



**CHALMERS**  
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# Assessing IT Maturity using the 'Stairway to Heaven' Maturity Models

Master's Thesis in Management and Economics of Innovation

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Color photo of a person developing software.

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## Abstract

The automotive industry has undergone major changes during the last decade due to digitalization. As software has become more integrated into modern cars, the automotive firms have been forced to transform their businesses into being able to develop software on a large scale. As a part of the effort to improve their software development processes, a software intensive R&D business unit (the R&D BU) within an automotive company has set out to gain a better understanding of their current capabilities. In this study, we aim to help the R&D BU to understand their software development capabilities by performing an IT maturity assessment of the business unit. Based on the assessment, we also provide the R&D BU with recommendations on what steps to take in order to improve these capabilities.

Our findings indicate that most of the teams within the R&D BU score low on the maturity assessment due to three main reasons. The first reason is that the teams within the R&D BU are developing safety critical systems, which require a high amount of documentation and traceability due to regulatory constraints. These characteristics makes it hard to improve their IT maturity by adapting agile practices, which is the next logical transition. The second reason for the low maturity assessment score is that the teams currently lack the capabilities to frequently integrate and test small chunks of newly developed code. Finally, the third reason for why the teams score low on the IT maturity assessment is that they have not yet come far in automating the collection and analysis of user data.

In addition to conducting the IT maturity assessment, the models used for the assessment have been extensively evaluated and discussed in this report. In order to help practitioners to apply the maturity models, we have created a set of questions that translates the criteria from the models into a practical assessment tool. This contribution is the first published attempt to provide questions that can guide the application of the models to a practical setting.

**KEYWORDS:** AGILE DEVELOPMENT, CONTINUOUS INTEGRATION, DATA DRIVEN DEVELOPMENT, IT MATURITY ASSESSMENT MODELS, THE STAIRWAY TO HEAVEN



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# List of Abbreviations

- BU: Business Unit
- CD: Continuous Development
- CE: Continuous Experimentation
- CI: Continuous Integration
- EBF: Evidence Based Firm
- IS: R&D as an Innovation System
- PI: Program Increment
- PM: Product Manager
- RTE: Release Train Engineer
- STE: Solution Train Engineer
- TM: Team Manager



# 1

## Introduction

### 1.1 Background

The automotive industry has undergone major changes during the last decade due to digitalization. As software has become more integrated into modern cars, the automotive firms have been forced to transform their businesses into being able to develop software on a large scale (Giaino & Berger, 2017; Bosch & Eklund, 2012). This thesis project was conducted at an automotive company (the company) who are putting large resources into developing new software intensive solutions that are used throughout their different car models. To ensure fast, qualitative software development that emphasizes business value creation, the company is in need of efficient software development processes.

Software development has improved significantly during the last decades, and several development models have been created that emphasize short development cycles and continuous feedback from customers. Several software companies have adopted these models and continue to improve them step-by-step. However, developing software that will be used as part of an embedded system (e.g. a car) requires the consideration of several factors that pure software companies do not need to take into consideration (Giaino & Berger, 2017; Bosch & Eklund, 2012). How can, for example, a car manufacturer utilize customer data to improve a system that combines several components, both hardware and software, with combined lead times of several months?

In order to improve their software development processes, we were requested by the company to investigate the Holistic DevOps framework (HoliDev), created by professor Jan Bosch at the Chalmers University of Technology. The HoliDev framework is one attempt to improve software development in embedded systems (Bosch, Olsson, & Crnkovic, 2018). The framework is formed around the premise that there exists three main software development methods, namely requirement driven development, data driven development, and AI-driven development. The requirement driven development is described by Bosch et al. (2018) as an approach where the software is developed to specifications that are provided by the product management. The second development method, data driven development, is in place when the developers first receive an outcome or a quantitative target. The developers are then free to use different solutions to improve the metrics of that target. Finally, in AI driven development, a company uses techniques such as machine learning to

let the software itself create new components based on collected data (Bosch et al., 2018).

However, after conducting a pre-study at the R&D business unit that is responsible for this software intensive development at the company (the R&D BU), we discovered that the HoliDev model was not yet mature, nor detailed enough to be implemented. Thus, we made the decision in accordance with the R&D BU to change the scope of the report. To be able to reach their final goal of implementing HoliDev, we found that the R&D BU first needs to focus on how to become more data driven in their development. By drawing upon earlier studies by the creator of the HoliDev framework, Jan Bosch (Bosch, 2017), we discovered that Bosch has done previous work that describes how organizations can work to become more data driven. In the book *Speed, Data, and Ecosystems* (Bosch, 2017), Bosch describes a set of maturity models called the Stairways to Heaven that can be used to guide organizations in working more data driven and, in extension, getting one step closer to implementing the data driven development method of HoliDev. We therefore decided to use the Stairways to Heaven maturity models to analyze where the R&D BU currently is, and what it needs to achieve in order to become more data driven and thereby get closer to implementing HoliDev. In order to provide a foundation for the R&D BU to improve their data driven software development, the domains that will be analyzed are how the organization works to increase the speed of its development, and how it uses data to support its development. The domains will be evaluated with the Speed Stairway to Heaven and the Data Stairway to Heaven maturity models, which will be further described in chapter 2.

## 1.2 Purpose

The purpose of this Master's thesis project is twofold. The first purpose is to provide the company's R&D BU with an understanding of their current software development processes in relation to the Speed Stairway to Heaven model and the Data Stairway to Heaven model by Bosch (2017), and what they should do in order to increase their maturity in these domains. The second purpose is to investigate the usability and rigor of Bosch's models when applied to a practical setting. The second purpose is not translated into a research question, but is instead discussed in detail in chapter 8.

## 1.3 Research Questions

In order to fulfill the purpose of this thesis project, the following two research questions will be answered in the report. Both research questions will be answered in chapter 7, and a summary of the answers will be presented in chapter 9

- *RQ1: What is the level of maturity within the R&D BU based on the Speed Stairway to Heaven and the Data Stairway to Heaven models?*

- *RQ2: What are the next steps that the R&D BU should take in order to increase its level of maturity in the two studied domains?*

## 1.4 Delimitations

This report will focus solely on the software development processes for the R&D BU and will not focus on the development of hardware. The analysis will be performed on the divisions within the R&D BU. However, one division within the R&D BU, Division C, could not be reached during the data collection phase due to Covid-19.



# 2

## Literature Review

Chapter 2 provides a description of the academic theories that form the basis for the theoretical framework used in this master's thesis. Section 2.1 presents a general description of IT Maturity Models which outlines the origins of IT maturity models and why they are used. The description of the maturity models is complemented by section 2.1.1 which provides a theoretical view on how to evaluate the quality of such models. Finally, sections 2.2 and 2.3 presents the two maturity models that are used in this thesis, namely the Speed Stairway to Heaven and the Data Stairway to Heaven.

### 2.1 IT Maturity Models

In order for companies to improve their IT capabilities, they first need to know what to measure, and how to measure it. After deciding on what to measure and how to measure it, the organizations need to decide on what they should compare those measurements with in order to assess their current situation. Finally, after understanding their current situation, the organizations are ready to decide on how to move forwards (Becker, Knackstedt, & Pöppelbuß, 2009). One set of tools that has been developed to help companies in this work is called maturity models.

Maturity models assess a company's maturity within some domain based on a set of criteria, usually placing the company somewhere on a 5-point scale (De Bruin, Rosemann, Freeze, & Kaulkarni, 2005). The sequential steps of the maturity models and its corresponding criteria give the company an objective way of evaluating its current situation, as well as showing the company what capabilities to improve in order to advance up the maturity levels (Becker et al., 2009). From their introduction in the '90s with the Capability Maturity Model (CMM), maturity models have spread to a large number of domains such as Innovation Management, Strategic Alignment, and Enterprise Architecture (De Bruin et al., 2005). Within the domain of IT, two of the most established maturity models are currently the Capability Maturity Model Integration (CMMI), which is an integration of several CMM-related models, and the Software Process Improvement Capability Determination (SPICE) by the International Organisation for Standardisation (ISO) and International Electrotechnical Commission (IEC) (Patón-Romero, Baldassarre, Rodríguez, & Piattini, 2019).

One group of less established maturity models are the Stairway to Heaven models

developed by Bosch (2017), which focus on helping embedded systems companies evolve within the domain of Software Development. Table 2.1 shows the different Stairway to Heaven models and their corresponding sub-domains. Sections 2.2 and 2.3 will give a detailed description of the first two of these models, as they will be the focus of this master’s thesis. In order to evaluate the quality of Bosch’s maturity models, section 2.1.1 will provide a brief theoretical overview that will serve as the basis for the discussion in chapter 8.

<b>Maturity Model</b>	<b>Sub-domain in focus</b>
The Speed Stairway to Heaven	The efficiency of software development in software-intensive systems industries
The Data Stairway to Heaven	The use of data to increase the effectiveness of the software company
The Ecosystem Stairway to Heaven	How the software company works with software ecosystems

**Table 2.1:** The set of Stairway to Heaven maturity models.

### 2.1.1 Evaluating IT Maturity Models

As pointed out by Becker et al. (2009), there seems to be a constant stream of new maturity models, which often look at domains very similar to those that have been studied before. This implies some degree of overlap between the models, and since the authors seldom give much information about the development of their models or the result they bring (Becker et al., 2009), an evaluation of the maturity models themselves is warranted.

Based on the work by Hevner, March, Park & Ram (2004) regarding the guidelines of design science, Becker et al. (2009) have adopted several requirements that they believe must be fulfilled in the development of a maturity model. The eight requirements are presented in Table 2.2.

Requirement	Description
R1 (Comparison with existing maturity models)	The need for the development of a new maturity model must be substantiated by a comparison with existing models. The new model may also just be an improvement of an already existing one.
R2 (Iterative)	Maturity models needs to be developed through an iterative, step by step process
R3 (Evaluation)	All principles and premises for the development of a maturity model, as well as usefulness, quality and effectiveness of the artifact, must be evaluated iteratively.
R4 (Multi-methodological Procedure)	Developing maturity models is a process that engages a multitude of research methods. The different research methods needs to be used in a well grounded and delicate manner.
R5 (Identification of Problem Relevance)	The relevance of the problem solution proposed by the projected maturity model for researchers and/or practitioners must be demonstrated.
R6 (Problem Definition)	The prospective application domain of the maturity model, as well as the conditions of its application and the intended benefits, must be determined prior to design.
R7 (Targeted Presentation of Results)	The presentation of the maturity model must be targeted with regard to the conditions of its application and the need of its users.
R8 (Scientific Documentation)	The design process of the maturity model needs to be documented in detail, considering each step of the process, the parties involved, the applied methods, and the results.

**Table 2.2:** Requirements for the development of maturity models (Becker, Knackstedt, & Pöppelbuß, 2009).

### 2.1.2 Hybrid Development Methods

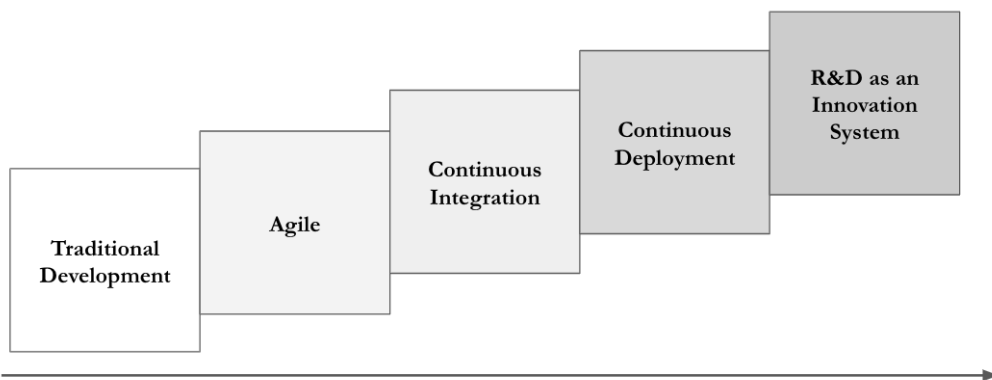
To end this section, we introduces the notion of hybrid development methods, as described by Klünder, Hebig, Tell, Kuhrmann, Nakatumba-Nabende, Heldal, Krusche, Fazal-Baqaie, Felderer, Bocco, et al. (2019). According to Klünder et al.

(2019), hybrid development methods are created when firms combine ideas from different models and methods in order to create something more suitable to their context. Two of the main conclusions of the study are that most firms create hybrid methods, and that creating hybrid methods is generally a good strategy in order for the firms to reach their goals related to the methods. The main drawback that was found by Klünder et al. (2019) is that it is not always obvious what strategy a firm should use in order to create a hybrid method in the first place.

## 2.2 The Speed Stairway to Heaven

In an ever-changing environment where disruptive technologies and new competitors constantly threaten to challenge the status quo of a market, firms need to be able to adapt and change in order to survive. There exists several examples of big players that have fallen throughout the 21st century, e.g. Facit and Kodak, partly explained by the fact that they were too rigid to respond to changing external trends (Lucas Jr & Goh, 2009; Sandström, 2013).

The first key capability that organizations need to develop in order to succeed in their data driven development is summarized by Bosch (2017) in the Speed Stairway to Heaven. This maturity model focuses on shortening the feedback loops in an organization’s software development in order to increase the chance that the organization makes successful R&D investments. As is common for maturity models (Becker et al., 2009), the Speed Stairway to Heaven is organized into five sequential levels where all criteria need to be fulfilled in one level before an organization can advance to the next. The Speed Stairway is visualized in figure 2.1.



**Figure 2.1:** The speed dimension of the maturity stairway, adapted from “Towards a digital business operating system”, by Jan Bosch in 2019 13th International Conference on Research Challenges in Information Science (RCIS) (pp. 1-9). IEEE.

The remainder of this section is dedicated to describing the five levels of this framework, which are traditional development, agile development, continuous integration, continuous deployment, and R&D as an innovation system. For each level, Bosch’s

definition will be presented together with the perspectives on the topics by other scholars.

### **Level 1 - Traditional Development**

The lowest level of Bosch's maturity model for efficient development of software-intensive systems, i.e. the Speed Stairway to Heaven, is called the Traditional Development level. Traditional development has, according to Bosch, traditionally been practiced by organizations developing hardware and is characterized by long lead times between initiation to delivery of developed features. As new features are developed, they move sequentially through different phases such as design, implementation and testing. This way of working is often referred to as a Waterfall method, which is described by Petersen, Wohlin & Baca (2009) as a stage-gate approach to development where each developed feature needs to pass rigorous quality checks before proceeding to the next phase.

In traditional development, an organization typically commits to a single design which undertakes rigorous testing and development. This way of working is adopted to fit the development of hardware, where making changes to the product during the development process requires large amounts of resources and time (Bosch, 2017). As the organization avoids making changes during the development process, it also aims to avoid external feedback loops. Instead feedback is gathered after a project is finished and is transferred to the start of the next project.

Although traditional development methods have been improved over a long period of time and adopted to fit the development of hardware, Bosch (2017) notes that there now exists other methods, such as agile development methods, which work better for software development. One reason for the emergence of modern development processes is that the environment in which software is usually developed moves too fast and is too unpredictable for traditional development methods to work well. The exception to this rule is, according to Bosch (2017), software developed for safety critical systems where software failure can lead to loss of life or otherwise large damages to infrastructure or the environment. Examples of such areas are cars, medical devices, and aircraft flight control systems (Bosch, 2017; Knight, 2002). In these cases, the need for fail proof software and the legal requirements for traceability in the form of extensive documentation of the software can make development methods other than traditional development unfeasible. The problems with developing safety critical systems using other development methods has also been voiced by other scholars. For example, Knight (2002) claims that verification by testing in the case of ultra-dependable systems is in fact impossible.

Another problem that can keep organizations from advancing past the traditional development level to the agile development level is the task of managing variability within the teams and subsystems (Boehm & Turner, 2005). If traditional and agile teams are simultaneously developing the same product, as could be case during a transition phase, there exists a risk that the teams' different developments will diverge to a point where they are not able to integrate (Boehm & Turner, 2005).

This could result in a situation where the commercial choices for the customers vary to a great degree, especially if the agile teams change their designs according to fast customer feedback. Another factor mentioned by Boehm & Turner (2005) as a potential blocker to proceed towards working more agile is the problem with working with different development cycles. Since traditional methods generally focus on development over long time periods, while agile processes focus on delivering functionality quickly, the two can be difficult to combine (Boehm & Turner, 2005).

### **Level 2 - Agile Practices**

Agile software development processes were first developed in the late 1990s and early 2000s as a response to the rigid nature of traditional waterfall development processes (Pinto, 2013; Highsmith & Cockburn, 2001; Dybå & Dingsøyr, 2008). According to Highsmith & Cockburn (2001), different agile software development approaches share a focus on creating and responding to change. This focus is based on the values and principles of the Agile Manifesto, which was created in 2001 by a number of representatives of different agile software development methods. The core values stated in the manifesto are, according to Fowler, Highsmith, et al. (2001):

- Individuals and interactions over processes and tools.
- Working software over comprehensive documentation.
- Customer collaboration over contract negotiation.
- Responding to change over following a plan.

The levels that follow the Agile Practices level in the Speed Stairway, i.e Continuous Integration, Continuous Deployment and R&D as an Innovation System, are all based on agile principles. In the Agile Practices level, Bosch (2017) has decided to only include the agile practices which he deems to be at the core of the agile methodology. These agile practices focus on how the development teams are organized, the size of the teams, and on developing working software in short iterations. The development iterations are called sprints, and can span anywhere from two to six weeks. By collaborating with the customer during the software development process, the teams design their functionality based on the customer's needs. These needs are translated to work items which are then placed in a backlog. Although agile practices were initially created for small software development teams, there exists frameworks for how to scale agile practices in large organizations as well. One such framework is the Scaled Agile Framework (SAFe) (Scaled Agile, n.d.), which has been implemented by the company. Despite the help of frameworks such as SAFe, Bosch (2017) mentions that agile practices are harder to manage when the number of teams in an organization grow larger.

Traditional development can, according to Bosch (2017), lead to situations where developers spend a minor part of their time on developing new functionality and most of their time on administrative tasks such as documentation. Thus, one key driver for why firms should adopt agile principles is to reduce the overhead of the developers and make sure they use their time to develop new functionality. An organization who reaches Bosch's Agile Practices level will shorten two main feedback loops.

The first is the development loop, described by Bosch as the time it takes for the developers to check in code in order to update their team members and allow them to build upon their code. In traditional development the time between check ins can vary up to several weeks or even months, while agile practices call for daily meetings to synchronize the team members. Thus, the development loop gets shorter. The second feedback loop mentioned by Bosch (2017) is the requirement loop, which is described as how often the teams are able to confirm that their interpretations of the requirements for the functionality that is developed is correct. Since the teams will get feedback from their customers after each sprint, the requirement loop is shorter compared to traditional development.

### **Level 3 - Continuous Integration**

The third level of Bosch's Speed Stairway to Heaven model is called Continuous Integration. Continuous integration (CI) is one of the rules of the agile software development method Extreme Programming, and revolves around the frequent integration and commitment of newly developed code to the development team's code repository (Wells, 2020). According to Fowler (2020), who is one of the authors of the Agile Manifesto (Fowler, Highsmith, et al., 2001), CI is one of the most basic and valuable best practices of software development.

In his maturity model, Bosch (2017) defines CI as the practice where new code is incorporated to the code base of the shippable product as soon as it is developed. CI is a solution to the integration problem that was common in traditional development, where developers worked on code separately until the end of the project. Waiting to integrate the code until the end of a project often brought large amounts of errors, as the developers' code would not fit perfectly with each others'. By continuously integrating code over the entire project, integration issues can be resolved quickly and close to the time that the code was written.

According to Bosch, an organization must have two activities in place in order to fully implement CI. First, new code should frequently be integrated, compiled and linked to a product. Second, automated tests should be run to check for errors that could be caused by the new code and report those errors back to the responsible team or developer. If the organization succeeds with these activities, they should have a product that is always of shippable quality.

