites active sharing but promoting sharing as a routine can be difficult. (Sandström).

5.2 Lack of Support for Devops

Another central challenge identified was the lack of support for Devops. The lack of support may show on several levels: on the management level, on the team level or as an overall lack of trust.

5.2.1 Lack of management support

Lack of management support is considered one challenge in Devops. Because Devops has to do with lots of changes to the ways different teams are working on a daily basis, a high commitment and support at the top level of the organization is necessary to change the company culture. The role of the managers is to “untie the knots executive personnel cannot untie themselves”, to “break down the walls” and allocate more time for communication and sharing. (Klemetti).

According to Klemetti, there are three profiles of managers that each reflect their attitudes towards Devops: tech-savvy, open to ideas and teflon. Tech-savvy managers are the easiest ones to convince. First of all, they usually have heard of Devops and are open to discuss it. If the argumentation is made correctly, the ideas will usually go through without problems. For instance, Ursin described the management at Alma-Talent tech-savvy and therefore IT could get their initiatives to develop infrastructure even at the cost of a longer overall project lifecycle approved easily.

Managers open to ideas are usually willing to discuss an idea but they are more concerned about the financial side of the changes. It might be challenging for a development organization to translate the improvements into cost reductions and other financial gains. Therefore, argumentation must be well thought out for it to pass. Fortunately, Devops can be tried out with small initial commitments. Finally, managers with teflon profiles are the most difficult to

deal with. In many cases, these managers are not even aware of the issues a Devops initiative is trying to solve. Thinking that the organization is doing just fine with current methods is quite common, or the notion that current systems are so complex they cannot be developed in the proposed way. Klemetti argues that it might end up in a sort of “guerilla warfare” with the teflon managers, training people to do things differently one person at a time without any help from the management. These kinds of endeavors may still end up in failure, says Klemetti, giving an example of an anonymous company where the main sponsor for Devops was lost when the management saw the person as a burden and decided to let the person go, even though the person contributed to Devops in that organization significantly.

Manager profile	Description	Strategy to gain support
Tech-savvy	Prior knowledge of Devops, open to new technologies	Reasonable argumentation
Open to ideas	No prior knowledge of Devops, open to new ideas	Argumentation based on financial gains
Teflon	No prior knowledge, no realization of issues	“Guerilla warfare”

The lack of “real” support from management is also an issue once the decision to adopt Devops has already been made. Klemetti states that more often than not, management doesn’t understand the scope of the change. Simply throwing money at Devops doesn’t lead to much, rather there are several aspects that the management needs to address. First of all, according to Katajainen, change is often mistakenly viewed as a R&D change where eg. an automation pipeline is set up. The change in culture needs to be facilitated by empowering different boxes with different communication tools and practices and seeing this as a value-adding measure: not just wasted time away from “actual” development work (Klemetti). Along with culture, staff needs to be properly trained to new processes and tools and it needs to be determined whether any 3rd party consultants are needed in any part of the change process. Moreover, the nature of product development changes from iterative work to continuous development and therefore eg. feature specifications need to be generated accordingly. (Katajainen).

5.2.2 Lack of team-level support

Lack of support can also be seen on the team level. The main reasons for lack of support lie in the change of working methods, change of roles and the organizational readiness to communicate. The change of working methods is perhaps the most profound change in Devops. As mentioned in the literature review, developers take more responsibility in running software, operations take more responsibility in building coherent, preferably code-driven infrastructure and quality assurance can focus on actual quality and not manual testing. As many tasks are automatized, the fear of a machine replacing jobs is a common one that raises opposition on the executive level.

There are roughly 3 types of issues related to this: lack of trust, lack of skills and lack of readiness to communicate. Lack of trust can be found anywhere where work gets shifted away from people. In some cases, especially when development is tasked with coding infrastructure, operations do not trust that development have the required skills to do this adequately, eg. setting up proper security measures etc. (Aapa) Moreover, people might be reluctant to let automation handle tasks that would require administrative rights – doing these tasks manually through change management processes ensure that it has been approved by the required people and not by an automated sequence. (Sandström).

Lack of skills is a very common issue when dealing with new tools and processes. Katajainen and Klemetti both realize the issue where there might be some people in the organization, especially operations and QA people that are intimidated by these new tools and skill requirements and instead of striving to learn them, they initially choose to oppose change. The key to solving this issue is to communicate that the change is necessary and once the skills have been acquired, the job will actually be more enjoyable. At the same time the members of staff have increased their market value by learning new skills. Among the interviewees, the fear of operations or QA staff losing their jobs was not encountered, although Devops can be sold to an organization as a means to reduce the need of manual work.

