How manufacturing goes beyond the production of the physical object.

A firm-level study to identify the challenges and needs for implementing Agile within an existing Stage-Gate system

W.J.Pit University of Twente September 2022

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Master Thesis

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A. Colophon

This document is a Master's Thesis to obtain the degree of Master of Science in Industrial Design Engineering from the University of Twente. Because the original research was conducted within a manufacturing company, and thus contained confidential information, this second report was established. In this second report, all confidential information has been redacted or removed. Therefore, only the public information is presented and the data and results have been generalized.

Title	How manufacturing goes beyond production of the physical object. - A firm-level study to identify the challenges and needs for implementing Agile within an existing Stage-Gate system
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B. Preface

The desire for this research has originally come from my personal interest in software integration within physical products, which causes a shift within physical product development to digital product development. As software and connectivity are becoming increasingly important within consumer products, I strongly believe that the knowledge I have gained during this research will be of value for the rest of my career.

I would like to thank my internal daily supervisor Benjamin Österle for his guidance during my research. Since I was not assigned a supervisor at the beginning, I had a challenging start. But from the moment you guided and advised me, the research progressed without a hitch. You were always willing to answer research-related questions, for which I thank you.

Finally, I would like to thank my family for their endless support, advice, and motivation when needed. The pleasant and often sporty weekends during my research were of great value to me.

I hope you will enjoy reading this thesis report.

Wessel Pit

Amsterdam, August 2022

C. Summary

One of the most critical and important tasks of a company is the development and launch of new products (Tzokas et al., 2004). With today's rapidly changing market environment, the flexibility to respond to this changing market environment is essential for the overall success of the product launch. Therefore, companies started to integrate the Agile-Stage-Gate approach to become more flexible, iterative- and responsive (R. G. Cooper & Cooper, 2008). Although previously performed research reveals the potential benefits of this approach, there are still some significant challenges and inconsistencies, such as determining where to implement Agile. Knowledge of these challenges and needs is required to clearly define the integration of this approach.

This study identifies the challenges and needs for the integration and modifications required to implement Agile in an existing Stage-Gate. Therefore, a case study is conducted within the manufacturing company. During this case study, two qualitative methods were applied. First, semi-structured interviews were conducted to gain valuable insights and an in-depth understanding of the current New Product Development (NPD) process and the market environment. The latter was hereby classified into three environmental characteristics derived from Kohli & Jaworski (1990) namely (1) Technological Turbulence, (2) Market Turbulence, and (3) Competitive Intensity. The second method consisted of an ethnographic study, which involved a long-term, experiential participation of the researcher in an NPD project. This is to observe important decisions, events, key moments, and challenges that occurred during the process.

The findings of both studies show various internal and external factors that create risks and uncertainties which impact the changes within the market environment. The main external factors affecting the environmental characteristics are the emerging connectivity trend, the unexplored customer compositions, the intensity of the competitors, the dependency and reliability of institutional sources such as the supplier, and socioeconomic events such as COVID and the Ukrainian war. The main external factors which created uncertainties and risks were related to the current adaptability & flexibility of the process, the utilization of data sources, the support for continuous development, and lastly the team set-up & expertise. While some of these factors can be well predicted or anticipated, the findings also indicate that several factors are unpredictable, meaning that their effect on the change in the market environment cannot be predicted. In this case, the Agile approach would be beneficial to address the risks that arise during the NPD process or even post-launch.

Consequently, modifications are made concerning the structure, approach, utilization of data sources, and involvement of institutional sources. This resulted in the establishment of the new NPD framework, in which the Stage-Gate structure serves as a strategic level framework, facilitating the coordination of the project through the process. While on the operation level, either a Stage-Gate or Agile approach is implemented to obtain the necessary structure or adaptability. Concerning the utilization of data sources, the real-time data from the Connectivity product is aggregated with other internal and external data sources to create deeper insights into product usage and customer compositions. Finally, the new framework includes early and frequent involvement of institutional sources to create transparency.

In conclusion, the NPD framework provides the required flexibility, iterative- and responsiveness needed within the market in which the manufacturing company operates. Due to the modifications made, the framework can respond to a changing market environment, which ultimately contributes to the success of the product launch. It should be stated, however, that before actual use, several pilot projects with the framework should be conducted to determine any improvements. By conducting a quantitative method for this purpose, methodological triangulation can be achieved, whereby process performance is examined. In this way, the actual increase in overall product launch success can be analyzed quantitatively.

II. Content

III. Introduction

A. Problem statement

One of the most critical and important tasks of a company is the development and launch of new products (Tzokas et al., 2004). The new products that are developed within a relatively short lead-time add customer value and provide competitive advantage, growth, and profitability (R. G. Cooper, 1990). Consequently, manufacturing companies are seeking to improve their new product development (NPD) process which refers to the complete process from product idea through to launch. This includes an extensive set of activities through which a product specification and its production processes are defined (de Almeida et al., 2021).

Research on the NPD process has increasingly grown in recent years (Barczak et al., n.d.; Brown & Eisenhardt, 1995; R.) with the structural design of the NPD process as one of the key success factors (R. G. Cooper, 2019). Especially the implementation of a formalized NPD procedure (Schmidt et al., 2009) and the use of the Stage-Gate system have been shown to increase the overall success of product launch efforts in the past (R. G. Cooper, 1990). This Stage-Gate system breaks the NPD down into certain Stages, separated by Gates. The Stage-Gate process aims to improve the quality of the output from the process by focusing on the process itself and removing uncertainties and risks up-front (R. G. Cooper, 1988a). The benefits of this structured gating process, such as improved teamwork, success rates, launch, reduction in recycling and rework, earlier detection of failures, and shorter cycle times, have often been reported (Griffin & ., 1997; Song et al., 1998).