Two main feedback loops are shortened by implementing CI, according to Bosch (2017). The first loop, called the development loop, concerns how often the team receives feedback regarding the quality of the system that they are developing. By continuously adding and testing new chunks of functionality, the developers will get direct feedback if the new code causes any integration errors. This fast and direct feedback is of high importance, as the developers who recently created the code will have it top of mind and thus needs to spend less time and resources to locate and fix the problem. The short development loop is especially important in large and complex systems, where errors can be very difficult and costly to both locate and fix if they are not identified early (Bosch, 2017). The second loop, called the

management loop, is based on how often and how accurately the R&D division can report and present its work to its management. CI shortens the management loop since the R&D teams always have a shippable product that they can demonstrate to its management teams. The fact that CI allows the managers to easily understand the status of the developed products, enables them to make more informed decisions regarding product planning, release dates and budgeting (Bosch, 2017).

### **Level 4 - Continuous Deployment**

Organizations will reach the fourth level of the Speed Stairway to Heaven when they have adopted the agile practice of continuous deployment. Different scholars define continuous deployment in different ways. As an example, Fitzgerald & Stol (2014) states that continuous deployment occurs when developers automatically deploys software to an environment that does not need to include actual users. In this report, we will use the definition provided by Bosch (2017) who defines continuous deployment to be achieved when the organization deploys a new version of software to their customers after each sprint.

Bosch gives multiple reasons for why an organization would want to adopt this principle. First, after an organization has reached the Continuous Integration level, it will have an improved and fully functional version of its product after each new sprint. By deploying the new version to the market as soon as it is completed, instead of keeping it "on the shelf", the organization can maximize the business value this version will generate.

The second reason to adopt continuous deployment is that it enables the organizations to deploy new features after each sprint instead of after each project, as in traditional development. The shortened lead times allows the organizations to adapt more quickly to changing customer demands. Finally, by deploying small and frequent updates to their customers, the organization can observe how the new functionality impacts the quality of the product. By doing this, the organization can act quickly if negative effects are observed and adjust its R&D efforts accordingly.

Bosch (2017) writes that an organization who reaches the level of Continuous Deployment will primarily shorten its quality monitoring loop, i.e. the time it takes for the organization to notice and react to quality issues. The shortened quality monitoring loop is a direct effect of the frequent deployment of new software to the organization's customers. The high deployment frequency allows the organization to measure the effect that the new features have on the whole system as they are being developed.

### **Level 5 - R&D as an Innovation System**

According to Bosch (2017), the highest level of maturity within the Speed Stairway is reached when the R&D organization starts to evaluate how new features and products affect customer behavior, and uses that data to improve its products. Bosch (2017) writes that the general way of working on this level follows the three steps

outlined below.

1. Model the expected business value of the new feature or product.
2. Iteratively collect data on the performance of the feature or product in the field.
3. Analyze the data and close the gaps between the expected and actual outcomes regarding the business value of the feature or product.

In essence, where the previous levels have been focused on building things right, an R&D organization on this level also focuses on building the right thing. The main change from the previous levels is that organizations on the final level of the Speed Stairway measure the business value of their new features and products, and use that data to improve the accuracy of their R&D investments.

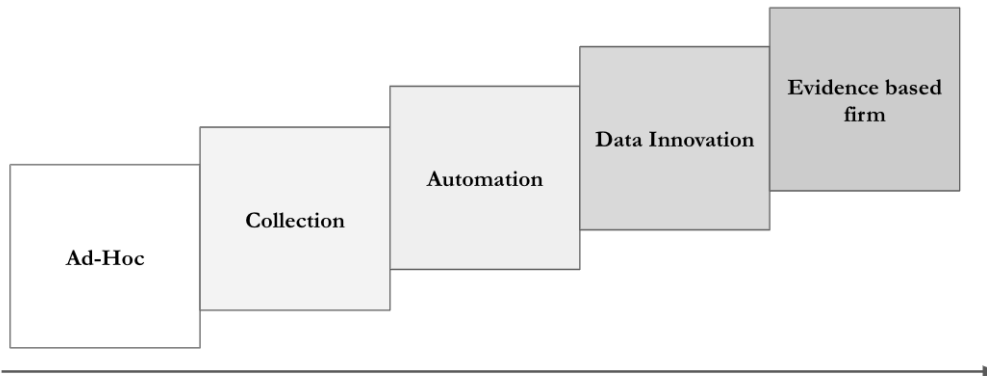
One way for the firm to work in accordance to the R&D as an Innovation System level is by using A/B-testing. In A/B-testing an organization will constantly have different versions of its software pushed to its customers, which means that it can constantly experiment and receive data regarding which features provide the most business value (Olsson, 2018). A/B-testing is one example of how organizations that have reached the final level of the Speed Stairway can shorten their functionality prioritization loop, i.e. the time it takes for the organization to adjust its development priorities based on user and market data. In an organization that has reached the final level of the Speed Stairway, the functionality prioritization loop can be shortened to days compared to the months or years that it could take in traditional development. This major improvement is the main driver for reaching the final level of the Speed Stairway, as it enables organizations to react quicker and with better accuracy to the fast changes of the organization's environment.

Bosch (2017) describes that organizations that have reached the final level of the Speed Stairway to Heaven also use data for prioritizing what tasks to do, which usually takes the form of a backlog. Although this way of working greatly shortens the R&D feedback loops, it does put more pressure on the relationship between the organization and its customers as it requires the customers to share large amounts of data with the organization. Reaching agreements regarding the sharing of data can sometimes be a challenge (Bosch, 2017).

### **2.3 The Data Stairway to Heaven**

During recent years, technological advances has simplified the collection, storage and analysis of data for firms. The improved technology has also enabled firms to gather data in areas where it was previously not possible (Bosch, 2017). Following the increased availability of data, Bosch (2017) claims that firms now intend to transform their opinion based decision making into one that is more data driven. A positive effect of working data driven is according to Brynjolfsson, Hitt & Kim (2011) that data driven organizations usually have both a higher market value and a higher level of productivity. The authors also state that there exist some evidence

that data driven decision making is positively correlated to profitability measures such as asset utilization and ROE (Brynjolfsson et al., 2011).



**Figure 2.2:** The data dimension of the maturity stairway, adapted from “Towards a digital business operating system”, by Jan Bosch in 2019 13th International Conference on Research Challenges in Information Science (RCIS) (pp. 1-9). IEEE.

In the Data Stairway to Heaven, Bosch (2017) describes five levels of maturity that organizations typically go through as they strive to work increasingly data driven. These levels are visualized in Figure 2.2. The levels differ in the degree of automation that is present in the collection, analysis, and reporting of data, as well as the decisions that follows from these activities. Bosch includes four labels for the degrees of automation. For the Collection, Analysis, and Reporting activities, the degree of automation ranges from Manual, where nothing is automated, to Automated, where the standardized processes are done automatically, to Dynamic where the automated processes are updated and developed continuously. For the Decision making activity, Bosch (2017) includes the Manual, Supported, and Automated labels. Similarly to the other activities, the Manual label declares a situation where all decision making is based on human efforts. The Supported label describes a situation where the software that the organization is developing can support human decision making by presenting its own analyses of the data that it is collecting. In the case of the Automated decision making label, which is the most advanced of the three, the software will make its own decisions without any human interference. A summary of the different stages and the corresponding degrees of automation is described in Table 2.3.

### Level 1 - Ad-hoc use of data

At the lowest and most basic level of the Data Stairway to Heaven, Bosch (2017) puts organizations that rarely collect data for anything other than what is legally required of them. These organizations have no standardized processes in place to support data-driven decision making, with the exception of a few curious individuals who go out of their way to collect and analyze data to solve their problems. However, due to the ad-hoc nature of their endeavors, both the required cost and effort of the data collection and analysis are high, and thus data is seldom used. The result

**Table 2.3:** The Five Levels of the Data Stairway to Heaven

Stage	Collection	Analysis	Reporting	Decision
<b>Ad Hoc</b>	manual	manual	manual	manual
<b>Collection</b>	automated	manual	manual	manual
<b>Automation</b>	automated	automated	automated	supported
<b>Data Innovation</b>	dynamic	dynamic	dynamic	supported
<b>Evidence Based Firm</b>	dynamic	dynamic	dynamic	automated

of not using data is an open loop problem where there is little feedback between the R&D organization and its customers. The feedback that does come back to the organization is often slow and is mostly focused on the product or the portfolio level, not on individual features. Furthermore, the feedback is often not representative of all the organization's customers as it is usually only the loudest ones who will provide it. The noise and low granularity of the feedback the organization receives ultimately lead to a low accuracy in its R&D investments, making them vulnerable to competitors (Bosch, 2017). Another negative consequence that stems from receiving data with low granularity is the fact that the feedback can be interpreted differently by different people within the organization. This can, according to Bosch (2017) lead to situations where the feedback can be interpreted in ways that suits certain individuals political agenda.

## Level 2 - Collection

After a few successful ad-hoc attempts to collect and use data to support decision making, an organization might realize the benefits of using data to support their decisions. This realization can nudge the organization to the second level of the Data Stairway, the Collection level. On this level, organizations will start to automate the data collection from their products and store it for later use (Bosch, 2017). Typically, the organization will start by collecting quality related data in order to understand why their customers' products malfunction. Although the data collection is automated on this level, the following analysis and reporting is still manual work. This work is usually performed by data analytics teams who receive questions from R&D managers and then work reactively to answer them. On the Collection level, the effort required to produce analyses and reports is still high and thus data-based decisions are still the exception rather than the rule.

Organizations who reach this level will often find issues in the field which they did not find during development. This realization is a key driver to collect more data in order to resolve quality issues. Moving up to the second level of the Data Stairway will also affect the culture in the organization. The biggest change will be that the R&D employees become more prone to look for data to support their decision making. However, as they do so they will likely face two challenges. Firstly, they might have trouble to get access to business sensitive data from their customers.

Secondly, they will probably realize the complexity of the data they collect and the need for structure in order to get any benefits from it.

### **Level 3 - Automation**

As the organization continues to experience the benefits of using data in their decision making, the requests that are sent to the data analytics teams will increase both in type and in frequency. Bosch (2017) writes that in this stage, managers will start asking questions relating to customer behavior and market performance in addition to their previous quality related questions. Furthermore, some periodic requests to the data analytics teams will become more frequent. The main factor that distinguishes this level from the previous levels in the Data Stairway is the automation of the analysis and reporting of these periodic requests. Usually, these automated analyses will be visualized in dashboards, which are graphic displays that present information to the employees (Hall Jr, 2010). Bosch (2017) describes two main benefits related to automating the analyses in this way. The first benefit is due to the fact that the data analytics teams gets more time to focus on complex and challenging requests. The second benefit is that the automated analyses are reported with a higher frequency, which shortens the feedback loop and allows for higher quality in the organization's decision making. The result is an increase in the R&D organization's efficiency (Bosch, 2017).

### **Level 4 - Data Innovation**

With automated data collection, analysis and reporting already in place, the R&D organization has constant access to updated and visualized data to support decision making. However, in an ever changing environment, the organization must make sure that the analyses that are performed and the data that is being visualized is keeping up with these changes. The institutionalization of processes that make sure that the organization is responsive to the market's changes is the hallmark of the fourth level of the Data Stairway (Bosch, 2017). Bosch (2017) writes that organizations who reach this level add activities on three main levels.

1. First, the organization adds processes that allow managers and other employees within the R&D organization to constantly formulate new ideas and hypotheses for insights that will be analyzed by the data analytics teams.
2. Secondly, the data analytics teams will go through this backlog and update the relevant dashboards if they find any new useful insights. This constant exploration allows the organization to quickly adapt to changes in the market.
3. Finally, the organization will improve its products in such ways that the systems themselves can perform standardized decisions based on the automated analyses. This development frees up time from the development teams who can focus on more complex issues and decisions.

The shift to the fourth level of the Data Stairway will have big implications for the organization's culture. The R&D organization will now as a rule use data for all decision making, and experiments will be run on a large scale. The continuous

exploration for new insights will also lead to a constant questioning of existing beliefs about the organization's customers and markets.

### **Level 5 - Evidence Based Company**

At the final and most mature level of the Data Stairway, organizations have reached a stage where all decisions in the entire organization is based on data (Bosch, 2017). This means that the data practices that have been implemented within the R&D organization has spread across all other functions as they too have realized the benefits of using data for decision making. At this level, the culture of the organization resists any opinion based decisions and demands data. The organizational culture is characterized by a strong experimentation mindset, and everyone continuously looks for new ways to gain business insights. Although an organization on this level is exceptionally data driven, it also realizes the risks of data. One such risk is to only look at what is easily measured, and thus miss valuable insights. The organization tries to minimize the impacts of such risks, and also works to find a balance between traditional hierarchical structures and egalitarian structures. This typically leads to a situation where big, strategical decisions that affects the entire organization are made by top management, while other decisions are made automatically (Bosch, 2017).



# 3

## Methodology

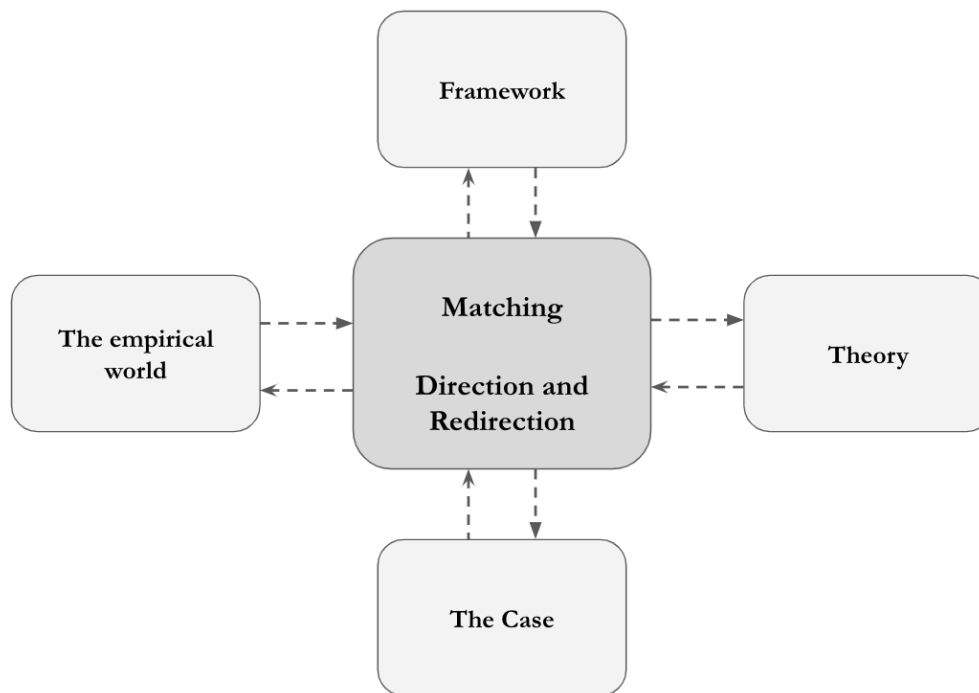
The methodology chapter of this report covers four main areas. These are the research approach, the research design, the research quality, and finally the ethics of this study. Each area is represented by a section that provides a theoretical background followed by a description of how the theory relates to the study.

### 3.1 Research Approach

This report was created using a qualitative, abductive research approach. In contrast to deductive and inductive reasoning, abductive reasoning can be seen as starting with a puzzle and then trying to explain it (Bell, Bryman, & Harley, 2019). The process of abductive reasoning is exemplified by Mantere & Ketokivi (2013) as making an observation in the light of a specific rule, and then deriving an explanation from the researcher's observation in accordance to this rule (Mantere & Ketokivi, 2013). Thus, the abductive research approach starts of by the researcher choosing a rule in the form of a theory, framework or model. The empirical findings, i.e. the observations, are later viewed in the light of that theory, resulting in explanations in the form of drawn conclusions.

Bell et al. (2019) further explains that abductive reasoning includes a back and forth involvement with literature and the empirical world. One particular type of abductive research approach that has been applied in the report and takes Bell et al. (2019) ideas even further is called systematic combining (Dubois & Gadde, 2002). Dubois & Gadde (2002) describes systematic combining as an abductive research approach where the researcher continuously iterates between their empirical findings and their models. As the researchers gain empirical insights, they need to rethink their underlying theoretical models. Systematic combining is discussed by Dubois & Gadde (2002) through two different processes. The first process consists of matching reality and theory, while the second process deals with the direction and redirection of the research. Figure 3.1 shows a visualization over the processes in systematic combining and how it connects theory and empirical findings.

Initially, the assignment that started the report was to investigate whether or not Bosh's HoliDev model (Bosch et al., 2018) could be implemented by the R&D BU. The leading theory was therefore, in a sense, given before any empirical data had been collected. Starting the empirical data collection, a pre-study was conducted on site at the R&D BU where 15 semi-structured interviews were held. By iterat-



**Figure 3.1:** Visualization of how Systematic Combining uses matching, direction and redirection to iterate between the empirical world and theory (Dubois & Gadde, 2002).

ing back and forth between the empirical findings of the pre-study and the theory regarding the HoliDev model, the scope was redirected to better suite the R&D BU’s current situation. The new scope was to assess the maturity level of the R&D BU’s data-driven software development, which is one of the pillars of the HoliDev model. The goal of the maturity assessment was to provide a picture of the R&D BU’s current capabilities in the studied domain and of what the R&D BU needed to develop in order to implement the HoliDev model in the future.

After the scope change, the decision was made to use Bosch’s Stairway to Heaven maturity models (Bosch, 2017) as the new theoretical model. The decision to use the Stairway to Heaven models were taken in collaboration with the company, and was grounded in the fact that the HoliDev model was not yet mature, nor detailed enough to be implemented.

The reason for choosing the Stairway to Heaven over any other IT Maturity model is based on the fact that the company were interested in using a model that had been created by the author of the HoliDev model. New empirical data was then gathered through 10 semi-structured interviews, which were designed based on the Stairway to Heaven models. Thus, in the light of Systematic Combining (Dubois & Gadde, 2002), a redirection took place where the framework was changed due to new empirical findings from the studied case. Iterating between the new theoretical model and the collected empirical data, explanations were finally produced to assess the maturity of the R&D BU and what it should do in order to work more data-

driven in its software development.

## 3.2 Research Design

Edmondson & McManus (2007) write that the purpose of a research design is to decide what data will be observed during the research, and also how it will be observed. In addition, the research design should also define and rationalize the chosen method of analysis. Sloss, Philliber & Schwab (1980) describe the research design as a map of the study, showing the research questions, what data to collect and how the results should be analyzed. This section will begin by presenting the research questions for this study, followed by the research method that was chosen to answer these questions. Data collection will be described in section 3.2.2, while the method of analysis is presented in section 3.2.3.

### 3.2.1 Research Questions and Research Method

The two research questions that were posed in this study were introduced in chapter 1 and are as follows.

- *RQ1: What is the level of maturity within the R&D BU based on the Speed Stairway to Heaven and the Data Stairway to Heaven models?*
- *RQ2: What are the next steps that the R&D BU should take in order to increase its level of maturity in the two studied domains?*

The questions are designed to fulfill the purpose of this study, which is to apply the academic Stairway to Heaven maturity models to an empirical setting, and to evaluate the quality of those models. As the research questions are created around the R&D BU, the study will be conducted as a case study. The fact that the study is of a contemporary event, together with the research question of how the Stairway to Heaven models applies to an empirical setting, makes the case study a suitable research method (Yin, 2018). The R&D BU is one of the more software intensive divisions of the company, and its development of embedded systems makes it compatible with the Stairway to Heaven maturity models. In fact, the R&D BU is precisely the type of organization that the Stairway to Heaven models was designed to help (Bosch, 2017). Because of this, the R&D BU case was deemed to be a good fit for the aim of this study. The data that will be observed during the case study is the R&D BU's software development processes. The development processes will be observed in the light of the Stairway to Heaven maturity models with the help of interviews. The data collection of this study is further described in section 3.2.2.

One of the main issues with using a case study research design is the low level of generalizability of its findings (Yin, 2018). Since the studied population within the company is a small population within a specific organization and time, this also applies to this report. The issue around generalizability will be further explored in section ??, together with questions regarding validity and reliability.