Finally, Halkosaari points out that inertia at the team level may rise from outside development and operations, namely from stakeholders who rely on traditional means of communication such as ITIL and release management, change advisory board (CAB) meetings and steering committees. While many of these practices prevail in a Devops organization, the nature of communication changes from a structured set of practices to being free and transparent, with

the aid of new tools and processes. Sandström mentions that the organizational structure might also be an impediment to free collaboration.

5.2.3 Lack of trust

Somewhat related to the challenges with managerial support, Lehtosalo and Ylä-Anttila identifies a challenge more widely related to Devops adoption: earning and keeping up trust with stakeholders who are not involved with day-to-day operations.

The challenge is the clearest at the very top level of the organization. In the traditional model, the services are developed in steering committees and CAB meetings and other agreements where deployment dates are set and approved. However, in a Devops approach the batch sizes are smaller and releases more frequent so many of these meetings can only deal with more abstract, higher level changes (Ylä-Anttila). This shifts responsibility more towards the development team and the teams are getting more and more autonomous (Vainio). In the process, a lot of the information and documents produced by the development teams to bring to these meetings are not produced anymore (such as weekly reports mentioned by Ylä-Anttila).

Without these agreements and reports, all stakeholders do not have a clear view of the day-to-day operations which may lead to situations where they are doubting whether the development teams “know what they are doing” according to Lehtosalo. This requires a certain level of trust between stakeholders and development teams without having to “constantly remind everyone that they are professionals and letting them do their work”.

Another related challenge is contracting external operations resources to work in teams that are doing Devops. Previously work was contracted on a transactional basis where a contractor would offer a certain service based on agreements such as SLA or deliverable based on a specification document. What Lehtosalo noticed at YLE was that it became significantly more difficult to contract people to work in teams, and managing these contracts were more difficult because they were now based on trust and not hard deliverables such as service availability or some feature in a product. The performance of these resources could not be determined in the same manner as in the agreement-based model.

5.3 Implementing Devops technology correctly

The key technological breakthroughs in Devops is the creation of an automated continuous delivery pipeline. This new way of delivering software has a profound impact on the processes

in development, quality assurance and operations. “Automatizing inefficient processes leads to automatizing inefficiency.” (Jyrki Kasvi) Sandström used the quote to point out that setting up automation technology alone doesn’t cut it. While automation promises benefits in lead times, application stability etc., implementing this technology and processes is not entirely challenge-free.

5.3.1 Automated testing

7 of 9 interviewees found challenges with building automated testing inside the development process. Many of these challenges are people- and skill-related, while others are more related to the way testing is organized in the new approach. In pre-Devops models, testing is usually handled downstream, that is, after features have been developed and handed off to the next person. Devops automation requires tests to be written simultaneously as a part of the development process. As a result, the need for manual click-based testing is reduced, testing time is dramatically cut and possible breaking errors can be spotted more easily since tests are run more often and in the exact same manner each time.

One challenge mentioned by several interviewees was the attitudes of developers towards writing automated tests. First of all, even though new practices regarding testing have been agreed upon, there are developers that have a hard time embracing these practices and continue to develop without writing tests (Katajainen, Vainio). According to Katajainen, writing tests is not considered fun nor a part of developers’ role. It might even be considered waste (Aapa). Many still assume testing is someone else’s responsibility (Ylä-Anttila, Katajainen). Finally, developers might not have adequate skills to do testing properly. For instance, lack of knowledge and know-how of different testing frameworks is quite common but somewhat surprisingly there have been cases where some developers didn’t know automated testing frameworks even existed (Katajainen).

Aapa names a few measures that can be taken to combat these reluctant attitudes towards testing. Leading by example is effective: writing a few tests that the team can take a look at makes the team understand what is expected of them. Additionally, when the team is making pull requests*, the person who makes the approval should not do so before test coverage is adequate (Aapa). By making it clear that no changes go through to production without the agreed level of tests forces developers to make writing tests a part of their development routine. In doing so, it is also made clear that the responsibility of testing lies on the developer (Ylä-

Anttila), and not the quality assurance people whose job is not to click through the application every time there's a change ready to be delivered. (Klemetti)

Another aspect is defining the added value of writing automated tests. Since writing tests is also a financial issue it is often a challenge to find the correct level of test coverage. As Vainio puts it, tinkering with tests is not their core business. Ursin reminds that all software is not equal: critical functionalities such as functionalities that handle monetary transactions should be tested thoroughly while others, such as components for internal use should only have a rudimentary coverage. It is up to the developer to understand the required level. In some cases, specifically in the banking industry, Sandström claims it might be cheaper to have a manual tester do the job rather than spending too much development time in complex test cases.