Previous research seems to suggest that every NPD process has the same generic structure (R. G. Cooper, 1988b). However, more recent studies have shown structural ambidexterity among these processes, thereby complicating the efficacy (e.g., time-consuming) of the overall development of products (de Visser et al., 2010). Structures of an NPD process may differentiate into functional or cross-functional (Griffin, 1997a) with either a low or high risk (R. G. Cooper et al., 2002; Song & Montoya-Weiss, 1998). This led to the evolution and acceleration of formalized NPD processes and the traditional Stage-Gate system. Subsequently, companies started to modify and adjust the system, resulting in the so-called Next-Generation Stage-Gate system (R. G. Cooper & Cooper, 2008) which was more scalable, flexible, and adaptable.

However, due to rapidly changing technologies and turbulent markets, some existing products become quickly obsolete and are replaced by new or improved products (R. Cooper et al., 1987). Other products simply continue to drain corporate resources and become low-profit items in highly competitive, commodity-type markets. Because of this, the flexibility to respond to these changing technologies and turbulent markets has become essential for the overall success of the product launch. This has increased the need for companies to become adaptive and continuously change on to go. That is, more flexible, iterative, and responsive (R. G. Cooper & Cooper, 2008). The current Stage-Gate does not allow this since the product definition, development plan, and associated costs have already been approved and are thus locked in, making the system too linear, overly rigid, and excessively planned to accommodate these changes. Another incentive for integrating Agile is the growing role of software within and along physical products (R. G. Cooper & Sommer, 2018). This forces companies to review and rethink their internal structures and processes, including their NPD process to facilitate changes and updates (Zaiden, n.d.).

Therefore, manufacturing companies have started to create Agile-Stage-Gate hybrid models, integrating Agile methods into their existing Stage-Gate borrowed from the software industry (R. G. Cooper et al., 2016). These Agile methods focus on a dynamic and evolving process, rather than a static and predefined one like Stage-Gate, creating a more flexible, iterative-, and responsive process that can respond to change (Lee & Xia, 2010).

Early studies revealed the potential benefits, as well as best-practice examples on how to run a hybrid model (R. G. Cooper, 2016). Nevertheless, there are still some significant challenges and inconsistencies while integrating Agile methods, such as determining where in the NPD process Agile methods should be integrated and for which type of projects. Because this hybrid model is new, a dominant model has not yet emerged. Therefore, the integration of this approach is not clearly defined and thus difficult. Knowledge of these challenges and needs is required to clearly define the integration of this approach. Such knowledge can give project managers direction and guidance for integration, leading to an improved NPD process. Therefore, this study aims to identify the challenges and needs for the actual integration and modifications required to implement Agile-Stage-Gate.

B. Aim & Research question

To identify the challenges and needs for the actual integration and adjustments required to implement Agile-Stage-Gate, a case study is conducted within a manufacturing company. For this purpose, a manufacturing company is used as an example. Valuable insights and an in-depth understanding of the current NPD process, as well as environmental characteristics in which the company operates, are gathered and used to identify the challenges and needs. Based on this, recommendations for the necessary modifications are presented through a newly developed framework.

The following primary research question of this study is to

How can Agile contribute to the required flexibility, iterative- and responsiveness within the current NPD process?

To answer the primary research question, several secondary research questions have been established. These include the following:

What are the environmental characteristics that change the market environment and thereby create uncertainties and risks?

How can Agile contribute to solve or reduce the challenges, uncertainties and risks?

Which modifications are needed within the NPD processes?

How can a framework be developed in which the required adjustments are achieved through the integration of Agile?

C. The scope of research

The scope of the study focuses on the NPD processes within the company and uses the information and data from the company. The study includes 11 participants with over 10 years of work experience within this business, each representing a specific product category or segment who are either acquainted with the NPD process or have been part of an NPD project. This study is executed within a nine-month period, starting from November 2021 until Augustus 2022.

D. Thesis outline

The current paper follows the structure of the Double Diamond design process model, which is originally based on a simple diagram that describes the divergent and convergent Stages of the design process (Tschimmel et al., 2012). The diagram consists of four phases, each representing either a divergent or a convergent Stage. First, within the Discover Phase, a literature review is presented to provide essential background information and a contemporary view of the NPD, Stage-Gate, and Agile. This is then followed by a Company analysis, which covers the Company profile, its Product Categories, Operating model, and Product Development processes. Hereafter, in the Define Phase, the Research methodology is described and the findings are presented. In the Develop Phase, the findings are translated into concrete modifications. This is to eventually develop a new NPD framework. The Define phase is closed off with the application of the NPD framework on the operational level. Finally, within the Deliver Phase, the Implementation Strategy is presented and the Discussion and Conclusion are established. The Discussion describes the meaning of the findings and relationship to previously performed research, as well as the limitations of the findings and suggestions for further research. Within the conclusion, an answer to the research question is provided.

IV. Discover

To provide essential background information and a contemporary view of NPD, Stage-Gate, and Agile, a literature review is conducted. The first section describes the General NPD process which includes both the Stage-Gate and Agile approaches. The second part describes the changing market environment in which a company operates. Several environmental characteristics are explained which can cause uncertainties and risks. This is followed up in the third section, which examines how the principles of both approaches respond to uncertainties and changes in the market environment. Finally, in the fourth section, the evolvement of Agile-Stage-Gate is described, explaining the potential benefits of combining the two approaches as well as the challenges accompanying the integration.