#### 3.2.2 Data Collection

Section 3.2.2 describes the methods that were used to collect data for this study. The primary data collection method was to conduct interviews, and the following section provides an introduction to this method as well as to the way that the interviews were performed. The section on the primary data collection is concluded with an outline of the interviewees that were part of the main study, together their positions within the the R&D BU. Section 3.2.2 concludes with a description of the secondary data that was collected and used for this study.

#### Primary Data Collection

Primary data is, according to Boeije & Hox (2005), data that is collected for the specific research problem at hand. The primary data collection method used in this thesis was interviews, which is one of the most commonly used collection methods in qualitative research (Boeije & Hox, 2005). A total of 25 interviews were conducted during the course of the study, 15 during the pre-study and 10 during the data collection phase. Interviews can be of different types, which are suitable to use in different settings and for different purposes. The most common types of interviews are highly structured, semi-structured, and unstructured interviews (Easterby-Smith, Thorpe, & Jackson, 2015). These three types differ in how strictly the interviewer will follow a pre-determined script. While the highly structured interview follows a detailed interview schedule, an unstructured interview is designed to stimulate an informal conversation without the interference of a guide (Easterby-Smith et al., 2015). The semi-structured interview falls somewhere between the two other types. Dalen (2015) describes semi-structured interviews as interviews where the conversation is targeted on certain topics that are predetermined by the researchers. Since the purpose of this study is to evaluate the the R&D BU according to a specific framework, it is important to make sure that the questions do not differ between each interview. At the same time, the interviewees should have room to expand on certain answers and provide comments that can help the research. Because of this, semi-structured interviews were well suited for this study as they allow for structure of the answers, while simultaneously allowing for some exploration (Lantz, 2013).

The questions that were used in the semi-structured interviews, described in chapter 4, was created in accordance to the suggestions by Dalen (2015). Dalen (2015) mentions that the interviews should be designed in a way that creates a relaxed environment where the interviewee can open up. To create such an environment, each interview started with open questions where the interviewee was asked to describe their role, history and work at the company. Dalen (2015) also states that the interviews should end with an open question. This was also implemented into the interviews where questions regarding the culture within the organization at large were asked at end of each interview. In addition, the following checklist provided by Dalen (2015) was followed in order to maximize the output from each interview. In the cases where the questions did not meet the requirements of the checklist, additional context and explanations were provided during the interview.

- Is the question clear and unambiguous?
- Is it a leading question?
- Does the question demand any special knowledge and information that the interviewee might not possess?
- Does the question include sensitive information that the interviewee will not answer?
- Does the question leave enough space for the interviewee to have their own opinion?

The interviewed subjects are all managers at different levels and divisions within the the R&D BU. The sampling of the interview subjects was based on their positions within the the R&D BU, where the aim was to interview employees who had a good overview of the software processes within their respective division. Representatives from each division within the the R&D BU were interviewed, with one exception. This representative was unavailable for an interview due to circumstances around COVID-19 pandemic. Table 3.1 shows the position and division of each interviewee who was interviewed during this study, excluding the interviews held during the pre-study. The divisions are further explained in chapter 5. Each interviewee was contacted after getting permission from the Master thesis supervisor at the the R&D BU. Some of the interviewees were interviewed multiple times.

Interviewee	Position	Division within the R&D BU
Interviewee A	RTE	Division B
Interviewee B	RTE	Division A
Interviewee C	RTE	Division A
Interviewee D	RTE	Division D
Interviewee E	PM	Division D
Interviewee F	STE	R&D BU Management Team
Interviewee G	TM	Division E

**Table 3.1:** Performed interviews during the data collection phase. Keys: RTE = Release Train Engineer, PM = Product Manager, STE = Solution Train Engineer, TM = Team Manager

### Secondary Data Collection

Secondary textual data are described by Edmondson & McManus (2007) as data that complements primary data sources, such as interviews. The main difference between primary and secondary data is that primary data is directly collected by the researchers, and therefore is well in line with the research questions at hand for the specific report where it is used (Edmondson & McManus, 2007). Thus, the disadvantage of using secondary data is that it will not necessarily fit directly into the investigated topic. However, secondary data sources have the advantage over primary data sources in that they save both time and effort from the researchers as they can leverage work done by other scholars (Edmondson & McManus, 2007). The secondary data sources used for this thesis are mainly academic articles, conference

papers and books covering the academic models used in the report.

While collecting and reviewing secondary data, the starting point was articles written by Bosch where he introduces and describes the HoliDev model and the Stairway to Heaven models. Additional secondary data sources were found by investigating the scholars quoted by Bosch. Other sources were found by searching for key concepts and academical models through search portals like Google Scholar and Chalmers Library.

#### **3.2.3 Analysis**

The interpretation and analysis of the qualitative data that was collected during this thesis project was done through content analysis (Easterby-Smith et al., 2015). Easterby-Smith et al. (2015) define content analysis as having the aim of "*drawing systematic inferences from qualitative data that have been structured by a set of ideas or concepts*". During the analysis of this project, outlined in chapter 7, the qualitative data have been structured using the maturity assessment questions presented in chapter 4. Based on the questions used in the report, the collected data have been connected to the different levels of the two Stairways to Heaven models in order to evaluate the maturity of the studied groups. The choice of applying content analysis in this study was based on the logic that the aim of the study was to evaluate the R&D BU using existing theory, not to build novel structures. Therefore, other alternatives such as grounded analysis, which aims to derive structure and theory from sets of data instead of framing data based on pre-existing structure (Easterby-Smith et al., 2015), were not chosen.

The answers from the interviews were compiled and compared to the criteria for each level of the Stairways to Heaven in order to assess the maturity of each studied group. In the cases where the answers provided by the interviewees did not clearly correspond to a level, interpretations were made to fit the empirical finding to the model. These discrepancies are further discussed in chapter 8.

### **3.3 Research Quality**

Section 3.3 concerns the quality of this thesis, which includes the logical tests of reliability, replicability, and validity. Each quality test will be defined and followed by a description of how it applies to this study.

#### **3.3.1 Reliability**

The degree of reliability of a research design is based on how well the results of the study are repeatable (Bell et al., 2019). This means that if a researcher repeats the study at a later stage in time, using the same procedures as in the original study, the researcher should arrive at the same result as the original study (Yin, 2018). However, as noted by Yin (2018), the possibility to repeat a case study is often difficult in practice. Despite this, a researcher can increase the reliability

of a case study by thoroughly documenting each activity and procedure. In this study, the findings are based on the interview questions presented in chapter 4. By providing a clear description of these questions together with their connection to the theoretical background of the Stairway to Heaven maturity models, a researcher who is repeating this study with the help of the questions should reach the same findings as the ones presented in this report. Thus, the reliability of the study has been increased.

### **3.3.2 Replicability**

Replicability is described by Bell et al. (2019) as the capacity of a study to be replicated by other researchers. The concept of replicability is closely related to reliability, since evaluating the reliability of a study requires it to be replicable. As in the case of reliability, increasing the replicability can be done by rigorously documenting the actions taken in a study and maintaining transparency throughout a report. An attempt to increase the transparency of this study has been made by explaining the sampling of interviewees, which questions were asked during the interviews, and how the answers from the interviews were analyzed to reach the conclusions of the study.

### **3.3.3 Validity**

The validity of a study represents the integrity of the study's conclusions. Yin (2018) mentions three common tests for evaluating a study's validity. The remainder of this section presents each of these tests, starting with construct validity, followed by internal validity, and ending with external validity.

#### **3.3.3.1 Construct Validity**

According to Bell et al. (2019), construct validity measures how well a report captures the phenomenon it intends to capture. Maintaining a high degree of construct validity can be especially difficult when conducting case studies (Yin, 2018). Yin (2018), proposes two steps to increase construct validity while conducting a case study. The first step is to clearly define the research concept, while the second step is to use established measurements that matches the concept. Following the steps proposed by Yin (2018), enables other researchers to evaluate the chosen measurement methods.

The research concept of this study is the maturity of an organization's software development processes with regards to data-driven development. The way that this concept was measured was by using the Stairway to Heaven maturity models developed by Bosch (2017). These maturity models have been developed to help organizations measure their capabilities within the data-driven software development domain (Bosch, 2017). By clearly describing the maturity models in chapter 2 together with a section on the formal evaluation of such models, readers should be able to more easily evaluate their appropriateness. Furthermore, the third research question of this study is centered around the quality of Bosch's maturity models.

Thus, the discussion that follows from this question provides additional material for the reader to evaluate the chosen measurements of the study. Through these actions, the two steps proposed by Yin (2018) have been followed in order to increase the construct validity of this study.

#### **3.3.3.2 Internal validity**

A study's internal validity concerns the issue of causality in its conclusions (Bell et al., 2019). Yin (2018) states that internal validity is mostly used as a test in explanatory research, i.e. research that seeks to explain why a certain event leads to another event. Since this study does not seek to explain a causal relationship between variables, internal validity is not of particular concern.

#### **3.3.3.3 External validity**

Bell et al. (2019) explains external validity as answering the question "*Can the results of the study be generalized beyond the context of the specific research?*".

Bell et al. (2019) claim that empirical generalizations cannot be made from a single case study. Since this is a single case study where a single division is analyzed during a specific time period, empirical generalizations are not possible. However, this is not the purpose of this study. The first two research questions presented in this report concern the maturity of the software development processes of the R&D BU specifically. The conclusion to these questions are not meant to be generalized. The third research question regards the quality of the Stairway to Heaven models and their usefulness when applied to a practical setting. Although the answer to this question will not provide grounds to make any empirical generalizations, they can allow for theoretical generalizations to be inferred. Theoretical generalizations are the type of generalization that Bell et al. (2019) claim can be deduced from single case studies.

One reason to why the R&D BU case is suitable for theoretical generalizations to be made regarding the application of the the Stairway to Heaven models is due to its fit with the models. The Stairway to Heaven models are designed to be implemented by organizations that develops embedded systems which includes a large degree of software. the R&D BU fits well into that category of organizations as it is highly software intensive in an embedded systems context. Thus, the hypothesis is that the models should work well in this empirical setting.

## **3.4 Research Ethics**

Different scholars present different views regarding the concept of research ethics. This study has been conducted in accordance to the following four ethical areas presented by Bell et al. (2019):

- Whether there is harm to participants

- Whether there is an invasion of privacy
- Whether deception is involved
- Whether there is a lack of informed consent

The participants of this study have been different managers within the R&D BU. The nature of their participation has been to attend a small number of interviews held at their office building. This type of participation has not put the participants in any physical danger, and the interviews have been designed to produce an unstressful experience for the participants. Finally, measures were taken to make sure that nothing that the participants said during the interviews was shared with anyone without their consent, protecting them from any reputational harm.

In order to comply with the privacy of the interviewees, all initial contact has been made after having a discussion with the thesis supervisor at the R&D BU. The names of the interviewees have also been left out of the report to increase their privacy. Regarding the problem of sharing confidential information from the R&D BU, the final report was shared with the supervisor at the R&D BU before it was published. This gave them to have an opportunity to change or remove sections from the report.

To ensure that no deception was involved during this study, all participants were informed that they were participating in a Master's thesis project. In addition, all participants were asked for their consent regarding the use of the information they provided, as well as if they allowed their interviews to be recorded for the purpose of transcription. After the audio files had been transcribed, they were subsequently deleted. By taking these precautions, all four areas that were highlighted by Bell et al. (2019) were taken into consideration.



# 4

## Developing the Maturity Assessment Questions

In his published work on the Stairway to Heaven models, Bosch (2017) does not provide any explicit questions to use in order to evaluate the maturity of an organization. Neither does it, to the knowledge of the authors, exist any other publications on the application of the Stairway to Heaven models in an organization that show the methodology the researchers used. Because of this, it has been necessary to interpret the work of Bosch in order to create a set of questions that can be used in order to evaluate the maturity of an organization based on the Stairway to Heaven models. This chapter describes this interpretation and presents the interview questions that have been created as a result. Section 4.1 contains the questions for the Speed Stairway to Heaven while section 4.2 contains the questions for the Data Stairway to Heaven.

This chapter is meant to present and describe the maturity assessment questions that we have derived from Bosch's models. Thus, the content in this chapter is considered to be theory development, and not a part of the thesis' results.

### 4.1 The Speed Stairway to Heaven

Section 4.1 presents the questions that have been developed to assess an organization's level of maturity in Bosch's Speed Stairway to Heaven (Bosch, 2017). The questions are based on the theory presented in chapter 2, and have been designed to determine whether their respective levels have been reached or not. For each level of the Speed Stairway to Heaven, the background for the level's questions will be presented, followed by the questions themselves. In the cases where Bosch has been unclear in his description of what an organization must do in order to fully reach a level, this will be noted as additional interpretation has been required.

#### **Traditional Development**

The questions regarding the lowest level of the Speed Stairway to Heaven have been created to investigate whether or not it is suitable for an organization to advance from the first level.

One factor that can make it unsuitable for an organization to leave the first step of

the Speed Stairway to Heaven is if it is developing safety critical systems. Safety critical systems are systems that might severely endanger the user or result in damages to property or the environment (Knight, 2002). The fatal consequences that might stem from errors in the final product demands rigorous testing and quality checks to be made throughout the development of the product's features. Another factor that can make it unsuitable for an organization to advance from the Traditional step of the Speed Stairway is if the organization develops products that are heavily regulated. Regulations in the form of legal requirements on the development can slow down the process and hinder the progression to higher levels within the Speed Stairway, as it often requires a high degree of traceability. As decreasing the level of documentation in order to gain development speed is one of the key pillars of the agile methodology, highly regulated projects are less suited to advance in the Speed Stairway to Heaven. The questions for the first level are:

- A1: Do you develop safety-critical systems?
- A2: Do you have legal requirements for the systems?
- A3: What level of traceability is needed?

### **Agile Practices**

The questions for the second level of the Speed Stairway to Heaven brings up the basic building blocks for the agile development. In Bosch's definition of the second level of the maturity model, he writes that the level has been reached when organizations have adapted core agile development practices. It is not obvious from his text which agile practices that he believes should be performed in order for an organization to reach this level. We have chosen to form our questions around the main practices that he does include in his text, which are that the development teams are working in sprints, and that they update their customers and incorporates the customers' feedback after each sprint. The questions for the second level are:

- B1: Are you working in sprints?
- B2: Are you updating your customers after each sprint?
- B3: How do you work with customer feedback after sprints?

### **Continuous Integration**

At the third level of the Speed Stairway, Bosch puts organizations who have adopted the Continuous Integration (CI) practice. In his definition, Bosch is relatively precise, stating that CI is achieved when small chunks of code are incorporated as soon as they are developed. This includes that new code should always be integrated into the code base as a complete product. The system should also automatically test the code for issues which, if found, should be reported back to the responsible developer. Based on this, we have created the following questions, which also include some follow up questions in order to assess to what degree the level is reached:

- C1: Are small chunks of new code integrated as soon as they are developed/are engineers checking in code frequently?

- C2: How often do the engineers check in code?
- C3: Are all tests automated?
- C4: Which tests are automated?
- C5: Which tests are not automated?
- C6: Are issues reported instantly to the responsible developer?

### **Continuous Deployment**

The main questions for the fourth level of the Speed Stairway to Heaven is based on Bosch (2017) definition of continuous deployment, namely that new functionality is deployed to customers after each sprint. In addition to the continuous deployment of new features, a system must be in place for the organization to gain information about the usage of the features which can be used in order to improve its products. A necessary requirement for receiving customer data is to ensure that the customers are willing to supply the organization with usage information. The questions for the fourth level are:

- D1: Is new functionality deployed to the customers after each sprint (minimum every 4 weeks)?
- D2: Are any tests being conducted in the field?
- D3: Are your customers willing to provide you with data?

### **R&D as an Innovation System**

The final level of the Speed Stairway is evaluated by questions regarding how well an organization is working data-driven. These questions relate to those presented in section 4.2, and covers to what extent the organization is working in an evidence-based manner. The questions are also designed to assess if the organization is utilizing data-driven experiments such as A/B tests in their innovation work.

Bosch (2017) states that adopting the final level of the Speed Stairway requires three activities, in addition to the previous levels. First the organization needs to model the expected business value of the product it is developing. Next, the organization should iteratively collect customer usage data on the product. This data is then used for the final step, which is to analyze the gap between the expected and the actual business value that was generated by the product and ultimately close that gap.

In order to have a data driven approach that is sufficient to reach the final level of the Speed Stairway, the developer teams should prioritize their backlog based on data, as well as use data to develop the functionality of their system. I.e. data should not only be analyzed in order to improve specific functionality, it should also be used continuously to improve the product on a system level. Finally, the firm should use tests directly on their customers in order to ensure that they are optimizing the features they are developing. The questions for the fifth and final level are:

- E1: Is SW development data-driven? I.e. following the following general steps:

1. Model expected business value
2. Iterative data collection
3. Analyze data and close gaps between the expected and actual outcomes.
  - E2: Is data used to prioritize the backlog?
  - E3: Is data used to optimize the existing system functionality?
  - E4: Are experiments such as A/B tests being run?

## 4.2 The Data Stairway to Heaven

When developing the questions for the Data Stairway to Heaven, the decision was made to group the questions according to the four activities that are present in each level of the Data Stairway, namely Data Collection, Data Analysis, Reporting, and Decision Making. The four activities are heavily integrated in the definitions of the levels of the Data Stairway, and their connection to the different stairway levels are summarized in table 4.1. Because of the fact that the four activities are integrated into the definition of each level, the maturity assessment questions have been simplified to include one set of questions for each activity that covers all levels rather than individual questions for each activity and level. The idea behind the design was to avoid repetitive questions which would have extended the time and complexity of the interviews and put additional strain on the interviewees. The answers to these general questions were then interpreted in order to understand the maturity level of the activity in question.

Similarly to section 4.1, the remainder of this section will present the questions that were designed to assess the maturity of an organization in the Data Stairway to Heaven. However, the questions will be grouped by the four activities of the Data Stairway rather than its five maturity levels.

**Table 4.1:** The Five Levels of the Data Stairway to Heaven

Stage	Collection	Analysis	Reporting	Decision
<b>Ad Hoc</b>	manual	manual	manual	manual
<b>Collection</b>	automated	manual	manual	manual
<b>Automation</b>	automated	automated	automated	supported
<b>Data Innovation</b>	dynamic	dynamic	dynamic	supported
<b>Evidence Based Firm</b>	dynamic	dynamic	dynamic	automated

### Activity 1 - Data Collection

The group of questions related to the data collection activity aim to assess the level of automation of the data collection within an organization, and explain the purpose of the data collection. Related to the Data Stairway to Heaven, the data collection activity mainly targets the second maturity level, i.e. the Collection level. The

question of who puts in requests for data collection is also of interest as this changes over the different levels, from only R&D management to multiple functions within the organization. Finally, a question of who is in charge of the data collection is included, as this also varies between the levels according to Bosch's definitions. The data collection questions are:

- F1: Is the data collected automatically?
- F2: What data is collected automatically and what data is collected manually?
- F3: What is the purpose of the data collection?
- F4: Who requests data to be collected?
- F5: Who is in charge of collecting the data?

### **Activity 2 - Data Analysis**

The questions related to the data analysis activity are created to evaluate the level of automation of the data analyses that an organization performs, who requests the analyses to be made, and why the analyses are performed. These questions are mainly related to the third level of the Data Stairway to Heaven, namely the Automation level. Since Bosch (2017) states that a large number of requests for analyses of similar nature provides an opportunity to automate these analyses, questions on this topic are also included. Bosch also writes that the search for new patterns and correlation in the data that an organization collects corresponds to the higher levels of the Data Stairway (Bosch, 2017). Thus, the final questions relate to this activity. The data analysis questions are:

- G1: Who analyzes the data?
- G2: Is data analyzed automatically?
- G3: How much is automated?
- G4: Who can request data to be analyzed?
- G5: How often are analyses requested?
- G6: How much do the requests vary in type?
- G7: Do you search for new patterns and correlations in the collected data?
- G8: How often?
- G9: Who does it?