5.3.2 Automation tool challenges

Five out of nine interviewees identified challenges with automation tools, namely determining which tools are right for the project and the maturity of automation tools. The challenges with automation tools were not considered technical - the configuration of these tools to work in a well-oiled continuous deployment pipeline was considered a laborious task but not a challenge per se.

Determining the suitable tools was considered a challenge since the industry is young and different options are plentiful. Katajainen highlights the main decision points: will the company go with open source tools that are easier to replace or will they commit and pay for these tools? Additionally, should the tools be hosted locally in some environment or should they be cloud-based? Are there restrictions to what tools an organization can use? For instance, if an organization is already using a test framework, is it "Devops-friendly" and if not, can it be replaced?

The other challenge related to tools is their maturity. Since many of them are quite new, they do not always work as intended (Ursin), they do not support all needed environments (Sandström) or they might become outdated too fast (Aapa). Unfortunately, the most common solution seems to be waiting for new versions to come out or trying to find workarounds using other tools. Aapa says it's not necessarily a bad thing: building your toolset out of various pieces that are easily replaceable also prevents vendor lock. However, the downside there is the ever-increasing skill requirements for different software.

5.3.3 The type of the application

The final set of challenges in automation is related to the type of the application that is the target of automatization. Three interviewees of nine identified this challenge. The most common problem is that the application architecture is not at all suitable for virtualization. Klemetti mentions the still-common mainframe computers in banking- and insurance industry, while Halkosaari mentions the type of architecture that has negative scalability – this can be databases that only have a limited amount of socket connections etc.

One response to these kind of architectural limitations is splitting down the application into small units, sometimes called microservices, and virtualizing as many of them as possible. This leaves only the core fraction of the service to run on the legacy hardware, and other parts of the service can now be developed with a Devops-approach. While all of this might be possible, many interviewees (eg. Halkosaari) remind that all transitions of this magnitude should only be considered if the business case is well-established. In some cases, it might be wiser to use the allocated automation money on developing a new, modern system from scratch (Klemetti).

5.3.4 Fragmentation of tools and practices

Another related set of challenges lie in common practices both inside and across teams. First of all, the use of various technologies and tools across teams is considered a challenge. (Ylä-Anttila, Vainio) Having different environments for continuous integration and not having a common deployment pipeline is an anti-pattern for the very foundation Devops is built on.

There are several ways of overcoming this. Keeping all application code in version control and available for everybody to audit and review makes all application development transparent and prevents reinventing the wheel effectively. Moreover, people from all teams can contribute to the code if they need a specific functionality implemented. This is especially true with infrastructure. Rather than making a different version of the infrastructure to use with a specific application, the enhancements made are available for all other applications that use the same infrastructure template as well. (Aapa). This prevents fragmentation and people dependencies (Sandström).

Sometimes it is necessary to use different technologies for application development. With the help of containerization, different software components written in different languages can function on the same infrastructure. Ylä-Anttila and Halkosaari both mention the use of Docker, which is a platform containerization software to address this issue. As a result, the programming language can be chosen somewhat freely by the developer. In other situations

where the use of containerization is limited (especially with legacy systems), building common Application Programming Interfaces (API's) around the special software helps isolate it from the common architecture while still providing the same kind of programmability as other common software do. (Ylä-Anttila, Halkosaari).

Additionally, the use of different communication channels across teams is to be avoided. All but one interviewee say their IT organization has started using Slack to counter this issue. In addition to basic chat functionalities, it's beneficial to be able to follow and subscribe to conversations based on their topic, which promotes cross-team communication. (Ursin, Vainio etc)

5.3.5 Finding the right scope for monitoring

With the help of Devops and new tools such as the cloud-based New Relic, it becomes easier to monitor different services in a consolidated view (Ursin). However, when more and more operations duties are shifted towards development, "No-Ops" being at the far end of the spectrum, it becomes also increasingly important to monitor the right things.

Many of the systems are better-equipped to raise alerts when a defect is found but this has introduced a problem with prioritization: with an increasing number of alerts it is often difficult to find which ones are critical and which ones need attention. (Vainio, Sandström) Receiving hundreds of different alerts daily from different sources is sub-optimal and costly to inspect. Therefore, setting ground rules for incident severity prioritization, used channels and which people are notified is necessary to overcome this challenge.