A. New Product Development process

Understanding NPD first leads to the question of what defines NPD. According to (de Almeida et al., 2021) NPD comprises an extensive set of activities through which a product specification and its production processes are defined. It refers to the complete process from product idea through to launch. NPD covers several types of approaches, two of which are Stage-Gate and Agile (R. G. Cooper, 2019).

Stage-Gate consists of a set of activities, Stages, and decision Gates and is mainly used by manufacturing companies (Griffin, 1997). It can be seen as a predictive linear model, in which several aspects such as product requirements, front-end plans, sequential Stages, and development activities are defined. Each of these aspects must meet pre-approved criteria, making the model especially suitable for projects where these aspects can be predicted as accurately as possible up front, resulting in lower risk.

In contrast, empirical/flexible models such as Agile, which originated in the software industry, have as few predefined plan aspects as possible. The product requirements and development activities can adapt and emerge until late in the process, involving users early through prototyping and frequent testing, organizing development work in iterations of time-boxed design-build-test cycles (Chan & Thong, 2009). Because of its iterative and flexible approach, this model is well suited for addressing risks that arise throughout the NPD process due to the changing market environments. Over the years, many manufacturing companies have been modifying, optimizing, and incorporating new methods or even creating hybrid models, as with the present Agile-Stage-Gate Method (R. G. Cooper et al., 2002, 2016).

1. Stage-Gate

In the ‘90s Robert G. Cooper developed the Stage-Gate process for NPD (R. G. Cooper, 1990). Robert G. Cooper can be seen as one of the most influential innovation leaders in business today with breakthrough discoveries in product innovation, including the Stage-Gate process. The Stage-Gate process breaks the product development process down into certain Stages, separated by Gates with its aim to improve the quality of the output from the process by focusing on the process itself and removing uncertainties and risks up-front (R. G. Cooper, 1988a). In its simplest format, it consists of distinct Stages, in which the project team gathers specific information to reach a certain maturity in the NPD process, followed by Gates, where a quality control check, business rationale, and a final go/kill decision are made to approve the planned resources for the next Stage. This linear and sequential approach secures that the next Stage can only begin once the previous Stage has been completed and successfully passed the Gate. A standard Stage-Gate format is presented in Figure 1 Stage-Gate Format (R. G. Cooper & Cooper, 2008).

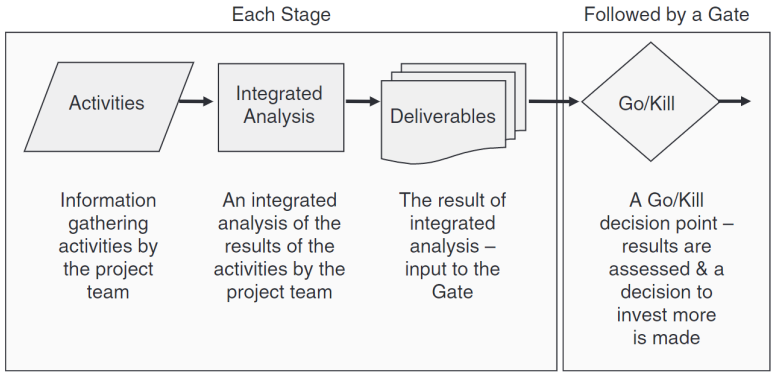

Figure 1 Stage-Gate Format (R. G. Cooper & Cooper, 2008)

a) The Stages

In a traditional Stage-Gate five distinct Stages can be recognized (R. G. Cooper & Cooper, 2008). This with the purpose to create a generic structure for the NPD process. These five Stages are Scoping, Business Case (BC), Development, Testing, and Launch. Before the first Stage, there is often a preliminary Stage called Ideation. In addition, a post-launch review can be added after the launch Stage. Table 1 provides an overview and description of each stage.

Each Stage consists of a series of activities conducted linearly and sequentially. During these activities, extensive information is gathered through desk research, market analysis, and forecasting to reduce the uncertainties and risks at later Stages. These activities are executed by a cross-functional team, consisting of people from Research & Development (R&D), Manufacturing, Engineering, and Marketing. Due to this joint involvement the overall quality, manufacturability, and marketability of the final product can be increased (Song et al., 1998). The information collected will then be analyzed to yield actual results, which will be subsequently used as input for the next Gate. Because of the linear nature of the process, the actual working product is only delivered at the end of the Testing or Launch Stage.

Stage	Description
Ideation	*Generating new ideas, discovering market gaps and business opportunities*
Stage 1 - Scoping	*Preliminary investigation and scoping of the project*
Stage 2 – BC	*Customer, market, and business research to create BC*
Stage 3 - Development	*Detailed design and development of the product, development of full-scale production process*
Stage 4 - Testing	*Testing, verifying, and validating product and operation plans*
Stage 5 - Launch	*Commercialization: scaling up to full-scale production, marketing, and sales*

Table 1 Activities per Stage

b) The Gates

Each Stage is followed by a Gate that can be seen as a quality control check during which the deliverables of the preceding Stage are discussed and assessed against a set of criteria (R. G. Cooper & Cooper, 2008). The set of criteria must be met before moving on to the next Stage. At the end of the quality control exercise, a go/no go decision, investment decisions, prioritization, and commitment along with an action plan for the next Stage has to be made. These decisions are critical because they are hardly reversible. An

example of this is the determination of the concept during a gate, where a final concept choice is made. Once this decision has been made and the necessary investments are made, it is difficult and also very expensive to change it. A traditional Stage-Gate system is shown in Figure 2 Overview of traditional Stage-Gate System for NPD.