### **Activity 3 - Reporting**

The group of questions that covers the reporting activity are designed to evaluate the level of automation of the reporting, and how often the reports are updated and improved. The reporting activity mainly concerns the three last levels of the Data Stairway, i.e. the automation level, the data-innovation level, and the evidence based company level.

The questions of the reports' update and change frequency are included to assess whether or not the dashboards are static, as this is an indication of the organization's current maturity level. The question regarding report access is of interest as a widespread access indicates that the data-driven methods are spreading in the

organization (Bosch, 2017). The questions on reporting are:

- H1: Is the data reported automatically?
- H2: What is reported?
- H3: Who decides what's being reported?
- H4: How often are new findings added to the reports?
- H5: How is it presented?
- H6: Who decides how the data is reported?
- H7: How frequently are the reports updated?
- H8: Who can access the reports?

### **Activity 4 - Decision Making**

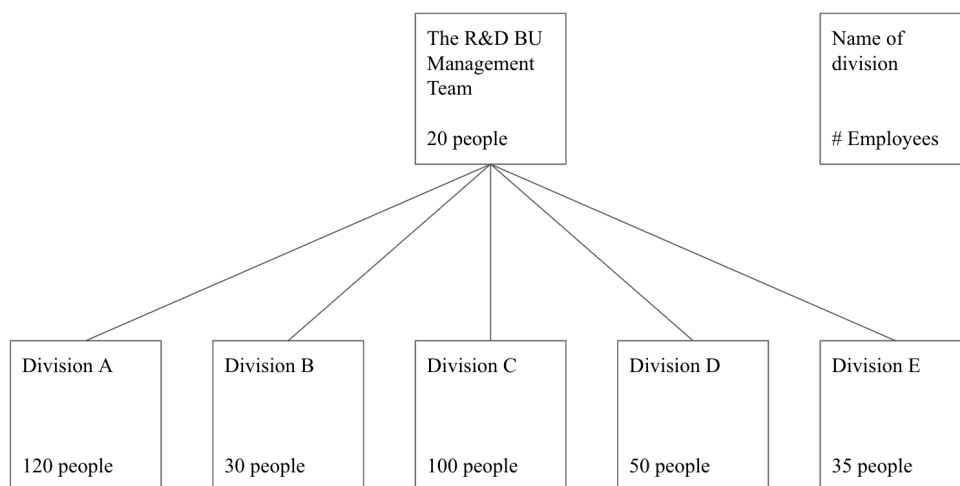
The final group of questions concern the decision making activity, which is the last of the four activities. The goal of the questions is to assess the level of automation of standardized decisions within the organization, and to what extent the decision making in the organization is based on data instead of opinions. The final question on the culture within the organization is included to understand to what extent the culture supports evidence-based ways of working, which is the basis for the highest level of the data stairway to heaven (Bosch, 2017). The questions on decision making are:

- I1: Are any (standardized) decisions being made by the system itself?
- I2: To what extent?
- I3: Which types of decisions?
- I4: Is decision-making in the organization based on the collected data?
- I5: To what extent?
- I6: Is the culture supporting evidence-based ways of working?

# 5

## The Case

This master’s thesis project is conducted at the R&D BU of the company, which is responsible for the development of active and passive safety, as well as of the company’ autonomous driving projects. The R&D BU consists of roughly 350 people, and is organized according to the Scaled Agile Framework (Scaled Agile, n.d.). The main divisions of the R&D BU, i.e. divisions A, B, and C, work with different safety related software development. In addition to these divisions, the R&D BU includes Division D, who is in charge of providing and maintaining a stable development environment for the divisions, and teams working with emerging technologies (Division E). Finally, the R&D BU is managed by the R&D BU Management Team. Figure 5.1 gives an overview of the organizational structure of the R&D BU, including the size of each division. Note that Division C is not included in the analysis of the study due to Covid-19.



**Figure 5.1:** Overview of the organizational structure of the R&D BU at the company.

The fact that the R&D BU is responsible for developing systems related to automotive safety suggests that they are working with safety critical systems. As mentioned in chapter 2, this type of development is typically more suited for traditional, rather than agile, development methods. The observation that the R&D BU is developing safety critical systems could thus indicate that the groups that are to be studied will have a fundamental problem to reach the high maturity levels of the Stairway

to Heaven models. If this hypothesis is correct will be answered in chapters 6 and 7 and further discussed in chapter 8.

# 6

## Results of the interviews

This chapter shows the findings from the interviews. The answers to the interview questions are summarized and ordered according to the maturity assessment questions from chapter 4 and were collected to answer research question 1 and 2. Section 6.1 presents the findings related to the Speed Stairway to Heaven, while section 6.2 presents the findings related to the Data Stairway to Heaven. Division E and the R&D BU Management Team does not primarily work with developing new software. Therefore, not all questions were applicable to their way of working. As a result, the findings from the interviews regarding these two divisions only includes the sections that were considered relevant.

### 6.1 The Speed Stairway to Heaven

#### 6.1.1 Division A

Division A within the R&D BU has two RTEs with different responsibilities. The first RTE, Interviewee B, focuses on the development within Division A. The second RTE, Interviewee C, focuses more on the coordination between Division A and its key suppliers. As these RTEs work with different projects, they were interviewed separately so that differences in the maturity between the projects could be discovered. This section begins by presenting the findings from Interviewee B in section 6.1.1.1, followed by the findings from Interviewee C in section 6.1.1.2.

##### 6.1.1.1 Internal Development

###### Traditional Development

Division A in the R&D BU is, according to RTE Interviewee B (personal communication, March 10, 2020), developing safety-critical systems with a growing amount of legislative constraints. Due to the legislations, the software that is being used in Division A's development requires a high level of traceability.

###### Agile Development

As for Agile methods, Interviewee B (personal communication, March 10, 2020) says that Division A works in two week sprints, although some teams within the division work according to the Kanban method instead. As for the feedback-loop between the teams in Division A and their customers, Interviewee B says that customer demos

are held two times per product increment, i.e. once every six weeks, instead of after each sprint.

### **Continuous Integration**

The actual software that is used in the development work in Division A is not developed at the company, but by suppliers (Interviewee B, personal communication, March 10, 2020). These suppliers deliver big chunks of code that are then tested by the teams in Division A. According to Interviewee B (personal communication, March 10, 2020), a framework is in place that enables the suppliers to send over smaller chunks of code right after they have passed the supplier's internal CI-tests. This would allow the teams in Division A to do their own tests on higher and more holistic levels which include more components. However, Interviewee B says, this is not being done as of now. If any errors are found by the developers in Division A's teams, they report them in a database that is shared with the suppliers and that is automatically updated when changes have been made. When an error has been reported in the system a notification is sent to the responsible developers at the supplier who then works on a solution.

Division A has automated some tests, mainly on the component level and somewhat on the system level. The function tests are still mostly done manually using actual cars. Interviewee B (personal communication, March 10, 2020) says that efforts are being made to automate the higher levels of the tests by using simulated environments, but notes that many challenges remain to be solved before this is a feasible substitute.

### **Continuous Deployment**

The teams within Division A have not yet reached a level where new functionality or updates are delivered to their customers after each sprint (Interviewee B, personal communication, March 10, 2020). The teams will also do their final tests on their products before they are released to the end customers, but will continue to collect data after the release in order to understand user patterns and to assess the performance of the products.

As for the data collection, Interviewee B (personal communication, March 10, 2020) describes three different ways that Division A can collect data. The first way is to collect data from end users. This is currently done when customers bring in their cars for service, at which point anonymized data is sent to the company regarding the car's performance. This system has been in place for a long time, but Interviewee B (personal communication, March 10, 2020) says that the new generation of cars will also be able to continuously both send data and receive software updates over the air (OTA).

The second way to collect data is to collect it from the company cars used by the company's employees. These cars are equipped with special equipment that enables the company to continuously collect data. Although this equipment used

to be something that was optional for the employees to use, it is now required in all company cars. Finally, Division A's teams can collect data by manually drive test-cars and use laptops to record the car's data log.

## **R&D as an Innovation System**

According to Interviewee B (personal communication, March 10, 2020), Division A does work data-driven in many ways, but not with business value as a metric. Data is sometimes used to prioritize what to build, but mostly when developing collision avoidance systems such as auto-breaks. Due to the fact that updates only have been able to be pushed to customers when the customers bring in their car for service, Division A has not yet been doing any A/B-test. However, Interviewee B (personal communication, March 10, 2020) says that this will be an attractive possibility as the next generation of cars with their OTA-functionality goes in to production.

### **6.1.1.2 External Development**

#### **Traditional Development**

Interviewee C, works as the "external" RTE of Division A and is responsible for the collaboration with the division's suppliers. Interviewee C agrees that the division develops safety-critical systems (personal communication, March 16, 2020). The legal requirements and the required levels of traceability are high and the development follows the ISO26262 standard.

#### **Agile Development**

Interviewee C (personal communication, March 16, 2020) explains that the teams in Division A works either according to the Scrum or the Kanban methodologies. Customers are being updated either continuously during the projects, at sprint demos, or during product increment demos. The collected feedback is then passed on to the corresponding development teams.

#### **Continuous Integration**

The software that is used in Division A's development is developed by suppliers who deliver complete software packages at a predetermined pace (Interviewee C, personal communication, March 16, 2020). Such packages can arrive every two weeks, but often the deliveries are less frequent. The tests that the division runs on the delivered code have a varying level of automation. Some tests are run with robots who are supervised by team members, while most higher level tests are done completely manually. Issues that are found during the tests will be reported to the responsible developers through a shared portal.

#### **Continuous Deployment**

Interviewee C (personal communication, March 16, 2020) states that Division A does not deliver new functionality to its customers after each sprint. It will not

perform any testing on end users' cars, but only on the company's test cars. In many cases, the tests will be conducted digitally using field data that has already been collected and stored in company databases.

### **R&D as an Innovation System**

When asked whether or not Division A works data driven, Interviewee C (personal communication, March 16, 2020) says that they do to a large extent follow that way of working. However, the data and KPIs that are used will not monitor any business value, but rather system performance and quality. This performance data is used to prioritize the backlogs of the teams within Division A, however they do not consider data regarding user experience. Interviewee C ends by stating that the Division A does not run any experiments, such as A/B-tests, that Interviewee C is aware of.

#### **6.1.2 Division B**

##### **Traditional Development**

According to Interviewee A (personal communication, March 16, 2020), who is the RTE of Division B, the development work in the division does to a large extent follow the ISO26262 standard. This standard puts both legal and traceability requirements on the division. In addition to the ISO standard, Division B follows other requirements that calls for high levels of traceability in its developed software, due to the fact that they are developing safety critical systems.

##### **Agile Development**

Interviewee A (personal communication, March 16, 2020) states that all the teams in Division B work according to the Scrum methodology and in sprints. After each sprint, the teams will hold sprint reviews to which stakeholders of their projects will be invited. However, although the stakeholders are updated on the progress of the projects, stakeholder feedback to the teams is minimal.

##### **Continuous Integration**

As is the case of most of the R&D BU, the teams in Division B does not develop their own software, instead they procure the software from multiple suppliers. According to Interviewee A (personal communication, March 16, 2020), the frequency at which software is delivered by the suppliers varies over the life cycle of a project. In the early stages, software could be delivered as seldom as once per quarter, while the frequency can increase to once every second week in the later stages. The software is delivered as a complete software package, rather than in small continuous streams of new code. The testing that is done on the code is mostly manual, and issues that are found are reported back to the suppliers for analysis.

## Continuous Deployment

According to Interviewee A (personal communication, March 16, 2020), the delivery of new functionality to Division B's customers follows the same pattern as the delivery of new software from the division's suppliers. This means that functionality is not deployed after each sprint. Tests are being run on the company's test cars, but data is also continuously analyzed and collected from end users' cars in order to run diagnostics tests and to make sure that the system functions in accordance to specification. As this data is required to be available by law, Interviewee A (personal communication, March 16, 2020) states that access is no issue.

## R&D as an Innovation System

In order to describe whether or not Division B works data-driven or not, Interviewee A (personal communication, March 16, 2020) explains their general process as follows. When new software and functionality is developed by the division, it is sent to the company's Safety Center division who runs crash tests and determines if the new software meets its requirements. Data is then sent back to Division B together with information if adjustments must be made to the software. This process is then iterated until the best possible configuration has been found, which is then placed in the cars for production. In this way, the development work is data-driven. However, since it is the Safety Center that performs the tests, which can be both done in the lab or out in the field, the teams within Division B does not know exactly where the data they receive after the tests comes from.

When it comes to the prioritization of the backlogs of the teams within Division B, Interviewee A (personal communication, March 16, 2020) says that the process is event-driven rather than data-driven. The work that needs to be done follows the Safety Center's time plan, and the work in Division B is prioritized based on where they are on that plan as well when the next version of test cars become available. This also means that the data that Division B's teams get access to becomes more refined as the projects, and the corresponding cars, evolve.

Finally, Interviewee A (personal communication, March 16, 2020) says that no experimentation in the form of A/B-tests or its like is currently performed in Division B.

### 6.1.3 Division D

#### Traditional Development

The systems that are developed by Division D are not used in the car, thus they are not explicitly safety critical (Interviewee D, personal communication, March 16, 2020). However, to be able to certify the car and its safety critical systems, the tests needs to be certified in order for the result of the tests to be validated. As a consequence, Division D needs to work in accordance to the ISO26262 standard.

According to Interviewee D (personal communication, March 16, 2020), Division D do not have any legal requirements on them, however divisions A, B, and C do. Therefore divisions A, B, and C need documentation of their software development with a high level of traceability, which Division D helps provide.

### **Agile Development**

Some, but not all, of Division D's teams work in sprints. According to the company's SAFe framework, the teams can choose between working according to Scrum or Kanban. The exact distribution between the teams is unclear, but Interviewee D (personal communication, March 16, 2020) states that more teams use the Scrum methodology than Kanban.

The teams sometimes have demos after their sprints where they invite their customers to show their progress. Bigger demos are held when the teams have finished a project that affects their customers. This is not done after each sprint, but at least once every 10 weeks during Program Increment (PI)-planning (Interviewee D, personal communication, March 16, 2020). During the PI planning, which is a key practice in the SAFe framework (Scaled Agile, n.d.), every development team under System Teams shows a demo of their progress. Occasionally some teams also update divisions A, B, and C directly with demos.

Interviewee D is not exactly sure how each team handles customer feedback but explains how the process is supposed to work, and states that each team works in different ways to prioritize their customer feedback. When the teams have received feedback they insert the feedback into their backlog and prioritize it against the other activities, often to be handled during the next PI planning. It is rare that you prioritize customer feedback highly in the middle of a PI period, since the teams have already committed to a scope.

### **Continuous Integration**

According to Interviewee E (personal communication, March 26, 2020), the continuous integration (CI) maturity varies between Division D. The CI team is the part of Division D that is responsible for developing the sequence of CI tools that are in the R&D BU, which we will refer to as the CI-chain. This team is the team that has gotten furthest with frequent check-ins of code and with automated unit tests. Although much of the functionality for the CI-chain has been put into place, Interviewee E (personal communication, March 26, 2020) says that the other system teams have not fully started using it in practice. As for the reporting of errors found in the CI-tests, Interviewee E (personal communication, March 26, 2020) says that information is sent to the responsible development team rather than the individual developer who wrote the code. The CI-chain is design in this way to encourage the whole team to take ownership of the code, instead of just the individuals by themselves.

## Continuous Deployment

Regarding the continuous deployment of the products developed by the CI-team, Interviewee E (personal communication, March 26, 2020) says that it varies depending on the customers. When delivering internally to the R&D BU, new products are deployed continuously, while deliveries to customers in other R&D BUs happens less frequently. Interviewee E (personal communication, March 26, 2020) also says that the CI-team has not yet been able to ensure that their customers use the same version of their software, nor do they have the capabilities to update their entire installed base at once. Interviewee E (personal communication, March 26, 2020) notes that having different software versions can lead to problems when the central system on which their software runs is updated, as it can break some functionalities in the different versions of their products.

According to Interviewee D (personal communication, March 16, 2020), Division D do not conduct any tests in the field directly. However, they sometimes support divisions A, B, and C while performing field tests. Since Division D have an internal support function, their main customers are divisions A, B, and C in the company's R&D BU. Therefore, Interviewee D (personal communication, March 16, 2020) have not found that there are any issues concerning data sharing.

## R&D as an Innovation System

Interviewee D (personal communication, March 16, 2020) claims that Division D are not following the three steps of data-driven software development. Instead, Interviewee D explains that the teams partly use data before updating their backlogs, but the process is not completely data driven. According to Interviewee D (personal communication, March 16), it is difficult to define accurate KPIs while solely using data. Instead, Interviewee D says that it is easier to use qualitative customer feedback and then use gut feeling. However, Interviewee D believes that if processes were in place to support data-driven software development it would be great.

Data is currently not used to prioritize the backlogs of Division D. The backlog is created according to demands from divisions A, B, and C (Interviewee D, personal communication, March 16, 2020). At the moment, these processes are not fully functioning, and instead Division D often prioritize their backlogs from what they believe divisions A, B, and C need. This prioritization is built upon opinions and gut feeling rather than data.

Data is, to a large extent, used to supervise different processes in the system. Interviewee D (personal communication, March 16, 2020) claims that it is rather easy to use data for supervision, since a checklist can give an overview of what works and what does not. If some functionality works, it works. If it does not work it has to be fixed. Thus, Division D do not use data at this point to optimize the functionality of the existing system, but rather to solve problems that might occur in the system.

As of now, Interviewee D does not know that any experiments, such as A/B testing

has been run in his teams. Since Division D provide a technical platform that is used by divisions A, B, and C, he states that useability is not their main priority. Instead the top priority is to deliver a functional platform that enables divisions A, B, and C to use it for their needs.

### 6.1.4 Division E

Interviewee G (Interviewee G, personal communication, March 25, 2020) states that the main purpose of Division E is to predict what lies ahead of the R&D BU. Where the other divisions focus on delivering functionality for the new car, Division E aims to understand what will be developed in the future and seeks to provide a development platform that enables the development of future applications. According to Interviewee G, the team consists of experienced system architects and is responsible to provide the whole R&D BU with insights.

#### Traditional Development

The final goal of Division E is, according to Interviewee G (personal communication, March 25, 2020), to provide predictions on a system level. As such, the division can sometimes also develop safety critical systems, or at least, make suggestions for the development of future safety critical systems. Although Division E primarily works within the R&D BU, it often involves other BUs within the company when evaluating new ideas. This is because the development of future features often brings up dependencies with other BUs. Thus, collaboration at an early stage is of high importance (Interviewee G, personal communication, March 25, 2020).

Working with identifying future trends and features in the R&D BU's field, Division E often needs to relate to new or changed legislations. To cope with the legislations, the team have one employee that works full time with analyzing and interpreting new legislations that are relevant for Division E. According to Interviewee G (personal communication, March 25, 2020), the amount of new legislations and legal demands are increasing, for many areas within the company. In addition, other types of regulations Division E needs to take into consideration are ratings, such as safety ratings, from Europe, China and USA.

#### Agile Development

Interviewee G states that Division E does not work in sprints. Instead they initiate a large planning cycle 12 weeks, and refines their backlog three times during each planning cycle. The division uses a Kanban approach where they always aim to finish the tasks at hand before approaching new tasks. If some tasks gets obstructed, they are replaced with new tasks in their backlog.

Division E's primary customers are the divisions within the R&D BU. The divisions are mainly updated about the progress of Division E during large demos, where Division E showcases work that can be of special interest to the divisions. Apart from

the larger demos, Division E also updates their internal customers after delivering specific requests.

The deliveries from Division E are often iterated several times before the actual delivery of a project (Interviewee G, personal communication, March 25, 2020). This often leads to a situation where the information is well understood by the customers even before the delivery. According to Interviewee G, Division E tries to keep all of their stakeholders informed about their progress in order to minimize the risk of delivering an unexpected result. Thus, the normal feedback loop between the team and its customers is normally a continuous, two-way process. The length of this feedback loop differ from case to case, where projects characterized by heavy legislations can call for weekly meetings. During other types of projects the team uses a more ad-hoc approach, where meetings are held when deemed necessary.