5.4 Adapting organizational processes to Devops

Devops promises speed and flexibility in the delivery of software. The speed and flexibility might not be fully realized, however, if the organizational processes do not accommodate it. The processes have to do with Devops initiation, software development mode, change management processes, metrics and team-related challenges.

5.4.1 Starting off with the correct scope

A challenge that was frequently mentioned was the notion of starting off with the correct scope in regards to Devops transition. As explained in the literature review, Devops calls for the virtualization of IT infrastructure. For existing applications, it means the server

stack needs to be converted to code that is able to provision the functional equivalents of previous hardware servers in order to run the application. For new applications the process is much easier: starting with a clean slate the infrastructure can be configured without any limitations using the latest available technologies and industry standards. Furthermore, the monetary investment is a significantly cheaper than in a traditional setting since no new hardware is usually needed.

While the application may be at the core of Devops, Klemetti reminds that the process and practice changes related also to software development, culture and IT governance are so significant, trying to start off with too much can become overwhelming.

Katajainen elaborates that starting off with several applications may result into reinventing the wheel when solving similar problems among projects. Additionally, solving the same problems in an uncoordinated manner can also lead to different solutions that cannot be later unified. A small scope proof of concept ensures that the automation is set up in a way that it can be reused later in other projects and that the governance model works the way it's intended before any of it is rolled out to the rest of the organization. Also Halkosaari notes that a proof of concept works: using only a fraction of the cost of a traditional software project, a successful Devops-oriented initiative can easily gain traction in the organization since it's possible to realize early wins and thanks to new measuring practices, the results can also be quantified.

Klemetti names four factors that affect how much an organization can do at the start of their Devops-initiative. The most important factor is effective agreements. If, for instance, the organization's operations is outsourced to an external vendor, there is little an organization can do to existing applications before their current contract expires or is renegotiated. The second factor is the type and scope of IT-infrastructure. There are still many companies that use mainframe computers or other special hardware as key components in their infrastructure that are not easily virtualized. Thirdly, application architecture also affects the outcome: using software technologies that are easily containerized makes them very flexible for Devops approaches. On the other hand, using complex application architecture that have a lot of dependencies in various places might make the job more difficult. Finally, Klemetti describes company culture as the last factor. The level of communication in the organization is a major component. The key question is: Does the organizational culture make it possible for developers, quality assurance, IT operations and those responsible for product specifications to come together and develop the product or service? Are they even in the same country? As stated above, taking a small-scale approach to Devops with early wins decreases the risk

considerably and buys time for the rest of the organization to adjust to the new ways of working without having to make a considerable leap of faith.

5.4.2 The mode of Software Development

There was a very common challenge associated with Scrum as an agile software development method. The main challenge with Agile, according to Klemetti, is that many organizations are developing the software in sprints without the goal of releasing the features immediately when they're finished. "You can do agile forever without ever releasing your software. Agile itself does not translate to added value for customers", says Klemetti. Moreover, Aapa claims that doing Scrum by the book is too rigid for the purposes of Devops. The model where a release package is created at the end of each (2-week) sprint does not fit well into the Devops-approach where the goal is to release once a feature is completed, often several times a day. This is the reason why Kanban fits into the Devops approach better (Aapa, Vainio, Sandström, Katajainen).

Many interviewees mention that their organization started off with Scrum by the book. However, according to Lean principles many teams were allowed to modify and cut down on the ceremonies that were considered waste. After the process, many organizations found themselves doing "something similar to Kanban" (Vainio). Teams got to decide autonomously the best ways of working after having experimented what works in Scrum. For instance, at Alma Talent, the daily Scrum check-up meeting was considered useful but not necessary to meet face-to-face every day so it was therefore moved over to the chat-tool Slack instead (Ursin). A good feature of Scrum is that it is better-equipped to guide overall product development on a longer time frame, however there are other tools that can be used to tackle that (Aapa).

Other challenging aspects with software development methods were identified when working with 3rd party vendors. Working methods between the two parties may conflict: the 3rd party might not be able to deliver features reasonably at the same pace the procuring organization expects it to. Also specification changes in a market-driven, volatile environment may prove to be challenging for the vendor to make if they work in a non-agile mode that does not allow specifications to change. (Sandström)

For instance, some of YLE's development is procured from third parties and the agreements were traditionally made on delivery-basis. According to Lehtosalo, this means that YLE was paying vendors to develop features and these features were considered as investments, which

in turn had pressure to increase YLE's value. In a continuous delivery setting, however, batch sizes are smaller and delivery is much more incremental, it was challenging to determine the price and value for each small increment. Therefore, the agreements were renegotiated to procure development work instead of features which also had major implications on budgeting: instead of release-based budgeting, budgets had to be converted into accommodating a reasonable amount of continuous development. (Lehtosalo)

5.4.3 Change Management Processes

The other major challenge with Devops-style continuous delivery is how it fits into the organizations current Change and Release Management Processes. Very often enterprises follow eg. ITIL processes by the book which are not necessarily designed to handle the amount of changes and the velocity of development Devops can bring to an organization.