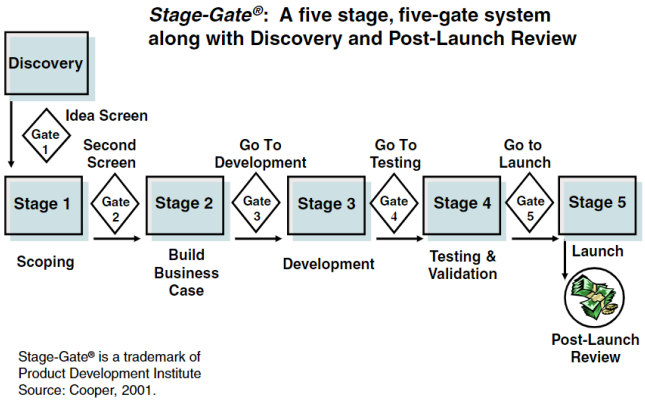

Figure 2 Overview of traditional Stage-Gate System for NPD

c) Stage-Gate modifications

Cooper's original Stage-Gate was set up with the idea that every NPD process has the same generic structure (R. G. Cooper, 1988a). However, companies found out in practice that this was not the case. This is supported by more recent studies showing structural ambidexterity among NPD processes (de Visser et al., 2010). The NPD process does not have a generic structure but is multidimensional; It includes both development processes that focus on extending or replacing an existing product (low risk) and processes that focus on generating new products (high risk) (de Visser et al., 2010). Because of the different structures, the original Stage-Gate model did not fit every process. When companies noticed this, they began to modify it to fit the respective structure. This resulted in the so-called Next-Generation Stage-Gate system (R. G. Cooper & Cooper, 2008) which was more scalable, flexible, and adaptable.

One of the most important modifications is the scalability of the Stage-Gate, which depends on the size and risk level of the project (R. G. Cooper & Cooper, 2008). Since an extension or replacement of an existing product has lower risks than the development of a new product, it is not necessary to go through all five different Stages. The number of Stages, ports, or even deliverables can be adjusted to meet business needs and to speed up the project. This scalability can lead to a Stage-Gate model with three Stages, resulting in faster project delivery, product development cycle, and a shorter time-to-market.

Furthermore, the process became more flexible, meaning that not all activities are mandatory; the project team can decide which are of importance and will be carried out and which will not. Additionally, companies can decide upon the simultaneous or sequential execution of activities and Stages in which they can overlap each other, with one able to start earlier than the other. For example, production activities can be brought more forward due to longer expected lead times of raw materials or extensive third-party validation processes. However, this 'overlapping' does come with risks. If production activities are brought forward before the previous Stage has been completed, the investment costs can already be incurred. This means that selecting the ‘right’ sequence of activities is important and that certain considerations or trade-offs need to be made.

Finally, companies tried to make Stage-Gate more adaptive to respond to the changing market environment. This since today’s market environment may change rapidly, making it impossible to establish the product definition and requirements up-front. During the NPD process, customer needs may

change, making the initial product definition or set of requirements obsolete (This topic will be discussed in detail later in Chapter 2.b)(1) Changing market environment). Therefore, companies built in multiple spirals or iterations, allowing for customer feedback throughout the process. These spirals or iterations can be integrated from Stage 2 – BC, Stage 3 – Development until Stage 4 – Testing and allow the product design and definition to adapt to the new information, customer feedback, and changing conditions (R. G. Cooper, 2014).

Stage-Gate	Spiral (Customer feedback)
Stage 1 - Scoping	-
Stage 2 – BC	*Voice of Customer, Needs & Wants Study*
	Proposition concept test
Stage 3 - Development	*Rapid Prototyping & Testing*
Stage 4 - Testing	*Field Trail, Beta Test*
Stage 5 - Launch	-

Table 2 Stage-Gate Spirals

2. The Agile 'Software Development' Manifesto

In 2001, the Agile 'Software Development' Manifesto emerged, consisting of a set of values and principles to improve the creation of new software (Beck et al., 2001). The Agile methods are a collection of different techniques that share these values and principles. What differentiates them from the traditional methods is the emphasis on feedback and change, and a dynamic, evolving, and organic rather than static and predefined NPD process (Lee & Xia, 2010). Agile adapts to the changing market environment until late in the NPD process, involving users early through prototyping and frequent testing, organizing development work in iterations of time-boxed design-build-test cycles (Chan & Thong, 2009).

Two key principles of the Agile 'Software Development' Manifesto are, first, that it welcomes changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage. Second, it delivers working software frequently, from a couple of weeks to a couple of months, with a preference for the shorter timescale (Beck et al., 2001).

a) Scrum

One popular method of Agile is Scrum, developed in the 1990s, which assumes that the software development process is unpredictable and complicated and therefore can only be described as an overall progression (Schwaber, 1997). It makes use of an iterative, incremental approach to optimize the predictability and control the risk throughout the NPD process. To do this, the NPD process is divided into a series of iterations, so-called 'Sprints' which are 'timeboxed', meaning that they are fixed lengths of a maximum of one month. During this period, a Minimum Viable Product (MVP) is created. This MVP is a continuously evolving concept, defined by (Eric, 2011) as "A version of a new product, which allows a team to collect the maximum amount of validated learning about customers with the least effort". It refers to a product that includes just enough specific features and backlog items to satisfy the needs of the customer.