### **Continuous Integration**

Interviewee G (personal communication, March 25, 2020) states that Division E does not develop software, instead it focuses on doing qualitative, business oriented analyses. The types of questions that they seek to answer can, according to Interviewee G, be in the form of analyzing which functions the R&D BU needs to develop in order to fulfill a specific customer need, or which functions the R&D BU should focus on developing to target a specific customer segment.

Division E's backlog is mainly prioritized by their manager, but also in part by the demands of their stakeholders. Requests in the form of long-term legislative questions or specific requests from within the organization takes precedence according to Interviewee G (personal communication, March 25, 2020), while the rest of the tasks in the backlog gets attention depending on their internal priority.

Division E is not involved in the design and creation of CI initiatives within the R&D BU. Interviewee G is however personally involved in the initiative, mostly due to his or her personal interest and experience in working with software development at the company (Interviewee G, personal communication, March 25, 2020). When asked about the biggest hurdles and blockers for the R&D BU to fully adapt CI in its development, Interviewee G (personal communication, March 25, 2020) states that tradition, knowledge and experience are all key factors in order to get CI fully implemented. Interviewee G continues by stating that the developers needs to experience the power of CI first hand before being able to completely embrace the methodology. In order to get there, Interviewee G proposes that more time and resources must be put aside to give the developers enough space to actually make the CI methodology work. By starting with automatizing the tests which are the least "fun" to do manually, Interviewee G believes that the company can start the change towards fully implementing CI in the R&D BU (Interviewee G, personal communication, March 25, 2020).

### 6.1.5 The R&D BU Management Team

Interviewee F works as a Solution Train Engineer (STE) at the management level of the R&D BU. The STE role is concerned with ensuring a constant flow of products and information to and from the R&D BU. The responsibilities includes holding PI-planning meetings, synchronizing the work with other BUs within the company and setting up and monitoring performance metrics for the R&D BU. According to Interviewee F (personal communication, March 23, 2020), the R&D BU is somewhat special at the company as it does not deliver a whole product as a R&D BU. Instead the three divisions, i.e. divisions A, B, and C, are responsible for their own products and deliver those products by themselves. This means that the STE of the R&D BU does not have as much operative responsibility for coordinating product deliveries as STEs in other BUs have.

#### Traditional Development

The management team at the R&D BU does not develop any product of their own, and is thus not directly concerned with legal issues. They do, however, have team members who work with legal questions full time, and who acts as an expert council for the R&D BU's divisions.

#### Agile Development

Although the R&D BU as a whole works according to sprints, Interviewee F states that the management team does not follow any agile methodologies themselves (personal communication, March 23, 2020). Instead, the way of working differs from role to role. As an example, Interviewee F says that the Solution Program Engineers (SPEs) who work with the different car projects follow the schedule of those projects, which tends to be structured as traditional waterfall development.

The feedback that the R&D BU management team receives comes from different sources. The SPEs bring back feedback from the internal car projects that they are working on to the R&D BU management team. Other sources of feedback are the internal issue reporting system and representatives from other organizations within the company who work with customer satisfaction (Interviewee F, personal communication, March 23, 2020).

#### Continuous Integration

Interviewee F (personal communication, March 23, 2020) says that since the divisions A, B, and C are responsible for their own products, these divisions also take responsibility for their suppliers and the relations they have with those suppliers. This implies that the R&D BU management team does not decide on the frequency that the suppliers deliver software to the divisions or the level of CI that is present. Interviewee F also states that the R&D BU management team is not present during the negotiations between the divisions and their suppliers.

## Continuous Deployment

Similarly to the question of continuous integration, Interviewee F (personal communication, March 23, 2020) says that the R&D BU management team have little to do with the delivery of the divisions' products. However, the R&D BU management team has begun to sync the delivery between both the different projects and BUs at the company in order to get a more smooth delivery. In practice, this means that instead of letting each project set its own schedule, the BUs have begun to cluster the projects so that they are all scheduled to deliver at a pre determined pace. Interviewee F (personal communication, March 23, 2020) does also say that even though much has been done, the R&D BU has a long way to go in its change towards an agile way of working. According to Interviewee F, the biggest challenge is that the workload in the R&D BU is too high, which gives the divisions too little room to change their ways of working.

## R&D as an Innovation System

Finally, when asked about the level of working data driven in the R&D BU, Interviewee F (personal communication, March 23, 2020) say that it is still very low. Currently the focus is on visualizing data and trying to find quality issues to fix, but not on business value or the output of the divisions. The R&D BU does look at some quantitative measurements, such as different safety ratings, but not much more when it comes to the end users.

## 6.2 The Data Stairway to Heaven

### 6.2.1 Division A

#### 6.2.1.1 Internal Development

##### Data Collection

According to Interviewee B (personal communication, March 10, 2020), Division A are currently performing all their data collection manually. Interviewee B states that some approaches have been made to automatize parts of the data collection, but continues by stating that the GDPR could propose a challenge to automatization.

Division A is currently collecting data from their customers for three main reasons. The reasons consists of learning about user patterns, getting data regarding the quality of the functionalities, and to find out if there are any problems with the cars. The collected user pattern data is used to understand how different functions are used by the customers, as well as understanding if some functionality is used at all.

The data collection is manually requested by the developers in Division A. The division does not have access to all the data from the car fleet, instead each data

point is requested from another department at the company which is responsible for data collection. However, Division A logs some data points that are continuously collected by the division. The logged data can for example be logs from sensors, and control units.

### **Data Analysis**

Division A does not have a devoted team of Data Analysts (Interviewee B, personal communication, March 10, 2020). Instead each developer perform the analyses they deem necessary to gain sufficient information from the collected data. Each analysis requires some type of manual interaction, thus no analyses are done completely automatically. However, Interviewee B (personal communication, March 10, 2020) claims that some analyses that are made manually by the developers should be automatized.

All employees within Division A can request data to be analyzed by the developers. When a request has been made, it is up to the developers to prioritize if and when the analysis will be made. Since the developers themselves analyze the data they need to develop new functionality, requests for data analyses are seldom made by other employees except for the developers.

According to Interviewee B (personal communication, March 10, 2020), it is common that the developers in Division A search for correlations and patterns in their collected data. Interviewee B continues by pointing out that this practice is an important part of the analyses that are performed within Division A.

### **Data Reporting**

According to Interviewee B (personal communication, March 10, 2020), the data that is analyzed by the developers in Division A is not automatically shared throughout the division. Instead, only the teams have access to their own data. General data is, however, reported via dashboards to the whole division in the form of problem reports from the testing cars. The data that is presented is for example how many errors that have been found during a week, and how many of these errors that have been solved. It is Interviewee B that chooses which data to report, with input from the other team members.

### **Decision Making**

There are currently no decisions that are being made by the software that Division A is developing, and Interviewee B believes that there is a long way to go before that is a possibility (personal communication, March 10, 2020).

Interviewee B believes that the company is trying, and succeeding, to an extent to be a data driven organization (personal communication, March 10, 2020). However, he continues, there is often manual work put in to collect the data and it is not always possible to be completely data driven. When asked for an example when it is not

possible to be data driven, he answers that some functionalities that are continuously regulated and changed can be harder to develop completely data driven. Interviewee B believes that there exists a culture at the company that supports data driven decisions. There still exists some situations where the managers opinion trumps data driven decisions, but it is something the company works to prevent (personal communication, March 10, 2020).

### **6.2.1.2 External Development**

#### **Data Collection**

Interviewee C (personal communication, March 16, 2020) states that no data collection done by the Division A is performed completely automatically. Some data collection is however made semi-automatically, using robots to drive test cars. Since there is always one employee present in the car, the collection can not be seen to be made fully automatically.

The purpose of the data collection is primarily to gain knowledge of the performance of different functionalities. What works, what does not work, and how well does it perform in different environments. As an example, sensors need to be tested in different environments to ensure their performance. Interviewee C says that anyone in the division can request data to be collected, and there is no assigned team in Division A that is responsible for collecting the data.

#### **Data Analysis**

Each development team in Division A is responsible of analyzing the data they need in order to develop the functionalities that they are in charge of (Interviewee C, personal communication, March 16, 2020). There does not exist a team that is solely responsible of performing data analysis. Interviewee C also says that no data analyses are made automatically at the moment.

Anyone in the division has the possibility to request data to be analyzed by the developers. If a request is made, it is the development team that prioritizes when and if they perform the requested analysis. Currently, the requests are made more or less solely by Interviewee C, who makes data analysis requests of various sorts each day. According to Interviewee C (personal communication, March 16, 2020) the nature of the data analyses that are requested varies depending on the phase of a project.

According to Interviewee C, Division A does not continuously search for new patterns in its collected data. However, they do search for new patterns in the occasions when they are searching for new technical solutions. Today, the data is mostly being scanned to ensure the quality of their developed applications (Interviewee C, personal communication, March 16, 2020).

### **Data Reporting**

The collected data is reported automatically through an internal system that can be accessed by all employees in Division A. However, accessing the reports require some manual effort (Interviewee C, personal communication, March 16, 2020). The report contains the current distribution of components, projects and teams within the division. The data that is used for the reports is queried from a database that is continuously updated with data from performance tests, mostly regarding true and false positives (Interviewee C, personal communication, March 16, 2020). The reports are automatically updated from the database on a continuous basis.

### **Decision Making**

No decisions are being made by Division A's software at this moment (Interviewee C, personal communication, March 16, 2020). Interviewee C states that he believes that the company is in many ways a data-driven organization, however, it depends on where in the organization you look. Interviewee C believes that some decisions connected to the products are also based on emotion. It is the belief of Interviewee C that Division A is data driven to a large extent, but that they can also be emotionally attached to developing the best possible product. Therefore, some decisions is not always evidence-based.

When asked if the culture at the company supports an evidence-based way of working, Interviewee C states that when decisions are based on data 99% of the times.

## **6.2.2 Division B**

### **Data Collection**

According to Division B's RTE Interviewee A (personal communication, March 16, 2020), no automatic data collection is currently done by the division. The data that the division collects is used to calibrate its various safety systems in order for them to activate at the right times and to not misfire. As such, data is collected both for quality insurance and for improving the system.

Interviewee A explains that there are no dedicated roles for data collection within Division A. Instead, the developers in the teams themselves take responsibility for collecting the data they need from other BUs within the company.

### **Data Analysis**

The data that is collected by the teams within Division B is, according to Interviewee A (personal communication, March 16, 2020), sent directly to the division's software suppliers for analysis. These suppliers analyze the data and then reports back to the teams in Division B who decides what changes should be done to the code. The suppliers and teams within Division B will then have a continuous dialogue until the new functionality has been developed.

As for who requests the analyses of the collected data, Interviewee A says that this is Division B's teams themselves (personal communication, March 16, 2020). The teams will collect the necessary data and deliver it to the suppliers. The suppliers will then deliver calibrated software back to the teams. New analyses are done each time the division receives new calibrations, and Interviewee A says that there is little reason to request or perform any more analyses than the teams already do (personal communication, March 16, 2020).

### **Data Reporting**

According to Interviewee A (personal communication, March 16, 2020), Division B itself does no automatic reporting or visualization of the data it collects or the analyses that are being made by the division.

### **Decision Making**

Division B has some automated testing in place for its new software. However, Interviewee A (personal communication, March 16, 2020) says that although a new piece of software passes all the automated tests, a test engineer will always do a final check before the software is approved. Thus no decisions are fully automated. As for the culture at the company, Interviewee A explains that it has become more data-driven since the re-organization to the SAFe framework, but that there is much improvement still to be made (Interviewee A, personal communication, March 16, 2020).

## **6.2.3 Division D**

### **Data Collection**

According to Interviewee D (personal communication, March 26, 2020), Division D log all the data that comes from their internal testing. However, they do not perform any further data collection on a systematic basis. Division D therefore lack a general data stream that could be used for various purposes. The data collection that does take place outside the basic data logs is performed manually by individuals who take it on themselves to perform some personal inquiries.

### **Data Analysis**

Interviewee E (personal communication, March 26, 2020) says that, similarly to the data collection, the data analysis within Division D is not yet automated. Instead, this is often carried out by individuals if anything of interest comes up. Interviewee E does, however, say that Division D are currently working on a new project which will automate much of their data collection and data analysis. The requests that Division D have receive related to this project are many but also very specific. Interviewee E says that the requests that they receive are often more based on specific problems rather than general strategies (personal communication, March 26, 2020).

Interviewee D (personal communication, March 16, 2020) states that there is no single person or team within Division D that is in charge of analyzing data. Instead each developer performs their own analyses if there is a need for an analysis. No data analyses are performed automatically, to the knowledge of Interviewee D.

Divisions A, B, and C in the R&D BU are encouraged to request data to be analyzed by Division D. Interviewee D gives the example that if a division has run a test where they do not understand the full extent of the outcome, they should send a request for analysis to Division D. When the teams receive a request, it is the teams Product Owner's responsibility to prioritize if and when the developers should perform the analysis (personal communication, March 16, 2020).

### **Data Reporting**

The reporting of the analyses and tests run by the CI-team within Division D are automated and presented in dashboards. These dashboards are continuously updated as the tests are run (Interviewee E, personal communication, March 26, 2020). The reports are found in a central system that is accessible by everyone. However, Interviewee E says that even though the reports are accessible, nearly no one looks at the reports.

Interviewee D (personal communication, March 16, 2020) states that data on Division D's performance is also reported and visualized in dashboards. Interviewee D does not, however, know how much of this reporting that is done automatically. In general, the dashboards visualizes the status of test cases, if any major errors have occurred, and how the tests have progressed. There is no single person or team in charge of reporting this data. Instead, the owner of each test case or systems decides whether or not to report the progress to the rest of Division D.

### **Decision Making**

Interviewee E (personal communication, March 26, 2020) claims that the CI-system that is in place within the R&D BU is designed to have the capability to make automated decisions. Such decisions are, for example, related to prioritizing what test cases to run based on previous results and the characteristics of the code that is being tested. Currently, however, this is not being done due to the fact that the system needs more data before automated decision making is possible.

When asked if decision making throughout the company is mainly based on data, Interviewee D answers that he believes it differs depending on where you look in the organization. Interviewee D mentions that decisions that are made on higher levels of the organization are supported by large amounts of data. Interviewee D also mentions that decisions regarding car safety requires a high level of documentation. However, Interviewee D believes that decisions regarding the prioritization of which new functions to develop is more based on opinion and gut feeling than on data. Since it requires more resources and time to make data-driven decisions there exist a mix of data-driven and opinion-based decisions throughout the organization.

Interviewee D concludes by mentioning that decisions made on his team level cannot always be based on data as that amount of data would take weeks to collect.

Interviewee D's opinion regarding if the company has a culture that supports evidence-based ways of working is that many people in the organization truly appreciate if decisions are based on hard data. Being an organization with a high population of engineers among the employees, Interviewee D believes that data-driven decision making is not opposed in any ways. However, due to issues regarding time and resource allocation, data-driven decisions are not always made (personal communication, March 16, 2020).

## **6.2.4 Division E**

### **Data Collection**

Division E team does not collect any data regarding how their reports and analyses are used by the employees at the company (Interviewee G, personal communication, March 25, 2020). Interviewee G mentions that the team does not measure the usage of the analyses themselves, but rather what impact they have in helping the company decide which features to use in the product portfolio.

The data collection that does take place within Division E's teams mainly exists of external market analyses, understanding the capabilities of their suppliers, and scouting the actions of the company's competitors to see what they are aiming to do in the future. After the collection, the data is analyzed by Division E. The analyses are followed by a planning meeting to understand which steps the company should take to continue having a competitive offering. Interviewee G also states that all data is collected manually (Interviewee G, personal communication, March 25, 2020).

### **Data Analysis**

As a consequence of covering the complete R&D BU, the analyses that are requested from Division E can differ greatly. Interviewee G claims that the requests are mostly made by corporate management or the company's business office (personal communication, March 25, 2020). Since the divisions within the R&D BU mostly need to focus on delivering functionality "here and now", they usually do not have the time and resources to request analyses that predicts the future (Interviewee G, personal communication, March 25, 2020).

All data analysis is currently being made manually by Division E. Interviewee G believes that improvements can be made in this area, especially by synchronizing the analyzes with other BU's within the company (Interviewee G, personal communication, March 25, 2020). Interviewee G states that value can be found in combining different perspectives and ensuring that the information is spread to all interested BUs, thus decreasing the number of performed analyses.

### **Reporting**

No reporting is done automatically by Division E. If they send out reports to their internal customers, it is usually as a response to a requested analysis (Interviewee G, personal communication, March 25, 2020).

#### **6.2.5 The R&D BU Management Team**

The R&D BU management team does not collect any data themselves, but uses various internal systems that visualize company data to support their decision making. However, as Interviewee F points out, most of the decisions that are made regarding the products in the R&D BU are taken by the divisions themselves (personal communication, March 23, 2020). The fact that the management team within the R&D BU does not seem to perform the activities of the Data Stairway to any large extent makes this model less applicable. Thus, there is little information to present in this subsection.

# 7

## Maturity Assessment

Chapter 7 presents the maturity assessments of the studied divisions within the D&D BU, according to the Stairway to Heaven models. The assessments are based on the findings that were described in chapter 6, and shows what level of maturity the studied groups within the D&D BU have reached in the Speed Stairway and the Data Stairway respectively. The results from the maturity assessment will be further discussed in chapter 8 where common characteristics and issues will be covered.

The maturity levels of the studied groups are visualized using column charts that give a general sense of how much of each level has been either fulfilled, partly fulfilled, or not fulfilled at all. The purpose of these charts is to show that although the divisions might not have moved past the initial levels of the Stairways, they might still have fulfilled some criteria on the higher levels. As the columns are only meant to give a general sense of the progress in the various levels, we do not claim the percentages to be exact.

The column charts begin with the second levels of the Speed and Data Stairways. This is because the initial levels, i.e. the Traditional Development level for the Speed Stairway and the Ad-Hoc level for the Data Stairway, are the starting points for any organization and are thus already fulfilled.