Klemetti offers a point of view where ITIL is especially good for "writing in stone" who to blame when something goes wrong with a change. The approvers are usually held responsible. However, Devops changes the situation and brings responsibility back to those that actually develop the software. Aapa stresses that it is extremely important that the developer is the one who takes the code into production. Not wanting to break anything, developers are forced build quality and integrity into their code. The reasons are transparent: every change can be tracked at the source code level – who changed and what (in the Git version control system a view that shows line-by-line code changes is actually called "Blame") and in the delivery pipeline. There is no longer a need for rigid change processes.

Ylä-Anttila describes their solution to the challenge: making own adjustments to the process to better serve the product development is a must. Therefore, at YLE they introduced "Domain CAB" –thinking where there's a person close to the team that is responsible for change management related to their specific domain. As long as the domain CAB-person has a holistic view of what is going on with their respective service, the approval chain does not extend further. For larger releases such as a new version, a more formal process is in place but other than that, changes are mostly business as usual. Aapa's views are in line with Ylä-Anttila's: the change ticket is informative, describing the change that was already deployed to production. According to Lehtosalo they have solved the problem in a manner that there is one change ticket that "basically says we're going to make changes all the time. So far the arrangement has worked out fine with the management, but if something goes wrong then we're back at the

discussion whether these models should be based on trust or more formal agreements”, says Lehtosalo.

All interviewees that saw change management as a challenge agree that ITIL, for instance, is still considered a well-thought library of principles but the prescriptive nature of some practices does not support Devops in all cases. Therefore, local adjustments and flexibility is necessary to overcome the challenge.

5.4.4 Finding common metrics

Finding common metrics for both development and operations as well as quality assurance was considered challenging. Traditional metrics such as uptime and the amount of tasks completed in a Scrum sprint, for instance, are still viable but the focus is shifting. The “Devops” metrics such as lead time, code quality and overall system health can be measured with new kinds of tools. Once the metrics are in place, it may take time for the numbers to be comparable with other applications. According to Klemetti, there are managers who might be over-enthusiastic with these new metrics. When these metrics are first put in place for an application that has been in development for several years, it is natural for these metrics, such as code quality, to be below average. The challenge is finding the balance between improving the score of the metrics and keeping up a rapid pace in development. Over-emphasizing the metrics can have an adverse effect on the development since a lot of time goes to refactoring code and making the application perform better from a metrics-point of view.

5.4.5 Team challenges

When development and operations are brought together to form Devops, the idea is that the amount of collaboration and communication between the two increases. Several aspects, such as location, the time spent together with other teams and product teams have some associated challenges.

Several interviewees recognized that having development and operations in separate locations is challenging for Devops. Unfortunately, an organization structure usually mirrors the way software is built (Conway’s law) which is an impediment to open communication. The same goes with other areas of the product development as well. Klemetti mentions a worst case scenario where some organizations still send their product specifications over from another building as printed documents without meeting with development in order to explain it all. In cases where co-location is not an option, Katajainen suggests visiting other teams at least once

a day. Klemetti says the only logical solution is the simple one: Co-locate development and operations.

While co-location serves as an informal medium of communication, there is a need for other, arranged meetings with teams as well. Ursin, Vainio and Ylä-Anttila all mention demo days where teams come together to show other teams what they have been working on. Moreover, hackathons (intense coding periods where something functional is built from scratch) work towards educating people about different tools and technologies as well as getting to work with different kinds of people from different teams. (Halkosaari)

6 Findings and Discussion

The purpose of this section is to summarize the findings relevant to the research question: *What are the main challenges organizations face with Devops?*

The secondary research question attempts to describe how these challenges can be overcome: *What are the ways to overcome these challenges?*

There were 16 notable challenges mentioned in the interviews. The four main challenges that emerged from these findings are: Lack of Devops Awareness, Lack of Support, Implementing Devops Technology Correctly, Adapting organizational processes to Devops

The following table summarizes the findings for each main challenge.