Figure 3 shows a standard Scrum framework. The framework starts with the creation of a Product Backlog, consisting of an emergent, ordered list of what is needed to improve the product (Schwaber & Sutherland, 2020) and a Product Goal, describing the long-term objective (i.e. desired state of the product), serving as the goal for the team to plan against. The following section will cover the phases to be carried out during a Scrum Sprint. These Stages are derived from the latest 2020 Scrum Guide by (Schwaber & Sutherland, 2020).

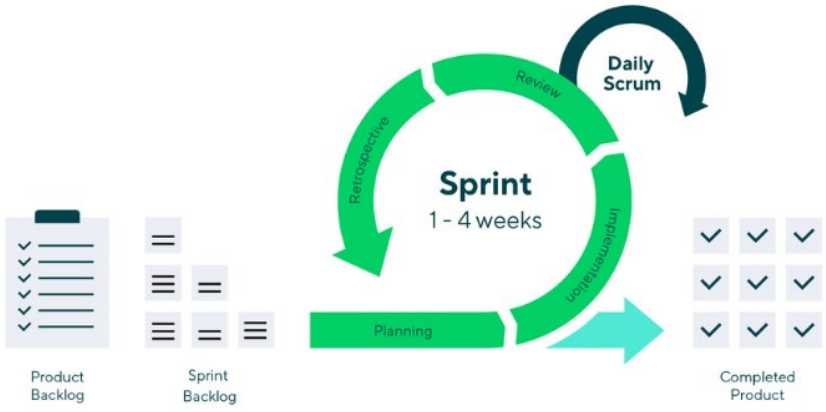

Figure 3 Standard Scrum framework

b) Phases during a Scrum Sprint

The Sprint is initiated with a Sprint planning, in which a Sprint Backlog is established. This Sprint Backlog is composed of a Sprint Goal, a selected set of Product Backlog items, and an actionable plan for delivering this goal. The sprint Goal can therefore be seen as a single objective for this particular sprint (Schwaber, 1997). Each item selected from the Product Backlog is decomposed into smaller work items. These can be seen as an increment; a concrete stepping stone toward the Product Goal. Within one Scrum Sprint, multiple increments can be completed. To complete the increments they must meet 'the definition of done', which is a formal description of the state of the increment when it meets the quality measures required for the product (Schwaber & Sutherland, 2020).

During the determined timeframe of the Sprint, a meeting is held every day to assess the progress towards the Sprint Goal, adapt the Sprint Backlog if necessary, and adjust the overall planning. This meeting is called the 'Daily Scrum'. At the end of the sprint, the sprint deliverables are presented, consisting of a prototype that will be reviewed and demonstrated to stakeholders and customers to validate and identify needed changes. This is called a Sprint Review. Based on this information, the next steps and needed adjustments within the Product Backlog are determined.

The last event within the sprint is the Sprint Retrospective, which is used to reflect on how the sprint went. During the Sprint Retrospective, the overall process, as well as the problems that were faced during the execution, are discussed and how those problems were or weren't solved. This is to identify improvements to increase the overall effectiveness and quality. These improvements are then added to the Sprint Backlog so they can be used for the next sprint.

(1) Changing market environment

NPD involves a comprehensive set of activities that define a product proposal, a product specification, and the associated production processes (de Almeida et al., 2021). The product proposition and specification emerge progressively as these activities are completed (Meyer & Loch, 2002). But the market in which a company operates can be affected by various uncertainties, coming from sources such as the customers, suppliers, competitors, distributors, and others (Charles H.M. & Scott. S.G., 1995). Uncertainty is in this context defined as the unpredictability of the environment, the inability to predict the impact of environmental change, and the inability to predict the consequence of a response choice. (Milliken, 1987) Kohli & Jaworski identified three environmental characteristics which can vary in magnitude and consequently create such uncertainties. These environmental characteristics are Technological turbulence, Competitive intensity, and Market turbulence. (Kohli & Jaworski, 1990). The following sections explain each of these characteristics.

3. Technological turbulence

Technological turbulence is the rate of technological change (Kohli & Jaworski, 1990). A company can operate in a market with relatively mature technologies, while on the other hand there are technologically turbulent markets, in which emerging technologies and innovations rapidly change. The unfamiliarity with- or rapid change in the technology relative to the product developed by a company is called Technological uncertainty (Tatikonda & Montoya-Weiss, 2001).

4. Market turbulence

Market turbulence is the rate at which the composition of customers and their preferences change (Kohli & Jaworski, 1990). This can range from customers with a fixed type and extent of needs to customers whose needs change over time, likely leading to ambiguity about the type and extent of customers' needs that can be met, known as Market uncertainty (Rowland T.M & Thomas J.K., 1989).

5. Competitive intensity

The second environmental characteristic is Competitive intensity, which is defined as the magnitude of effect that a company has on its competitor's life chances (W.P. Barnett, 1997). Weak or even absent competition has no or little effect on the life chances of the organization. While as a result of high competition, customers have many alternative options available to meet their needs. As a result of this high competitive intensity, the life chances of the company are drastically reduced.