### 7.1 Division A

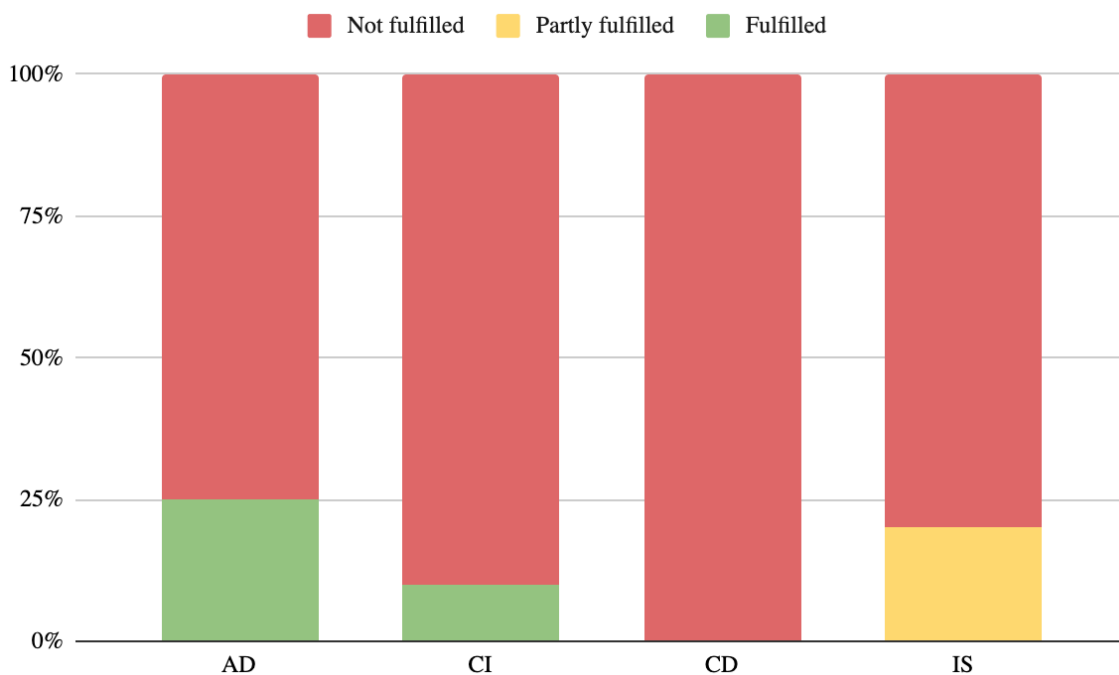
#### 7.1.1 The Speed Stairway to Heaven

Like Division B, Division A develops products which follow strict legal requirements and requires high levels of traceability. Thus, Division A could also benefit from some traditional development methods, and might not want to fully transition to an agile way of working. That being said, our analysis shows that the maturity of Division A differs between the work done internally in the division and the work performed in closer collaboration with external suppliers. In its internal work, Division A has reached the beginning of the Agile Development step in the Speed Stairway to Heaven. To fully develop the capabilities required to reach this step, the internal development group of Division A must increase the frequency at which they update and collect feedback from their customers. The frequency should be increased to each sprint, instead of the current interval of every six weeks. When this has been done, the next task will be to build CI capabilities and start utilizing the CI chain

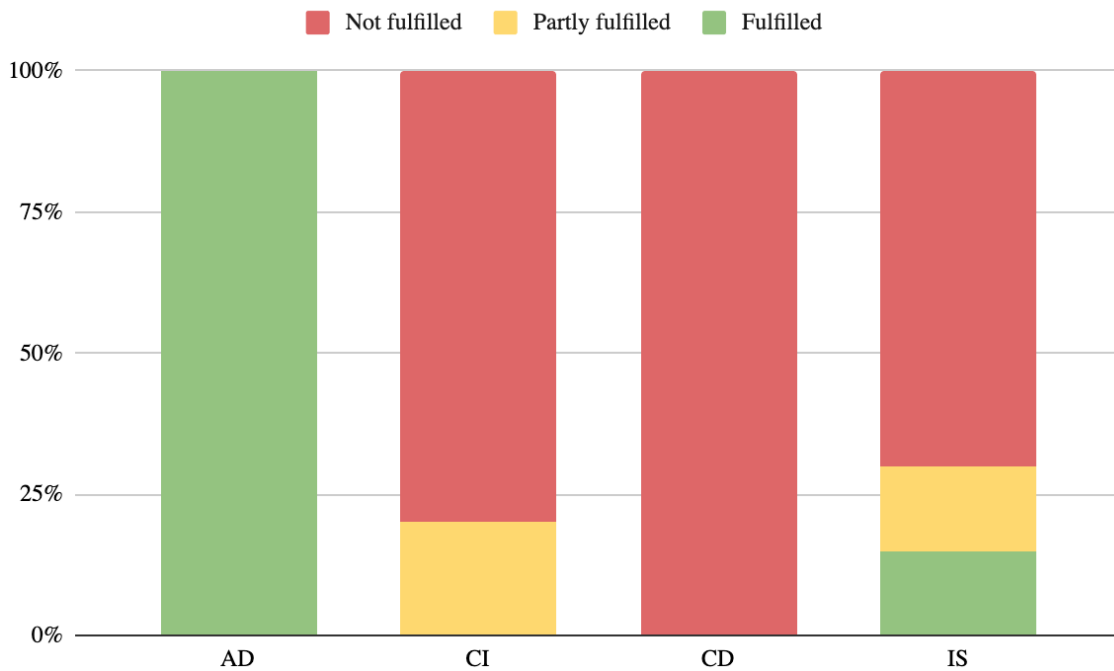
developed by the System Teams.

The external development group within Division A have on the other hand already fully reached the Agile Development step, and should thus focus on CI. This means that they must start utilizing the CI chain that has been developed by the System Teams. To use this tool to its full potential, the external Division A group must increase the frequency at which they get code delivered from their suppliers so that this happens continuously rather than with weeks apart. They must then also assure that feedback of the errors that are found in the CI-tests are sent back directly to the responsible developers at the suppliers to be resolved.

Seeing how one part of Division A is further developed in their agile development than the other, additional knowledge sharing between the groups is an obvious first step to take in order to increase the maturity of the internal Division A group. Figures 7.1 and 7.2 shows a summary of the maturity within the Speed Stairway to Heaven for the internal group and the external group respectively.



**Figure 7.1:** Summary of the Speed Maturity of the internal groups in Division A based on the Speed Stairway to Heaven. Keys: AD = Agile Development, CI = Continuous Integration, CD = Continuous Deployment, IS = R&D as an Innovation System.



**Figure 7.2:** Summary of the Speed Maturity of the external facing groups of Division A based on the Speed Stairway to Heaven. Keys: AD = Agile Development, CI = Continuous Integration, CD = Continuous Deployment, IS = R&D as an Innovation System.

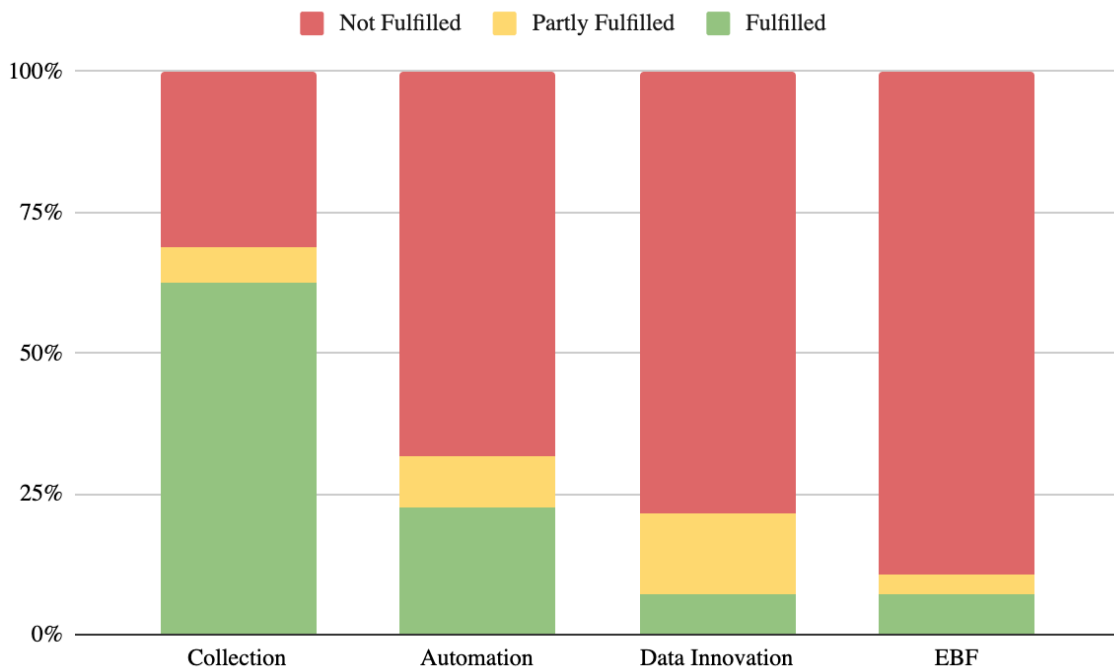
### 7.1.2 The Data Stairway to Heaven

Our analysis of the data provided by Interviewee B and C shows that although the internal and external groups of Division A also differ in their data maturity, they can both be placed somewhere between the Ad-Hoc and the Collection levels of the Data Stairway to Heaven. What keeps both groups from moving up the stairway is that neither of them have automated their data collection. This is thus the first step that both groups should take. However, it should be noted that the feasibility of automating the data collection during some tests, such as the ones of autonomous functions, could be low due to current legal restraints. In this case, the Division A groups could instead work to automate some of the analyses made on their collected data in order to move up to the automation step of the stairway.

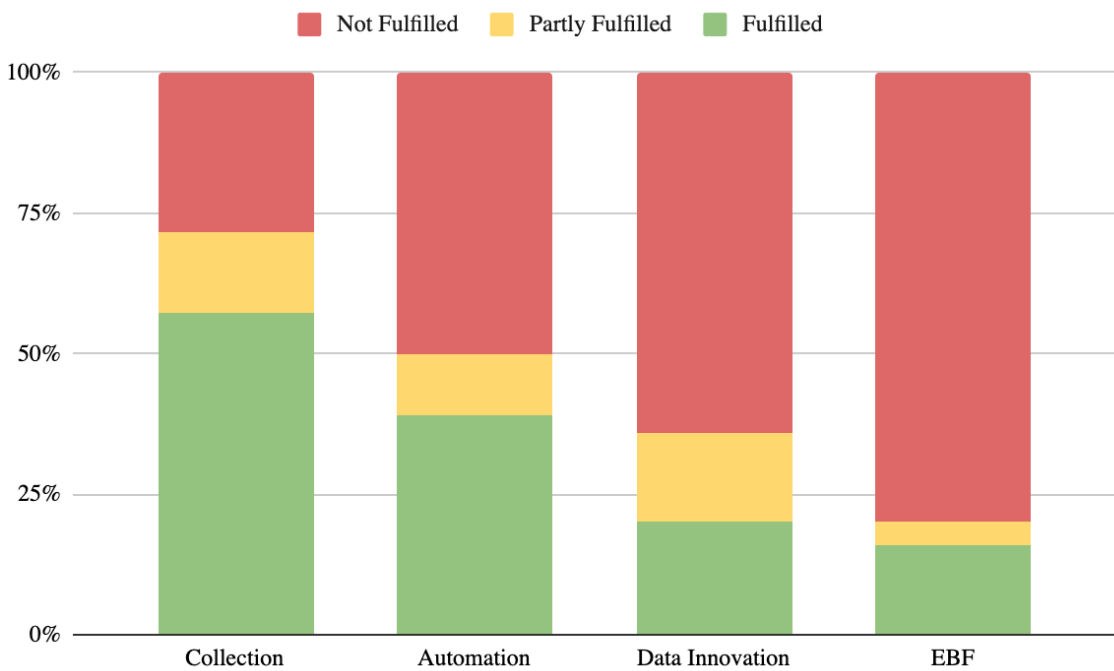
The Division A groups have developed some capabilities a lot further than other Divisions. For example, both the internal and the external groups are reporting their analyses using continuously updating dashboards. Further, the internal group collects data regarding customer behavior in addition to the collection of quality and troubleshooting data. In this regard, they are more mature than the external Division A group, who could learn from the internal group in this case. Figures 7.3 and 7.4 summarize the analyses of the Division A groups' maturity within the Data Stairway to Heaven.

## 7. Maturity Assessment

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**Figure 7.3:** Summary of the Data Maturity of the internal groups of Division A based on the Data Stairway to Heaven. Key: EBF = Evidence Based Firm.

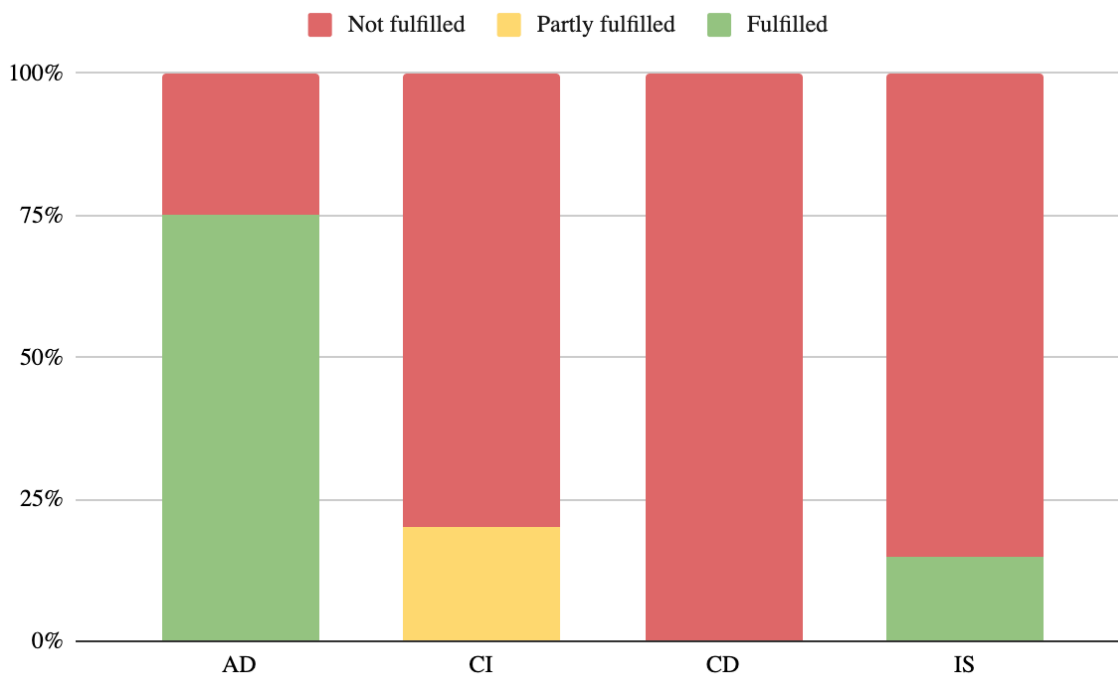


**Figure 7.4:** Summary of the Data Maturity of the external facing groups of Division A based on the Data Stairway to Heaven. Key: EBF = Evidence Based Firm.

## 7.2 Division B

### 7.2.1 The Speed Stairway to Heaven

Based on the data gathered in the interview with Interviewee A, we find that Division B is currently at the lowest level of the Speed Stairway to Heaven. Much of the development work that is done in the division follows strict legal requirements and requires a high level of traceability. These characteristics mean that traditional development methods could be suitable for Division B. If Division B still wants to increase its capabilities and move up the Speed Stairway to Heaven and work more agile, their next step is to incorporate collecting customer feedback about the division's projects after each sprint. The second step is to start using the CI chain that has been developed by the System Teams in the R&D BU. This will likely require closer collaboration between Division B and its software suppliers. The reason for this is that the development of CI capabilities will require much more frequent deliveries of new code, as well as direct feedback going back to the developers at the software suppliers as soon as errors are found during the CI tests. The maturity of Division B is summarized in figure 7.5.



**Figure 7.5:** Summary of the Speed Maturity of Division B based on the Speed Stairway to Heaven. Keys: AD = Agile Development, CI = Continuous Integration, CD = Continuous Deployment, IS = R&D as an Innovation System.

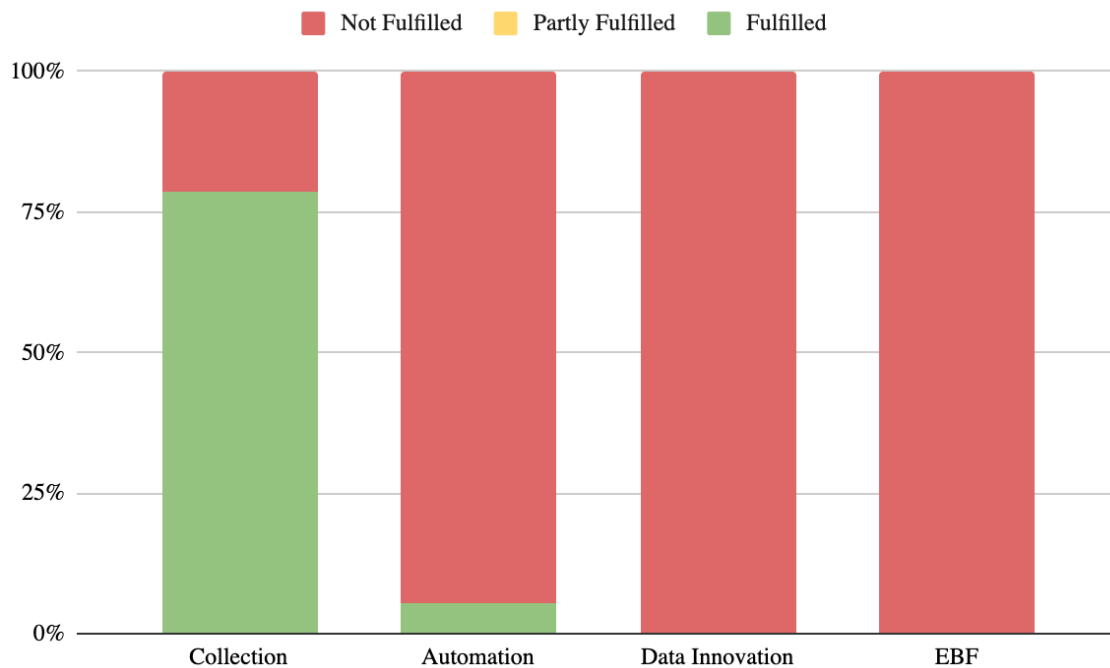
### 7.2.2 The Data Stairway to Heaven

The analysis of Division B shows that it currently lies somewhere between the Ad-Hoc and the Collection stage of the Data Stairway to Heaven. In general, we find

that the next major steps for the division will be the automation of the data collection regarding its products, followed by the automation of the analysis of the data and finally the reporting of the analyses. As the analysis and reporting is currently performed by the division's suppliers, the automation of the collection-analysis-reporting chain will most likely require additional and closer collaboration between Division B and its suppliers.

A second change Division B could aim for in order to move up the Data Stairway to Heaven is to expand the scope of its data collection from troubleshooting and quality related issues to also include customer behavior. The benefit of this change would be to better connect R&D efforts to actual business value. Finally, we find that Division B could move up to higher stages of the data stairway to heaven by increasing the frequency of data analysis and reporting.

Similarly to the case of the Speed Stairway, we find that the nature of division B's development can hinder its advancement within the Data Stairway. Division B is responsible for developing hardware and software to ensure that protective systems are activated in the event of a car crash. Due to the safety-critical nature of the protective systems, rigorous testing and validation are required before launching new functionality. A large part of the data that is collected by Division B is performed by manually crashing physical cars. The process is necessary in order to follow regulations and certifications, despite being both time- and resource consuming. This need for manual testing can be a big challenge for the division as the higher levels of the Data Stairway, starting at the CI level, requires fully automated testing to be in place. Figure 7.6 presents a summary of Division B's maturity within the Data Stairway to Heaven.



**Figure 7.6:** Summary of the Data Maturity of the internal groups of Division B based on the Data Stairway to Heaven. Key: EBF = Evidence Based Firm.

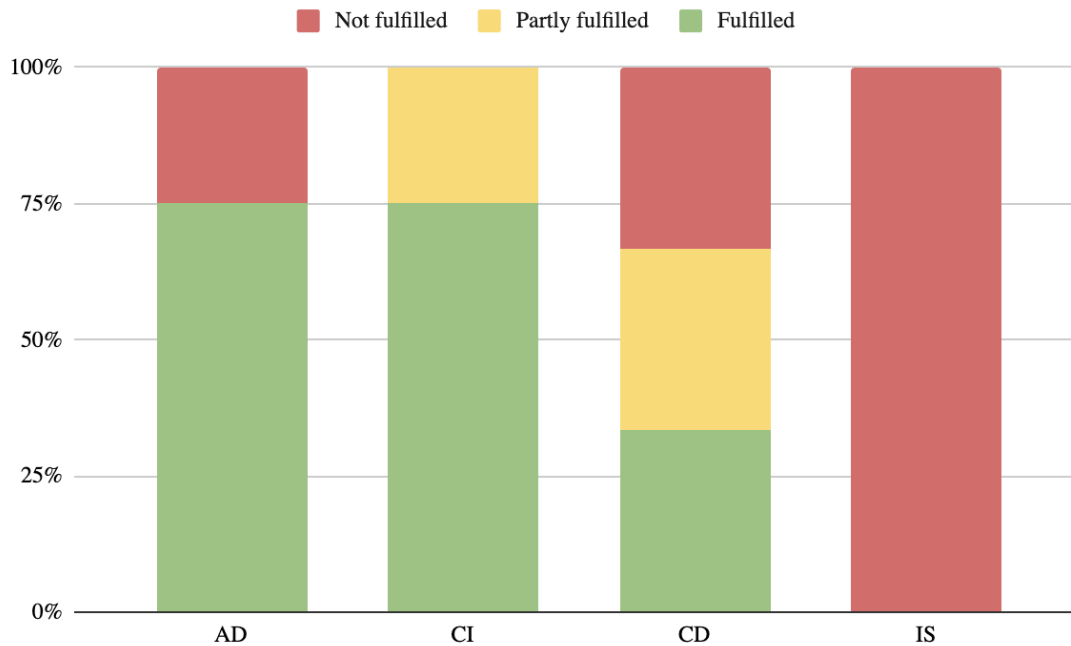
## 7.3 Division D

### 7.3.1 The Speed Stairway to Heaven

Our analysis of the Division D shows that the division is currently somewhere between the Traditional Development and the Continuous Integration levels on the Speed Stairway to Heaven. The fact Division D work as a support function to the divisions of the R&D BU and that they are not as affected by legal constraints should make it easier for them to move up the Speed Stairway. Our analysis shows that this is somewhat the case, as Division D have reached further in both the Continuous Integration and the Continuous Development levels. However, despite this, Division D have not yet fulfilled all criteria for the Agile Development level and is thus technically still residing at the Traditional Development level. The reason for this is that Division D lack an efficient way of using customer feedback to prioritize their backlog after each sprint. The prioritization is currently done during the PI-planning in 12 weeks intervals, which is much too slow. Seeing how far Division D have reached regarding both CI and CD, a much shorter interval would be expected. To decrease the prioritization interval to take place after each sprint should be the first action of Division D.