CHALLENGE	SUB-CHALLENGES	REFERENCE
Lack of Devops Awareness	Maturity of the Concept	
	Allergy to Buzzwords	
	Lack of Awareness	
Lack of Support	Lack of management support	
	Lack of executive support	
	Replacing agreements with trust	
Implementing Devops Technology Correctly	Automated testing	
	Automation tool challenges	
	The type of application	
	Fragmentation of tools and practices	
	Finding the right scope for monitoring	
Adapting organizational processes to Devops	Starting off with the correct scope	

	Mode of Software Development	
	Change Management Process	
	Finding common metrics	
	Team challenges	

The first main challenge of Devops is the lack of awareness. The novelty of Devops as a concept results in ambiguity, confusion and the word meaning different things to different people. Moreover, being a hot buzzword at the moment, people can grow reluctance towards it which hurts organizational buy-in and the sales of Devops-related consultancy services. Additionally, Devops is not adequately known throughout the IT organization and training these people is often overlooked. Joe Hendren agrees in his blog that Devops has a marketing problem: “Clearly, the concept of Devops has a marketing problem, and it's making the hurdle to entry for new participants in the Devops community needlessly high.” (Hendren). Another blogger, Topher Marie (2014) notes that an organization’s business drivers change the definition of Devops in their respective organization. In resonance with many interviewees, Hendren advises to “Leave buzzwords at home”. However, Spikelab notes that labeling phenomena with buzzwords is necessary to cross the Chasm in the Technology Adoption Lifecycle where the majority of adopters are risk averse and require enough momentum and bandwagon effect to adopt a technology. Therefore, “being able to identify a set of good practices and tools with a word like Devops is a necessity if we want to hope for larger adoption in the industry”. (Spikelab). Katajainen says spreading Devops to all parts of the organization needs proper management effort, where training and the identification of key sponsors (Klemetti) is imperative for success.

The second main challenge of Devops is the lack of support. The subchallenges consist of lack of management support, lack of team-level support and the lack of trust. The main problems with management are “teflon” managers mentioned by Klemetti where Devops sponsors have to exercise “guerilla warfare” inside the IT organization, training individuals one person at a time to embrace the new ways of working. Many times management doesn’t understand the

scope of change: Devops is viewed as an R&D project instead of a major organizational shift (Moss-Bolaños, 2016). The 2013 State of Devops (Puppet Labs, 2013) report is in line with these findings: According to the report, 48% of the respondents stated that the value of Devops is not understood outside their group.

On a team level, the change of working methods and roles leads to inertia where automation that replaces manual tasks is not trusted. Joy Ma (2014) from New Relic also lists these challenges in her blog “5 Things You Need to Know When Implementing Devops”. Both the interviewees and Ma suggest that showing concrete ways of making daily jobs easier and more meaningful via Devops is the key of overcoming this challenge.

Additionally, the readiness to communicate without fixed CAB meetings and change management processes can be an issue. Finally, without these fixed managerial tools the clear view of day to day operations is obstructed and needs more trust. The lack of trust between management and teams is considered an impediment.

The 2015 State of Devops report (Puppet Labs, 2015) states that IT managers play a critical role in any Devops transformation. Building trust and enabling the teams to fulfill strategic objectives is the key to Devops success. By ensuring work is not wasted and investing in developing capabilities inside teams is necessary to overcome this challenge. Both the earlier 2013 report and the ebook by New Relic (2014) suggests that building open channels of communication between teams is essential to Devops success.

The third main challenge identified is Implementing Devops Technology Correctly. It is important to note that “correctly” here is broad term: it deals with having the correct attitude, building correct patterns and common rules and practices.

With automated testing, it was noted that there lies an initial challenge of team member buy-in. The attitudes behind automated testing need to be changed and training to write tests promoted. This can be done with leading by example and setting the correct kind of approval gates to control and ensure that tests are indeed written in the required way.

Organizations have challenges choosing the correct tools, due to the related risks of application maturity. When choosing tools for automation, the risks of changing them often need to be taken into account. Therefore, the use of setup where tools can be replaced and interchanged is recommended to overcome the challenge.

The type of application was found to be an issue since not all applications are suitable for virtualization. When either legacy applications or applications using special, non-common technologies are fitted into Devops, the use of microservices-architecture and containerization is key. Finally, when establishing a culture for sharing and collaboration, extra attention needs to be paid to common practices and tools. Riley (2014b) also identifies the challenge with fragmented tools for support when the original adopter leaves and more importantly in a governance aspect. To overcome the challenge, there is a need for common tools, rules and practices with both infrastructure and communications. Riley (2014b) also mentions tool management and the use of shared services. Using common infrastructure code, common API's and abstraction via the use of containers in order to use the same infrastructure for all applications regardless the technology they are using is necessary to prevent a fragmented landscape.