B. Managing uncertainties within Stage-Gate & Agile

As described in the previous chapter, it can be difficult to accurately predict the environmental characteristics since they can change or evolve radically over time. Therefore, it is of importance to effectively manage the uncertainties and resulting changes during NPD. In this perspective, Stage-Gate and Agile are fundamentally different approaches with different principles. This chapter will discuss both models and their principles related to the management of uncertainties and resulting changes.

1. Stage-Gate principles

Within Stage-Gate, the product definition, requirements, front-end plans, sequential Stages, and development activities are predicted as accurately as possible up front, seeking to control uncertainties early to avoid later changes and risks (R. G. Cooper, 1988a). This accurate planning and early freezing of activities during the NPD process enhance stability, discipline, and compliance (R. G. Cooper, 1990) This is only possible when the market environment is stable, meaning that the requirements do not change over time and are therefore easy to predict up-front. Conversely, when there is a changing market environment, aspects that have been determined up-front or activities that have been frozen early on in the NPD process will no longer fit with the emerging requirements (Meyer et al., 2002).

A second important topic is the involvement of user feedback throughout the NPD process. Due to the linearity of Stage-Gate, user feedback is not collected until the end, when a working product has been delivered. The benefit of this late involvement is the saving of traditionally long and expensive prototyping tasks by focusing on the final design that is likely to be launched. however, in a changing market environment with a lot of market turbulence, customer needs may change over time, meaning that the insights from customer feedback no longer align with the original product specification. The "frozen concept" then needs to be revised, which is contrary to the original Stage-Gate principles.

2. Agile principles

In Contrast, Agile is an empirical/flexible model that adapts to the changing market environment, addressing uncertainties throughout the NPD process (Lee & Xia, 2010). The product definition should be seen as tentative, including both fixed and variable elements. The former can be fully specified and locked-in, in and are not expected to change (R. G. Cooper et al., 2016), while the variable elements are fluid; defined at a high level, and progressively refined through numerous time-boxed sprints (Lee & Xia, 2010).

The sprints, as outlined in Chapter A.2 The Agile 'Software Development' Manifesto, increase the flexibility to respond and adapt the product specification to the changing market environment without the need for rework. This is mainly due to the smaller scope of the sprint Goals allowing for a more accurate prediction of the recourses needed to meet the requirements. The result of each sprint is a prototype, which is tested with the user to obtain valuable feedback. The early and frequent involvement of the user allows for the identification of the changing needs of the customer.

C. The evolvement to Agile-Stage-Gate

As of today, several large manufacturing companies have integrated Agile within their traditional existing Stage-Gate model, resulting in the Agile-Stage-Gate hybrid model Research into this hybrid approach suggests that the integration of both principles has significant potential benefits for manufacturing companies. Such a model has been described in some detail (Sommer et al., 2015). This new approach promises the benefit of both approaches; it embeds the Agile methods within the traditional Stages, replacing the existing tools, sequential Stages, activities, and milestones with Agile tools such as Scrum. Consequently, each Stage consists of several time-boxed sprints. Resulting in an iterative, incremental approach, making it more flexible and adaptive to the changing market environment. In addition, the Gates and Stages provide a high-level overview, enabling go/no go decisions, investment

decisions, prioritization, and commitment along with an action plan for the next Stage. In doing so, the two approaches support the NPD process at different levels: Stage-Gate act as a strategic level framework that facilitates the coordination of NPD teams, whereas Agile provides effective planning of day-to-day activities and monitoring the progress at the operational level (Karlström & Runeson, 2006).

1. The Benefits of Agile-Stage-Gate

The study of (R. G. Cooper & Sommer, 2016) consisting of several manufacturing companies that implemented Agile-Stage-Gate identified the following additional benefits, summarized in five areas:

1.	Gets the product right	- *Iterative development, validates the product, provides physical prototype early and frequent to the customer* - *A solution to technical issues and early 'Proof of concept'* - *Management is more comfortable moving forward* - *Deals with emerging requirements – fast revisions*
2.	Deals with uncertainty	- *Problem is identified and understood before Development starts* - *Requirements for the solution defined correctly before Development starts* - *Trail and error – exploring and testing the solution with the customer* - *Understanding the requirements is part of the solution-finding*
3.	Accelerates development	- *Time-boxed sprints & tasks within sprints* - *Fixed duration of sprints* - *Commitment to a set of deliverables*
4.	Focusses teams	- *Agile-Stage-Gate is dedicated to one project* - *Use of focused teams due to Scrum*
5.	Improves within-team communication	- *Dedicated teams* - *Daily Scrum meetings*

Table 3 Benefits of Agile-Stage-Gate (R. G. Cooper & Sommer, 2016)

2. The integration of Agile and its Challenges

The potential benefits emerging from these early studies are driving other manufacturers to adopt Agile as well. But besides the above-mentioned benefits, it also brings challenges, to begin with, the inconsistency between the two approaches; such as short-term fluidity versus Stage-Gate's long-term planning, as well as fixed product definition versus Agile's evolving product definition.

A second challenge is the delivery of a product increment or prototype with every sprint, meeting the 'Definition of done'. Whereas with software development a product increment or prototype can be easily delivered, this is not the case with manufacturing companies. This is because the development of a physical prototype typically takes longer than a time-boxed sprint.

A third challenge is the early and frequent involvement of the user throughout NPD; Software increments or prototypes can be easily shared and tested in an online environment while physical product increments or prototypes cannot be shared and tested as quickly.

A fourth challenge is the integration of Agile - Both where in NPD and for which projects. Since this hybrid model is new, no dominant model has emerged yet. Therefore, the integration of this approach is not clearly defined and thus difficult. While some companies integrate Agile throughout their NPD process, others integrate it only in their Development and Testing Stages (R. G. Cooper & Sommer, 2018).