After ensuring that they are working in accordance to Agile Development, the next task for Division D is to fully implement Continuous Integration. As they have already fulfilled most of the criteria of this level, such as frequent integration of small chunks of code, the next step will be to fully automate testing on every level.

Figure 7.7 summarizes the maturity of Division D within the Speed Stairway to Heaven.



**Figure 7.7:** Summary of the Speed Maturity of Division D based on the Speed Stairway to Heaven. Keys: AD = Agile Development, CI = Continuous Integration, CD = Continuous Deployment, IS = R&D as an Innovation System.

### 7.3.2 The Data Stairway to Heaven

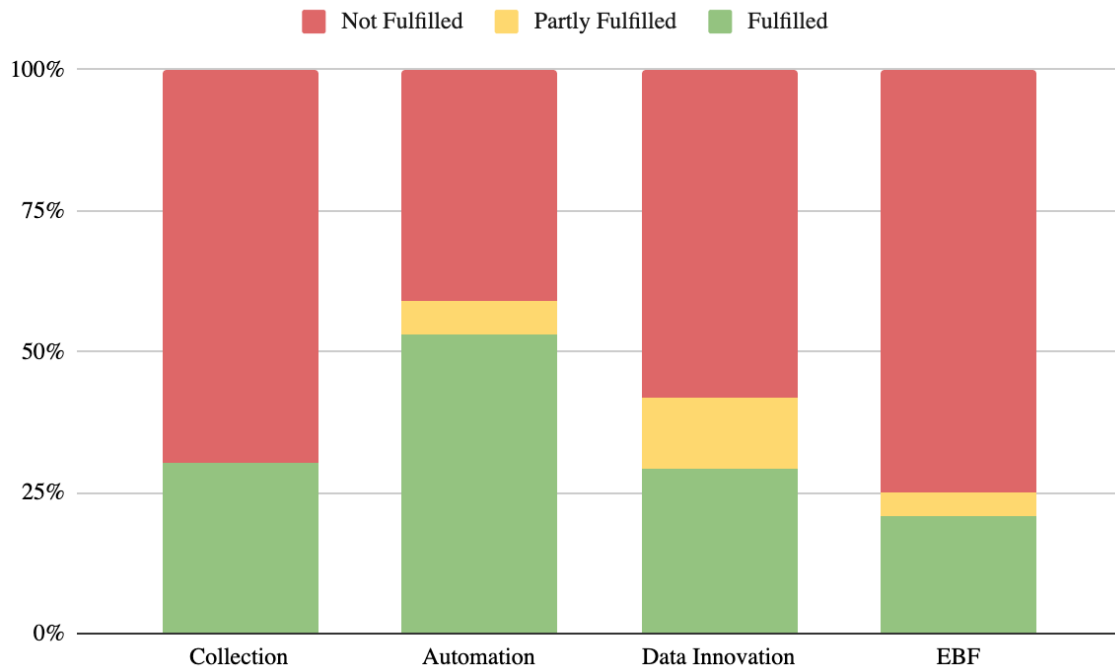
Division D is currently positioned on the Ad-Hoc level of the Data Stairway to Heaven. The major reason to why Division D have not climbed further on the Stairway is due to their manual data collection and data analysis. Further progress have been made in other areas, for example within automatic reporting and visualization of data.

One action that Division D could aim for is to expand the automation of their data collection. Division D is currently receiving data by automatically logging their internal tests, however all collection of data outside of the data logs are performed manually. Division D could also expand the scope of the data that they are collecting. As an example, instead of only collecting quality and troubleshooting related data, the teams should also collect data on user behavior and business value in order to better prioritize its R&D efforts.

To further improve its capabilities and maturity within the Data Stairway to Heaven, Division D could focus on their data analysis. Currently, Division D receive request form the divisions of the R&D BU when they are in need of support. The requests are then prioritized by the PO, put in the backlog of the teams, and finally analyzed

manually by a developer or team of developers. By looking for similarities between the requested analyses, Division D could seek to automate the analyses that are the most similar and the most frequent. By doing so, they can free up time for the developers to analyze more complex problems and at the same time move up to the Automation level of the Data Stairway to Heaven.

Division D current maturity within the Data Stairway to Heaven models is summarized in figure 7.8.



**Figure 7.8:** Summary of the Data Maturity of Division D based on the Data Stairway to Heaven. Key: EBF = Evidence Based Firm.

### 7.4 Division E

Division E in the R&D BU is not developing any products of its own, but works as a research group for topics related to the work of the R&D BU. This means that many of the capabilities evaluated in the Speed- and the Data Stairway to Heaven do not apply directly to Division E. What can be noted from our analysis is that Division E does not work according to the agile methodology, as they believe that the type of research they do is more suited for longer increments than what is practiced in agile development. They do, however, work iteratively with their customers in order to ensure that their reports are of highest quality.

Division E have not automated any of their work. Although they do not develop any technical product, similarities can be seen between Division E and the data analytics teams described by Bosch (2017). By this logic, the next step in the evolution of Division E would be to automate some of the data collection they perform. As an example, as the teams are constantly looking for news about their competitors, efforts could be made to automate the collection of news data from the competitors communication channels. To further advance in maturity, Division E could also look to automate some of their more frequent types of analyses. This could free up time that the teams could use to investigate more complex and unique issues.

### 7.5 The R&D BU Management Team

Similar to Division E, the managing group at the R&D BU does not develop any products themselves. This means that the Speed- and Data Stairway to Heaven are not very applicable to this group either. It is worth noting that like Division E, The R&D BU Management Team does not work in sprints. Instead the different roles in the group work in accordance with what they find most suitable, which sometimes seem to follow a more traditional waterfall model. The R&D BU Management Team have not automated their data collection, analysis, reporting, or decision making processes. Based on the same logic as presented for Division E, the R&D BU management team could look to automate both data collection and some analyses in order to become more efficient in its work.

# 8

## Discussion

The following chapter presents the discussion of this study. The discussion begins with an interpretation of the maturity assessment presented in the previous chapter, and is followed by a discussion regarding the theoretical framework and the feasibility of implementing theoretical models in an empirical setting. The chapter is concluded with a discussion of our study itself. Table 8.1 outlines the questions that will be discussed as well as their locations in this chapter.

Discussion point	Section
What are the possible reasons for the current maturity levels of the studied divisions?	8.1
What could the R&D BU do in order to advance its maturity levels?	8.1
What can be said of the quality and usability of the Stairway to Heaven models?	8.2
Could it be that problems with using the Stairway to Heaven models are symptoms of a broader problem regarding implementing general frameworks in specific settings?	8.3
If this study was to be performed again, what could be done differently?	8.4

**Table 8.1:** The topics that will be discussed in this chapter together with their location.

### 8.1 Discussion regarding the Maturity Assessment

The maturity of the different divisions within the R&D BU are summarized in Table 8.2. Where the figures in chapter 7 showed the maturity of the studied divisions over all the levels of the two maturity models, this Table only shows the levels that have actually been reached. As all the criteria of a level must be fulfilled before a division can be said to have reached it, very few divisions have reached further than the initial maturity levels of each Stairway. In fact, it is only the external group of Division A that has reached a higher level, namely the Agile Development level of the Speed Stairway to Heaven. As noted in chapter 7, both Division E and the R&D BU Management Team worked in ways that made the Speed Stairway and the

Data Stairway models difficult to apply. Because of this, their maturity levels have been marked as N/A to illustrate that they were not applicable.

Division within the R&D BU	Speed Maturity	Data Maturity
Division A: Internal	Traditional Development	Ad-Hoc
Division A: External	Agile Development	Ad-Hoc
Division B	Traditional Development	Ad-Hoc
Division D	Traditional Development	Ad-Hoc
Division E	N/A	N/A
R&D BU Management Team	N/A	N/A

**Table 8.2:** This table presents the maturity levels of the studied divisions within the R&D BU. The column called "Speed Maturity" shows the divisions' maturity within the Speed Stairway to Heaven, while the column called "Data Maturity" shows the divisions' maturity within the Data Stairway to Heaven. As many of the criteria for the maturity levels were not applicable to Division E or the R&D BU Management Team, their maturity levels have been marked as N/A.

The major reason for why most divisions within the R&D BU is still at the initial level of the Speed Stairway is that they do not update their customers after each sprint. Furthermore, only the part of Division D that is responsible for developing the R&D BU's CI-tools fulfills many of the criteria for the CI maturity level. The lack of progress regarding CI within the other divisions seems to be linked to the fact that the divisions buy most of their software from external suppliers. The outsourcing of the software development seems to have led to a situation where the divisions have difficulties to get frequent deliveries of small chunks of code from their suppliers. Instead, a more traditional development situation is present where the suppliers deliver complete software packages with low frequency. This way of working is opposite to the fundamental rule of CI, which makes it problematic. In addition to this problem, the divisions have not been successful in connecting their own CI-chain to the suppliers. Together, these two challenges makes it very difficult for the divisions to move up the Speed Stairway to Heaven.

The fact that many teams within the R&D BU seems to be struggling with similar issues, especially concerning the CI, suggests that there are systematic issues that needs to be addressed. Therefore, we suggest that the issues regarding the CI-chain and the collaboration with the divisions' suppliers should be raised to a higher level within the organization. As an example, this could be a question for the R&D BU's Management Team.

The reason for why the issue of infrequent deliveries has not yet been solved can be one of many things. As is often the case in profit seeking organizations, we suspect that this issue can be boiled down to a matter of cost. Improving the collaboration between the R&D BU and its suppliers would require resources in the form of time and personnel. Perhaps the coordinative system that is currently in place will even

need to be replaced by a new one. However, if no efforts are made to improve the current system, we believe that the CI-chain will not improve enough to enable the R&D BU to advance on the Speed Stairway to Heaven. Thus, there is a trade off between how much resources that should be put into improving the supplier collaboration, and how valuable the R&D BU believes it is to improve its CI-chain. The observation that fully implementing the CI-chain will require a lot of coordination between the R&D BU and their suppliers, together with the fact that the software developed for the R&D BU is highly customized, suggests that the transaction cost for this exchange is high. This could be one of the reasons for why the R&D BU has not yet committed all the resources necessary to make the CI-chain work. It could be the case that it would be cheaper for the R&D BU to bring some of the software development into its own organization, as the administrative cost of coordinating such complex and specific development could be lower than the transaction cost. Based on the observations regarding the coordination between the R&D BU and its suppliers, we suggest that the Management Team of the R&D BU perform this cost comparison. When investigating whether or not to allocate resources into improving the CI-chain, i.e. all the tools used in the R&D BU's CI efforts, the R&D BU should consider two things. First, they should calculate the cost of improving the current collaboration with their suppliers in order to improve the CI-chain. Secondly, the R&D BU should analyze if parts of the software development can be moved into the organization, and if so what the cost of doing so would be.

Another common factor between the divisions is that they are all developing safety critical systems. As stated by Bosch (2017) and Knight (2002), the development of safety critical systems is often highly regulated and requires detailed documentation to ensure traceability. As these characteristics are opposite to the fundamental idea of Agile Development, we believe that advancement to the higher levels of the Speed Stairway might prove difficult. Since developing safety critical features are integral to the R&D BU, a question can be raised to whether the Speed Stairway to Heaven is a feasible model to use, or if another framework that is more adapted to the development of safety critical systems is needed.

Having established that the nature of the development done by the divisions within the R&D BU will make it difficult for them to advance far on the Speed Stairway to Heaven, we believe that it could be efficient to focus on climbing up the Data Stairway to Heaven instead. All divisions are currently on the lowest level of the Data Stairway, mostly due to the fact that no automatic data collection is in place. Automatic data collection regarding customers' use of the company will be difficult before the cars have been fitted with equipment that enables wireless data transfer. However, when such a system is in place, the possibilities to automate both data collection as well as analysis and reporting will open up. As this development could be believed to happen in the near future, we suggest that the divisions already start to investigate how they can leverage this in order to advance within the Data Stairway to Heaven.

Due to the fact that they do develop any products themselves, the larger parts of

the Speed and Data Stairways were not applicable to either the R&D BU Management Team or Division E. However, we believe that they would benefit greatly from working more data driven. The automatic collection of data would be the first step in this journey. As mentioned in chapter 7, one such example could be automatic collection of information regarding the communication of the company's competitors. By working more data driven, the Management Team of the R&D BU could also set a good example for the rest of the R&D BU.

When performing the analysis of the R&D BU, it became apparent that many of the criteria from the Stairway to Heaven models did not fully match the situations of the divisions. The following section expands on this observation by providing a discussion regarding the discrepancies between our empirical findings and Bosch's academic models.

## 8.2 Critique on the Stairway to Heaven models

The Stairway to Heaven models were designed to be implemented by what Bosch (2017) refers to as software intensive embedded system firms. In addition, the author specifically mentions firms within the automotive industry as fitting candidates to apply the models. Since the R&D BU within the company is an exceptionally software intensive R&D division in an automotive firm it was our opinion that it should fit the models well.

Despite the probable fit between the R&D BU and the Stairway to Heaven models, we found some discrepancies between the situation at the R&D BU and the models. The biggest discrepancy we found concerned the Data Stairway to Heaven, specifically the absence of a data analytics team within the studied divisions within the R&D BU. In Bosch's description of the Data Stairway levels, he describes that organizations typically have dedicated teams that handle all analyses and reporting for their respective R&D division. In case of the groups within the R&D BU, all such activities are performed by the developers themselves, not by a specific data analytics team. Bosch does state that the existence of data analytics team is a common model for organizations, and not that it is required by all organizations. However, most of the criteria regarding the different levels within the Data Stairway are based on the fact that such teams exist. Bosch's frequent use of data analytics team term, when discussing the criteria of the maturity levels, suggests that it is an integral part of the Stairway model. If this is the case, the first activity for an organizations to perform should be to create data analytics teams. If, however, the data analytics teams are not crucial for increasing the IT maturity within organizations, we suggest that the model should cover situations where such teams are not present. It is our belief that this would increase the clarity and useability of the model.

One of the main findings regarding the Speed Stairway to Heaven is the fact that all divisions within the R&D BU develops safety critical systems to some extent. Developing safety critical systems is mentioned by Bosch as a major hindrance towards advancing from the lowest level of the Speed Stairway, i.e. the Traditional

Development level, due to the fact that it is often highly regulated. After having studied an R&D division in an automotive firm during the last couple of months, it is our opinion that most of the features of a car can in fact be considered to be safety critical. Although there are some exceptions to this statement, for example infotainment systems and climate control, we believe that the Stairway model could be reviewed for specific implementation within the automotive industry. The main reason of this statement is that we believe that organizations within the automotive industry that seeks to use the model, in its current state, will not pass the first level due to the fact that they are safety critical systems. In these cases, the Speed Stairway to Heaven loses most of its value to the organizations. Thus, an adopted version of the maturity model which better suits the context of an organization who develops safety critical systems would likely be valuable.

A third observation that was made during the analysis of the R&D BU was that neither the Data Stairway, nor the Speed Stairway explicitly takes into account situations where an R&D organization outsources much of its software development. As described in chapters 6 and 7, this is the case for all the divisions of the R&D BU. The fact that the divisions are outsourcing their software development creates multiple challenges regarding CI and CD. One such challenge is the difficulty to get small and frequent deliveries of code. Another challenge is that the divisions seems to have little knowledge of how the information they send to the suppliers is used, and the development processes of the suppliers. As both the CI and the CD levels require a fast and closed loop between the software developer, the testing of the code, and the customers, this gap becomes a big problem for the R&D BU. In order to help organizations who face similar situations, we suggest that the Stairway to Heaven models should include guidance for how to manage these types of situations.

### **8.2.1 Requirements for developing maturity models**

In addition to the discussion of our own observation regarding the application of Bosch's Stairway to Heaven models, we will now provide a section regarding the academic rigor of the models based on the framework by Becker et al. (2009), summarized in Table 8.3. The discussion will be structured in accordance to the requirements presented in the Table. Of the eight requirements in Table 8.3, the discussion will not cover requirements two, four, and six. The reason is that these three requirements deals with actions that the author of a new maturity model must take either prior, or during, the design and development of the model. As Bosch does not provide sufficient documentation regarding the design process of the Stairway to Heaven models for us to make an assessment of either of the requirements, they have been omitted from the discussion.

The first requirement for developing new maturity models is the comparison of the model with existing maturity models (Becker et al., 2009). In essence, Becker et al. (2009) writes that a new maturity model should provide something that existing models does not already provide. Thus, it is important to compare the new model

Requirement	Description
R1 (Comparison with existing maturity models)	The need for the development of a new maturity model must be substantiated by a comparison with existing models. The new model may also just be an improvement of an already existing one.
R2 (Iterative)	Maturity models needs to be developed through an iterative, step by step process
R3 (Evaluation)	All principles and premises for the development of a maturity model, as well as usefulness, quality and effectiveness of the artifact, must be evaluated iteratively.
R4 (Multi-methodological Procedure)	Developing maturity models is a process that engages a multitude of research methods. The different research methods needs to be used in a well grounded and delicate manner.
R5 (Identification of Problem Relevance)	The relevance of the problem solution proposed by the projected maturity model for researchers and/or practitioners must be demonstrated.
R6 (Problem Definition)	The prospective application domain of the maturity model, as well as the conditions of its application and the intended benefits, must be determined prior to design.
R7 (Targeted Presentation of Results)	The presentation of the maturity model must be targeted with regard to the conditions of its application and the need of its users.
R8 (Scientific Documentation)	The design process of the maturity model needs to be documented in detail, considering each step of the process, the parties involved, the applied methods, and the results.

**Table 8.3:** In order to help the reader to remember the eight requirements by Becker, Knackstedt & Pöppelbuß (2009), we include a copy of Table 2.2

with older models in order to motivate its existence. In the case of Bosch's Stairway to Heaven models, no references are made to previous IT maturity models in this regard. We can therefore say that Bosch fails to fulfill the first of the requirements proposed by Becker et al. (2009).

The third requirement considers how extensively the new maturity model has been tested and evaluated by practitioners and scholars. The purpose of this requirement is to make sure that the usefulness, quality and effectiveness of the model has been sufficiently tested before it can be trusted. To our knowledge, there exist none, if any, documented studies related to the third requirement for the Stairway to Heaven models. As such, there is little evidence apart from the claims made by Bosch himself about the usefulness and quality of the models. Furthermore, the lack of examples regarding the use of the Stairway to Heaven models means that there exists no documentation, besides Bosch's, of how to objectively evaluate the maturity of an organization. As Bosch himself does not provide any explicit questions to use when evaluating an organization, this creates a lot of room for interpretation and makes it difficult to know if the criteria used are in line with what was meant by Bosch. Based on our own experience of doing an evaluation based on the Stairways to Heaven models, we find that the lack of clear and tested objective criteria decreases the usefulness of the models. As a conclusion, we find that the Stairway to Heaven models does not fulfill the third requirement of framework by Becker et al. (2009).