Finally, monitoring scope was also an issue to some interviewees. They speak of 'alert fatigue', also mentioned by Bass et al. (2015). Aligning practices used in monitoring across different applications combats 'alert fatigue'.

The fourth and final main challenge relates to Adapting organizational practices to Devops. Firstly, establishing the correct scope when starting with a Devops initiative can be challenging, since there are no practices in place. The risk with doing too much results in reinventing the wheel with different applications in an organization structure that is not yet equipped to handle a large scale Devops transition. This view is supported by a blog post by Moss-Bolaños (2016), who suggests creating a tiger team with a focus to show early results in order to facilitate management buy-in.

The mode of Software development is also considered a challenge. Doing Agile development without the goal of releasing features as soon as they are ready doesn't create value for customers. This is especially a problem where the goal is to release only when a Scrum sprint ends. Also, working with outside vendors in different mode of development is also problematic. These views are supported by a blog post by Upguard "Devops and Kanban – a Match Made in Heaven", (Upguard) where taking the "time box" out of the equation is deemed beneficial for Devops, because it enables the team to work on a feature exactly the amount of time required with the required amount of resources. Additionally, cutting down ceremonies considered wasteful and renegotiating contracts with 3rd parties to fit the development mode of the team are ways to overcome this challenge.

Heavy change management and approval processes such those suggested by ITIL are considered challenging in a fast-moving development environment if they are followed by the book. Levitan (2016) notes in his blog post that these should be aligned carefully with the development velocity in order to prevent bottlenecks in delivery. Supporting the views of the interviewees, the processes need flexibility in order to make Devops work (Techbeacon, 2015). Further agreeing with the findings of this research an article by Forbes (Bloomberg, 2015) quotes that “many organizations have been able to modify ITIL to work within the Devops context, but it’s unclear whether such rework will provide much value long-term. ‘ITIL isn’t part of the success patterns for the fastest moving, most innovative organizations,’” Finally, Chris Jackson, CTO of Rackspace sums this challenge up: *“We have seen a trend proliferated by ITIL and post-Enron legislation that led to the operations teams becoming mired in managing risk and compliance. For them it wasn’t possible to think about doing things quickly. As a result, operations could find themselves bypassed by developers who wanted, and probably needed, to take risks and speed up deployment so they started to use shadow IT. Ultimately they were no longer aligned and working to completely different outcomes.”* (Rackspace 2014)

Finding common metrics in all aspects of product development was further considered a challenge. When these metrics have been found, there needs to be a balance where the metrics, such as quality of code, can be improved without the cost of slowing down the speed of development.

Finally, the challenges related to collaboration between teams were mentioned. When development and operations are brought together to collaborate in Devops, it’s considered challenging if these teams are physically located in different premises. Additionally, the scarcity of random and free encounters with people from other teams constricts the flow of ideas and co-operation. To overcome these challenges, the interviewees stated that co-location is somewhat a necessity, and arranged meetings like demo days help to “cross-pollinate” between teams to foster the kind of exchange that is required by Devops.

7 Conclusions

7.1 Research Summary

The constantly changing business needs and the requirement for faster time to market with software of present day has created a paradigm shift towards a 3rd generation Software Development philosophy called Devops. The lack of collaboration between IT Operations and Software Development as well as mismatch in configuration between development, testing and production environment has made deploying software releases slow and painful for many organizations. Different incentives between teams makes it difficult to work towards a common goal of bringing added value to customers.

A Devops approach to software development brings down the walls between the teams and align incentives through a collaborative culture, automation, lean principles, measurement practices and sharing. The benefits of Devops have been shown to be substantial with a significantly faster time to market and increased software stability. The organizational change is substantial which makes the challenges in adopting Devops an interesting topic to research. This thesis studied the challenges of Devops by interviewing nine experts who had been involved with Devops initiatives in their companies.

The findings were divided into four main challenge categories based on their topic. Due to the novelty of the approach, the concept of Devops for many is unknown or biased which hurts the overall implementation of practices. The lack of support in both management and organizational levels is a hindrance, since especially changing culture needs strong support and organizational buy-in in order to succeed. The toolset needed for Devops is particularly diverse and finding the fit, correct usage and attitudes towards that technology is challenging. Finally, when shifting to Devops that requires a certain level of lean principles and agility, aligning existing organizational processes such as the change management process to accommodate the new way of working was found challenging.

7.2 Conclusions

This part of the thesis provides a foundation to evaluate the implications of the results and conclusions related to the challenges of adopting Devops. There are four categories to address each of the main challenges and provide means to overcome the challenges.