This is because Agile principles may not be beneficial at every Stage. Some Stages may need a more structured and fixed approach to achieve a specific quality and accuracy of the deliverable.

A fifth challenge related to the integration of Agile is to decide for which projects it will be beneficial. This decision can be addressed in different ways, but mainly depends on the market environment (i.e. Market turbulence, Competitive intensity, Technological turbulence) in which the newly developed product will be launched. Projects with a stable market environment may be more suitable for a Stage-Gate approach. Since there are fewer uncertainties and low risks, a predictive/linear approach is more appropriate, enhancing stability, discipline, and compliance. While a project with a changing market environment is more suitable for an Agile approach; The many uncertainties and high risks require adaptability and flexibility to respond and adjust accordingly.

V. Define

The Definition phase focuses on the methodology and research design used within this study to arrive at answers to the research question. The first section explains the overall methodology, explaining the two research designs. The third section concludes the Define phase with the findings of these methods. These findings are then used in the Develop Phase to develop the NPD framework.

A. Methodology

The primary objective of this study is to examine the required flexibility, iterative- and responsiveness within the current NPD process to determine the need for Agile. To answer this objective, two qualitative methods have been executed to gather information on this topic. These methods are semi-structured interviews and an Ethnographic Study. The Research design for the semi-structured interviews is presented in section 1 Semi-structured interview Research Design. This includes the Research Strategy, Sampling Strategy, Data Collection Method, and Data Analysis Method. The Research Design for the Ethnographic Study is presented in section 2 Ethnographic Study Research Design, including the same topics.

1. Semi-structured interview Research Design

a) Research Strategy

To generate valuable insights and an in-depth understanding of the objective stated above, qualitative research is executed with the use of a case study. During this case study, semi-structured interviews were conducted with the employees within the company. A semi-structured interview is a verbal qualitative research method in which the interviewer asks a series of open-ended questions and follows them up with probing questions to provide the participants with an opportunity to explore or explain topics that they feel are important This allows focusing on a specific topic while exploring relevant topics that may be addressed during the interview. The structure of the interview is based on the interview guidebook of (Braun & Clark, 2013). The topic list of the semi-structured interview can be found in Appendix A.

b) Sampling Strategy

A purposive sampling strategy was used to select the participants for the semi-structured interview. This involved the selection of participants who can provide information and rich data to analyze. The sample consists of 11 employees, each representing a different product category or segment and either acquainted with the NPD process or have been part of an NPD project. By including various departments a diversity of perspectives is captured. See appendix B for the Interview characteristics.

c) Data Collection Method

The data of the semi-structured interviews are collected at one point in time (i.e., cross-sectional). Since most participants work at a geographically different location, online interviews, 40-60 minutes in length, have been held and were audio-recorded to collect the data.

d) Data Analysis Method

The collected data from the semi-structured interviews were orthographically transcribed and selectively coded using a hybrid coding scheme, consisting of both a deductive and an inductive approach. This analysis is conducted utilizing ATLAS.ti (*ATLAS.Ti Scientific Software Development GmbH* , 2022). The deductive approach was used to explain identified phenomena in the research context using existing theory, for example, Kohli & Jaworski's magnitude of three environmental characteristics (Milliken, 1987). The inductive approach was used to identify important new themes or concepts that emerged from the research context itself. An example of the inductive approach within the coding scheme is the type of risks or uncertainties and their associated challenges. These findings are then used to expand on the

already existing theoretical concepts. The coded data were then analyzed with the use of the thematic analysis (TA) method (Holton, 1998). This method identifies themes and patterns of meaning across a dataset concerning a research question (Braun & Clarke, 2006). Finally, the patterns across the data were analyzed and interpreted. See appendix D for the Hybrid Coding Scheme.

2. Ethnographic Study Research Design

a) Research Strategy

In addition to the semi-structured interviews, which form the core of the dataset, an Ethnographic study was conducted. An ethnographic study implies the long-term, experience-oriented participation of a researcher in a specific context to increase the likelihood of encountering important decisions, events, or key moments within the context (Fernandez, n.d.). Some of these additional findings were affirmative and reiterated what the core dataset had already revealed. Other input provided new insights, especially regarding the problems and challenges that occurred during the actual execution of the NPD process.

b) Sampling Strategy

Regarding the sampling strategy of the Ethnographic study, an NPD project was proposed by the company. Since the timeline of this NPD project is about 1.5 years and the kick-off took place in December 2021, it was not possible to cover all phases during the ethnographic study. Therefore, a 'compressed time approach' was used, which involves a shorter period of ethnographic research rather than a more traditional long-term approach (Jeffrey & Troman, 2004). Consequently, the study took place over nine months, from the Gate 1 until Gate 4, covering the Scoping Stage, Build BC Stage and Development Stage. (see Figure 2 Overview of traditional Stage-Gate System for NPD).

c) Data Collection Method

The observation for the ethnographic study of the NPD project also took place online with weekly participation in the online team- and Stage-Gate meetings. Based on the taxonomies of Gold (1954), this role can be seen as a 'Complete participant'. Through active interaction, participation, and collaboration in the NPD team, as well as responsibility for the delivery of several deliverables, the NPD process was observed. As a result, information was captured over an extended period of time which reduced the retrospection, recall, and reframing of errors. This longitudinal approach captured events and observations that might be neglected by single-recording methods because participants view them as insignificant, take them for granted, or forget them (Wheeler & Reis, 1991).

d) Data Analysis Method

Regarding the Data analysis Method of the Ethnographic study, Key decision moments and events were captured and documented in a Log of Descriptive events. This log is derived from fieldnotes which can be understood as an objective record of observations made in a particular context (Newbury, 2001). Due to confidentially, this Log of descriptive events is not included in the Appendix.