Requirements five and seven are related to how well the relevance of the problem that the maturity model is supposed to solve is described, and if a description of the model's target audience is provided. In the case of the Stairway to Heaven models, Bosch is rather clear on these points. In his book *Speed, Data, and Ecosystems* (Bosch, 2017), Bosch writes extensively of the trends and industry challenges that have led up to the creation of the Stairway to Heaven models. As for the target audience of the book, Bosch names general managers and leaders outside of R&D, leaders in R&D and product management, and technical staff such as senior engineers and architects as the primary audience, while researchers, students and academics in general compose a secondary audience (Bosch, 2017). Due to this, we assess that Bosch fulfills both requirements five and seven.

Finally, we will discuss the last requirement, which concerns the scientific documentation of the Stairway to Heaven models. As for any scientific endeavour, this requirement is included in the framework by Becker et al. (2009) to enable others to critically evaluate the design process of a maturity model. In his book on the Stairway to Heaven models (Bosch, 2017), Bosch does not provide any detailed scientific documentation of his design process. He writes that the content in the book is based on a combination of industry experience, consulting engagements, and the knowledge of the Swedish Software Center, which is a collaboration between Swedish universities and large organizations (Bosch, 2017). Bosch also claims that the topics in the book have benefits that "have been confirmed and documented in real, large-scale software-intensive companies" (Bosch, 2017). However, no references are included to support this claim. The only real documentation we have found relating to the Stairway to Heaven models comes from the article *Climbing the "Stairway to Heaven"* (Olsson, Alahyari, & Bosch, 2012) where Bosch and his colleagues first introduce the Stairway to Heaven concept. This article presents a multiple-case study of four companies which laid the foundation for the first Stairway to Heaven

model. However, the article only covers the first iteration of the model and not the additions that Bosch subsequently has done to produce the versions used in this report. Based on the relative lack of scientific documentation, we conclude that the last requirement of the framework by Becker et al. (2009) is not fulfilled.

The fact that the Stairway to Heaven models fail to fulfill three of the five discussed requirements presented in this section brings up some doubts around the academic rigor of Bosch's models. Because of this, organizations such as the R&D BU should be cautious of accepting Bosch's statements as validated facts. However, this does not mean that the Stairway to Heaven models hold no practical value. It is still our opinion that the recommendations that have been derived from our analysis can be useful for the R&D BU to improve its capabilities within data driven software development.

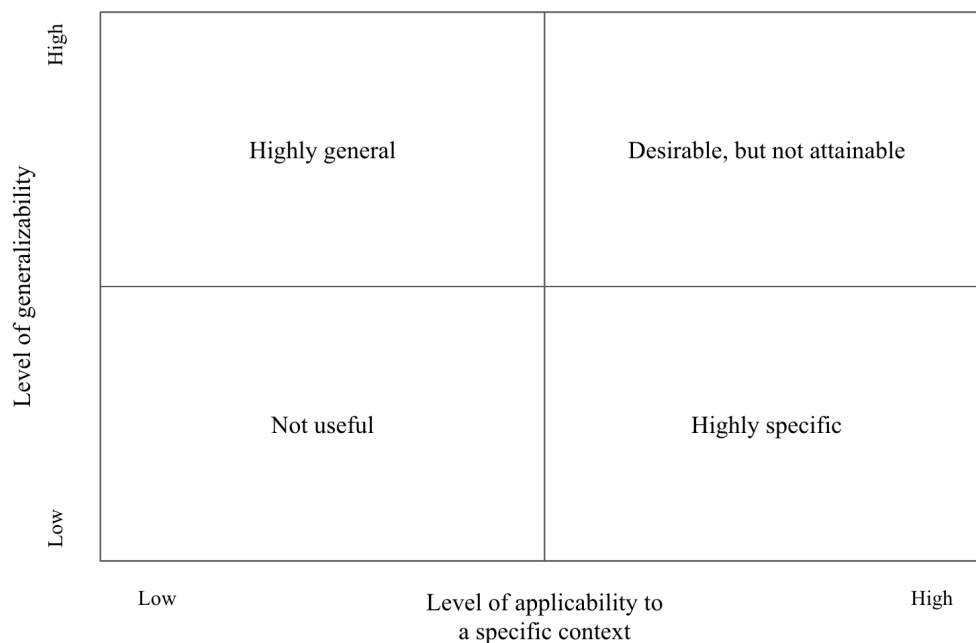
A question could also be raised if it is necessary, or even feasible, for a the development of a maturity model to fulfill all eight criteria that are presented by Becker et al. (2009) for the model to be valuable. Perhaps a similar assessment to the one just made of the Stairway to Heaven models would show that the requirements by Becker et al. (2009) themselves somewhat lack in quality. It is also important to note that the requirements that are used as the basis for our evaluation in this section come from only one study. There might exist other authors with other views on what needs to be fulfilled in order for a maturity model to be of high quality. However, the research area of IT maturity model assessments is, to our knowledge, quite narrow. Thus, we chose to use the most highly cited assessment model. In either case, we suggest that a future action for the R&D BU could be to complement our maturity assessment with one that uses another, more validated, maturity model. By using different models to perform their assessment, the R&D BU could gain a more nuanced understanding of its situation and of what actions to take in order to improve its capabilities.

### 8.3 Implementing general models in specific settings

The critique presented in section 8.2 against the models created by Bosch can partly be explained by the fact that they are too general to perfectly match the reality of any specific industry or organization. The question can therefore be raised to whether it is a problem with the models themselves or a general problem with implementing general models in a specific setting.

From a practical point of view, each firm have different capabilities, different contexts and faces different challenges. Thus, no general models can completely cover all the needs of any one firm. In order to create models, or frameworks, that are applicable to a range of firms, a trade off will therefore have to be made between the having the model fit very well to a few contexts, or slightly worse to many.

Figure 8.1 shows a visualization of how this trade off can be conceptualized. This 2x2 matrix shows four general states that we argue a model can have. The second and the fourth quadrants represents cases where most models will end up, i.e. either being general but not capturing specific details or specific but not applicable to many situations. The first quadrant represents what is desirable, but arguable not attainable according to the logic above. Finally, a model can have both a low level of generalizability and a low level of applicability to a specific context. Such a model is, of course, not very useful. The fact that Bosch's models does not apply perfectly to the specific context of the R&D BU can partly be explained by this idea. The models are not weak per se, they might just be a bit too general to be fully implemented by the R&D BU.



**Figure 8.1:** Visualization of the trade off between a model's level of generalizability and its level of applicability for specific organizations.

Klünder et al. (2019) states that most firms does not implement new development approaches directly, instead the firms often combine different theoretical frameworks and models. By creating contextualized models by using bits and pieces of different models, the firms are able to align the ideas to their situation. This is referred to by the authors as hybrid development methods (Klünder et al., 2019). Although hybrid development methods have proven to be successful in order for firms to reach their goals, there are also some drawbacks with these methods. The main drawback is that there does not, according to Klünder et al. (2019), exist any perfect strategies to create hybrid methods. However, we believe that in order for the R&D BU to make the most out of the ideas presented by Bosch, they should adopt some of the concepts from the models and devise their own hybrid development methods. As an example, we believe that adopting the Stairway to Heaven models to better fit the development of safety-critical systems in a context with many software suppliers

would benefit the R&D BU and help the improvement of its capabilities.

### 8.4 Contributions and suggestions for future research

To conclude this discussion chapter, we will present our reflection on our research process, our contributions, and what could be considered for future research.

One of the main challenges of this study has been to translate Bosch's texts on the Stairway to Heaven models into questions that can be used to perform the maturity assessment. As no previous work had been published regarding this topic, the translation required a lot of work and interpretation. We believe that the creation of these questions is one of the main academic contributions of our study. Our questions represent the first published attempt to complement the Stairway to Heaven models with a set of questions to use when performing the maturity assessment. This contribution should benefit future researchers and practitioners who want to use the Stairway to Heaven models, as they now have a point of reference to use. We also believe that our questions improves the quality of the Stairway to Heaven models themselves, as they help to fulfill requirement number three of the requirements presented by (Becker et al., 2009).

Another challenge in this project was narrowing the scope from looking at the HoliDev framework, which was the original request from the R&D BU, to the Stairway to Heaven models. We started our research by conducting a pre-study where both the HoliDev framework was reviewed as well as the R&D BU's current situation. During the pre-study it became clear to us that the original request by the R&D BU would be unfeasible to fulfill, as there were not nearly enough information published on the HoliDev framework for it to be used. Thus, the scope of the study was changed to better fit the R&D BU's current challenges. This process was difficult, yet crucial for the study. One reason for why this was difficult was that we had to discard the original idea that was provided by the R&D BU. It can be hard enough to kill your own darlings, however, killing someone else's darlings proved to be even harder. The second reason to why changing the scope was difficult was that we needed to balance the interests of both the R&D BU and our supervisor at Chalmers. The way we solved these issues was by maintaining a good and transparent communication with both the R&D BU and our academic supervisor.

Based on the observations regarding our study, we have two recommendations for future researchers. Firstly, in order to avoid a situation where you, late in the research process, understand that the scope of the project is not feasible, we recommend that you conduct a pre-study as early as possible. Secondly, if you have multiple stakeholders in your project, we recommend openness and transparency in your communication in order to quickly resolve any situations where your stakeholders tries to pull you in different directions.

As discussed in section 8.1, we believe that there could be a relation between the R&D BU's low level of maturity in the CI level of the Speed Stairway to Heaven and the high transaction cost that could be related to their software development. We conclude this chapter by proposing that an interesting future research topic would be to investigate if this relation is correct, and if so what implications it would have for organizations who want to advance in the Speed Stairway to Heaven.



# 9

## Conclusion

In this study, we set out to fulfill two purposes. Our first purpose was to provide the company's software intensive R&D BU with an understanding of its current software development processes in relation to the Stairway to Heaven models, and of what it should do in order to increase its maturity in these domains. The second purpose was to investigate and discuss the usability and rigor of the applied models. Our first purpose was translated into the following two research questions:

- *RQ1: What is the level of maturity within the R&D BU based on the Speed Stairway to Heaven and the Data Stairway to Heaven models?*
- *RQ2: What are the next steps that the R&D BU should take in order to increase its level of maturity in the two studied domains?*

Research question one was answered in chapter 7, and the maturity of each studied division is summarized in table 9.1.

Division within the R&D BU	Speed Maturity	Data Maturity
Division A: Internal	Traditional Development	Ad-Hoc
Division A: External	Agile Development	Ad-Hoc
Division B	Traditional Development	Ad-Hoc
Division D	Traditional Development	Ad-Hoc
Division E	N/A	N/A
R&D BU Management Team	N/A	N/A

**Table 9.1:** The maturity levels of each studied division, copied from table 8.2

Although some of the divisions have partly fulfilled the criteria for the higher levels of the maturity models, they have not completely developed all the capabilities necessary to leave the initial levels of the Stairways. The three main criteria that the divisions are consequently missing are:

- The divisions are not frequently collecting feedback from their customers.
- Their CI-chain is not yet completely functional.
- The divisions do not yet collect data automatically.

The second research question was also answered in chapter 7. We can conclude that the general steps that the divisions within the R&D BU should take is to collect feedback from their customers at a more frequent rate, as well as starting to collect customer data automatically. In order to advance their maturity levels, the divisions within the R&D BU should also move towards closer collaboration with their software suppliers. The closer partner collaboration can increase the frequency of newly developed code, leading to an increasingly functional CI-chain.

The second purpose of the study was to investigate the usability and rigor of Bosch's models when applied to a practical setting. This purpose was reached through the discussion presented in chapter 8.2. In this chapter we conclude that even though the models lack some academic rigor, they can serve practical purposes. However, in their current state, the models provide too little guidance for how to actually perform a maturity assessment in accordance to the models. To solve this problem, we developed two sets of questions which were presented in chapter 4. These questions will be the first published attempt to create a practical way to perform the maturity assessment for the Stairway to Heaven models. We believe that they will help future researchers and practitioners who want to use the models, and we consider them the biggest academic contribution of this study.

In addition to fulfilling the purpose of the study, we have also raised a number of other discussion points in chapter 8. One discussion point which could be of special interest is whether or not the Stairway to Heaven models are a good fit for an organization that is developing safety critical system. We conclude that although the Stairway to Heaven models provide some valuable insights to such organizations, we believe that a more adopted version of the maturity models would be better suited to the context of safety critical systems.

# References

- Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009). Developing maturity models for it management. *Business & Information Systems Engineering*, 1(3), 213–222.
- Bell, E., Bryman, A., & Harley, B. (2019). *Business research methods*. Oxford University Press.
- Boehm, B., & Turner, R. (2005). Management challenges to implementing agile processes in traditional development organizations. *IEEE software*, 22(5), 30–39.
- Boeije, H., & Hox, J. (2005). Data collection, primary vs. secondary. *Encyclopedia of social measurement*, 1, 593–599.
- Bosch, J. (2017). *Speed, data, and ecosystems: Excelling in a software-driven world*. CRC press.
- Bosch, J., & Eklund, U. (2012). Eternal embedded software: Towards innovation experiment systems, In *International symposium on leveraging applications of formal methods, verification and validation*. Springer.
- Bosch, J., Olsson, H. H., & Crnkovic, I. (2018). It takes three to tango: Requirement, outcome/data, and ai driven development., In *Sibw*.
- Brynjolfsson, E., Hitt, L. M., & Kim, H. H. (2011). Strength in numbers: How does data-driven decisionmaking affect firm performance? *Available at SSRN 1819486*.
- Dalen, M. (2015). *Intervju som metod*. Gleerups Utbildning AB.
- De Bruin, T., Rosemann, M., Freeze, R., & Kaulkarni, U. (2005). Understanding the main phases of developing a maturity assessment model, In *Australasian conference on information systems (acis): Australasian Chapter of the Association for Information Systems*.
- Dubois, A., & Gadde, L.-E. (2002). Systematic combining: An abductive approach to case research. *Journal of business research*, 55(7), 553–560.
- Dybå, T., & Dingsøy, T. (2008). Empirical studies of agile software development: A systematic review. *Information and software technology*, 50(9-10), 833–859.

- Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2015). *Management and business research*. Sage.
- Edmondson, A. C., & McManus, S. E. (2007). Methodological fit in management field research. *Academy of management review*, *32*(4), 1246–1264.
- Fitzgerald, B., & Stol, K.-J. (2014). Continuous software engineering and beyond: Trends and challenges, In *Proceedings of the 1st international workshop on rapid continuous software engineering*.
- Fowler, M. (2020). Continuous integration (original version). Retrieved March 16, 2020, from <https://martinfowler.com/articles/originalContinuousIntegration.html>
- Fowler, M., Highsmith, J. Et al. (2001). The agile manifesto. *Software Development*, *9*(8), 28–35.
- Giaimo, F., & Berger, C. (2017). Design criteria to architect continuous experimentation for self-driving vehicles, In *2017 IEEE International Conference on Software Architecture (ICSA)*. IEEE.
- Hall Jr, O. P. (2010). Using dashboard based business intelligence systems. *2003 Volume 6 Issue 4*, (4).
- Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly*, 75–105.
- Highsmith, J., & Cockburn, A. (2001). Agile software development: The business of innovation. *Computer*, *34*(9), 120–127.
- Klünder, J., Hebig, R., Tell, P., Kuhrmann, M., Nakatumba-Nabende, J., Heldal, R., Krusche, S., Fazal-Baqaie, M., Felderer, M., Bocco, M. F. G., Et al. (2019). Catching up with method and process practice: An industry-informed baseline for researchers, In *2019 IEEE/ACM 41st International Conference on Software Engineering: Software Engineering in Practice (ICSE-SEIP)*. IEEE.
- Knight, J. C. (2002). Safety critical systems: Challenges and directions, In *Proceedings of the 24th international conference on software engineering*.
- Lantz, A. (2013). *Intervjumetodik*. Studentlitteratur AB.
- Lucas Jr, H. C., & Goh, J. M. (2009). Disruptive technology: How kodak missed the digital photography revolution. *The Journal of Strategic Information Systems*, *18*(1), 46–55.
- Mantere, S., & Ketokivi, M. (2013). Reasoning in organization science. *Academy of management review*, *38*(1), 70–89.
- Olsson, H. H. (2018). Challenges and strategies for undertaking continuous experimentation to embedded systems: Industry and research perspectives. *Agile Processes in Software Engineering and Extreme Programming*, 277.

- Olsson, H. H., Alahyari, H., & Bosch, J. (2012). Climbing the "stairway to heaven"—a multiple-case study exploring barriers in the transition from agile development towards continuous deployment of software, In *2012 38th euromicro conference on software engineering and advanced applications*. IEEE.
- Patón-Romero, J. D., Baldassarre, M. T., Rodríguez, M., & Piattini, M. (2019). Maturity model based on cmmi for governance and management of green it. *IET Software*, *13*(6), 555–563.
- Petersen, K., Wohlin, C., & Baca, D. (2009). The waterfall model in large-scale development, In *International conference on product-focused software process improvement*. Springer.
- Pinto, J. K. (2013). *Project management: Achieving competitive advantage*. Pearson Upper Saddle River, NJ.
- Sandström, C. (2013). Facit and the displacement of mechanical calculators. *IEEE Annals of the History of Computing*, *35*(3), 20–31.
- Scaled Agile, I. (n.d.). Safe 5.0 framework. Scaled Agile, Inc. Retrieved March 3, 2020, from <https://www.scaledagileframework.com/#>
- Sloss, G. S., Philliber, S., & Schwab, M. (1980). *Social Research: Guides to a Decision-Making Process*.
- Wells, D. (2020). Continuous integration. Retrieved March 20, 2020, from <http://www.extremeprogramming.org/rules/integrateoften.html>
- Yin, R., K. (2018). *Case study research and applications: Design and methods*. SAGE Publications.



# Appendix A

## Maturity Assessment Questions

### A.1 The Speed Stairway to Heaven

#### Traditional

- A1: Do you develop safety-critical systems? (Y/N)
- A2: Do you have legal requirements for the systems? (Y/N)
- A3: What level of traceability is needed?

#### Agile

- B1: Are you working in sprints? (Y/N)
- B2: Are you updating your customers after each sprint?
- B3: How do you work with customer feedback after sprints?

#### CI

- C1: Are small chunks of new code integrated as soon as they are developed/are engineers checking in code frequently?
- C2: How often do the engineers check in code?
- C3: Are all tests automated? (Y/N)
- C4: Which tests are automated?
- C5: Which tests are not automated?
- C6: Are issues reported instantly to the responsible developer?

#### CD

- D1: Is new functionality deployed to the customers after each sprint (minimum every 4 weeks)?
- D2: Are any tests being conducted in the field?
- D3: Are your customers willing to provide you with data?

#### CE

- E1: Is SW development data-driven? I.e. following the following general steps:
  1. Model expected business value
  2. Iterative data collection
  3. Analyze data and close gaps between the expected and actual outcomes.
- E2: Is data used to prioritize the backlog?
- E3: Is data used to optimize the existing system functionality?

## A. Maturity Assessment Questions

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- E4: Are experiments such as A/B tests being run?

## A.2 The Data Stairway to Heaven

### Data collection

- F1: Do you collect data automatically?
- F2: What is the purpose of the data collection? (quality issues, other)
- F3: Who requests data to be collected? (R&D, management, etc.)
- F4: Who is in charge of collecting the data?
- F5: What data is collected automatically and what data is collected manually?

### Data analysis

- G1: Who analyzes the data?
- G2: Is data analyzed automatically?
- G3: How much is automated?
- G4: Who can request data to be analyzed? (R&D, management, etc.)
- G5: How often are analyses requested?
- G6: How much do the requests vary in type?
- G7: Do you search for new patterns and correlations in the collected data?
- G8: How often?
- G9: Who does it?

### Reporting

- H1: Is the data reported automatically?
- H2: What is reported?
- H3: Who decides what's being reported?
- H4: How often are new findings added to the reports?
- H5: How is it presented (dashboards?)
- H6: Who decides how the data is reported?
- H7: How frequently are the reports updated?
- H8: Who can access the reports?

### Decision making

- I1: Are any (standardized) decisions being made by the system itself?
- I2: To what extent?
- I3: Which types of decisions?
- I4: Is decision-making in the organization based on the collected data?
- I5: To what extent?
- I6: Is the culture supporting evidence-based ways of working?

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