7.2.1 Clearing misconceptions and spreading the knowledge

The main challenge behind Devops is the novelty of the concept. The findings related to the challenge encourage clearing any confusion related to Devops early on. It is necessary to highlight the gravity of the change: Devops is not merely a product or a toolset. Neither is it a team or a role. The entire IT organization should adapt to the new culture and processes that follow. Another takeaway of the study suggests dropping the term Devops at first where reluctance and biases are met. It is easier to talk about the benefits of eg. collaboration and automation before mentioning Devops. Finally, training and educating the entire IT organization across the board early on helps to combat the awareness challenge. Finding the key sponsors inside teams is also important since these people are very efficient in spreading knowledge in teams.

7.2.2 Building commitment and trust

An organizational change can rarely happen without the full commitment of management and teams. In getting management aboard, the findings conclude that identifying the type of management profiles, whether they are tech-savvy, open to ideas or teflon, helps choosing a strategy to onboard management. It's also a question of attitude: Devops needs to be communicated as a major change and not just a R&D endeavor. Similar to management, teams need to be engaged as well. The change of roles and new skill requirements should be communicated as a factor of increased job satisfaction as well as an increase to employee market value, considering that there is an increasing demand of "Devops skills" in the job market. Finally, promoting trust and autonomy both horizontally across teams and vertically with management is important because many of the agreement-based models such as rigid RFC processes and CAB meetings are not necessarily valid anymore. Devops needs organizational flexibility and velocity in decision-making.

7.2.3 Establishing common ways of working and leading by example

The main challenge with Devops technology is applying it correctly across the organization without fragmentation or varying practices and ways of working in teams. Highlighting the responsibility of single developers in playing by the rules (eg. writing automated tests) and leading by example was found efficient in establishing common principles. To further prevent fragmentation, being as transparent as possible helps to prevent reinventing the wheel with most technologies. This entails source code repositories and version control visible to everybody, with the possibility of everyone making changes to the code as well as common

infrastructure and shared communication channels such as Slack, which enables topic-based conversation across teams. Where special technology is required, such as legacy systems, the application can be split up into separate services and further virtualizing them. Abstracting technology layers as far as possible is recommended in order to maintain a common architecture, with the help of containerization tools such as Docker. The challenge with the maturity of “Devops tools” such as configuration management tools can be overcome by keeping the tools interchangeable in order to prevent vendor-lock.

7.2.4 Ensuring the flexibility of the organization

As mentioned several times before, Devops needs a certain amount of flexibility in an organization to succeed. The findings of this study suggest that starting a Devops initiative off with a quick proof of concept is essential to Devops success. Not only does it create traction in the rest of the organization by being able to show early wins, decisions can be made quickly and flexibly, leaving the rest of the organization to follow when the “coast is clear”. Flexibility is needed also in the Software development mode the company uses: overcoming this challenge entails ensuring that the development mode fits into the Continuous Delivery approach with a goal of releasing features as soon as they are ready (Instead of waiting for the sprint to finish). With change management flexibility is needed: a rigid RFC process with CAB meetings for instance, might need some adaptation to get the most out of Devops. For example, the Domain CAB –mentality used at YLE is a way to overcome the challenge. Finally, adding informal time spent together with teams and co-location improves communication.

7.3 Limitations and suggestions for further research

The study is limited to only nine industry experts. Although the interviewees all have considerable experience in this field, the amount of interviewees is quite small. Moreover, all the interviews were done in a Finnish context. A large part of Devops is connected to company culture. Therefore, the Finnish company culture might influence culture in the targeted companies and might have resulted in somewhat different implications if the study had been conducted in a different country. The lack of academic research in the field of Devops had an effect on the literature review and therefore many of the sources used in especially the literature review of this study were non-academic.

Although the results of this study are not directly generalizable, they do provide implications of what the main challenges of adapting a Devops approach to Software Development and Operations might be. In addition, the means to overcome these challenges are based on the experiences of the interviewees.

For further research I suggest expanding the amount of respondents and carrying the research out as a quantitative analysis. A larger research material could give a better overall picture of the challenges and finding out which of them are the most common ones. Moreover, a study carried out at a later point of time might give a more mature picture of Devops.

7.4 Own reflections

A new concept such as Devops is always met with a certain amount of skepticism in the beginning. For me, Devops seemed like a great suggestion for improvement of rigid processes in an organization, although grasping the concept in its entirety took a considerable amount of time. It wasn't until the very final interview with Klemetti when I thought I knew enough about Devops to actually write a thesis about it. Bearing this in mind, it's no wonder that understanding Devops also proved to be one of the main challenges in the findings.

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