B. Semi-structured Interview findings

The following chapter objectively reports the interview findings. The findings also include statements from the interviews, where each interviewee is given a number from 1 to 11 to indicate the statements made. The structure of this chapter is derived from the dimensions and indicators that emerged from the Concept Indicator Model (CIM). the CIM, as described by Adoplh et al., (2008), consists of a number of concepts with corresponding indicators. The concepts can be seen as overarching categories, which consist of various indicators. these indicators are factual data expressed by the interviewee.

The indicators were established based on the patterns that emerged from the TA. These indicators are Market Turbulence, Competitive Intensity, Technological Turbulence, the Process approach, and The contribution of Agile. Each of these indicators consists of various factors that influence the subject. These indicators were then divided into two dimensions, categorized into internal or external environmental characteristics. These two dimensions are grouped under the concept 'Uncertainties & Risks'. See Appendix C for the Concept Indicator Model Semi-structured Interviews.

1. External environmental characteristics

Statements related to the external environmental characteristics were sorted into the main factors Technological Turbulence, Market Turbulence, Economic Turbulence, and Competitive Intensity which were derived from Kohli & Jaworski (1987).

a) Technological Turbulence

The interviews revealed that, in terms of Technological Turbulence, the pace of the technological change is not disruptive throughout the actual execution of an NPD. This is since the duration of the NPD range from six months to two years. Two interviewees indicated that the change is of such pace that it allows for a long-term response when developing a successor or new solution. However, they also explicitly stated that it is still of importance for the technical team to constantly evaluate emerging technologies to determine their relevance for integration in the long term.

Despite the Technological Turbulence not being perceived as intense, all interviewees mentioned the importance of software and connectivity playing a larger role. In doing so, they reported important emerging technical trends:

[redacted]

[redacted]

Although the technologies are considered mature and the general trend is obvious, the actual integration of these technologies and thus the creation of these connected or digital solutions within most product categories is still new within the company. The underlying uncertainties that the two interviewees mentioned are related to technical relevance and consumer relevance:

[redacted]

[redacted]

In addition to the uncertainties related to the technical and consumer relevance, another prominent risk mentioned by seven interviewees is the actual creation of a new function during the Ideation Stage in which these technologies are created. Within this Ideation Stage it is not necessarily the maturity of the technology itself, but the composition of the components for creating a new function that creates uncertainty. Since it is not clear how the parts will be orchestrated, the function may not be proven in time, or ultimately even fails. The interviewees gave the following examples in this regard:

[redacted]

[redacted]

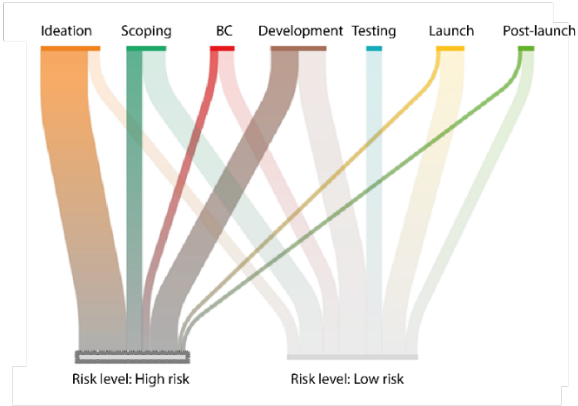

Figure 4 Risk level across Stages of NPD

These technical uncertainties in turn lead to cost risks or time risks (i.e., the possible delay of the next Gate or even the launch date). Other time-related risks mentioned by interviewees concerned the estimation of the required time frame. While for typical projects a good estimate can be made based on previous projects, the estimate for creating a new function or product is a major uncertainty. If a function does not reach the required maturity level in time due to improper planning, this again leads to postponement or delay of the actual launch date. When the interviewees were asked what other external factors might be influencing or creating risks, two interviewees mentioned the customer needs:

[redacted]

[redacted]

b) Market Turbulence

Regarding the Market Turbulence, the interviewees revealed the rate at which the composition of customers and their change in preferences differ per product category, product type, and even geographical location. Notably, three interviewees mentioned not so much the change in customer composition, but the exploration of new customer compositions. They indicated that there are still unexplored customer compositions. The type and extent of needs are relatively new or even unknown which creates market uncertainty. The interviewees gave the following examples in this regard:

[redacted]

[redacted]

Concerning the product type, the difference lies in strategy, evolvement, growth, or even the creation of new business product categories to offer a solution to these different type of customer compositions. From the interviews, three product types can be distinguished, namely a physical product, a digital product, and a connected product. A physical product is a product that a consumer can hold in his or her hand, while a digital product is based on a software solution, such as an application. A so-called 'Connected product' is a combination of both; a physical product that is connected to an application via a software solution. Two interviewees clearly stated that the customer composition for physical product segments are perceived as stable, meaning that the customers' needs are known and do not change rapidly. However, interviewees from the connected product categories indicated that, due to the connectivity within their products, the customer experience expands, creating more unknown customer needs. In this regard, the extent of customer preference also changes over time, resulting in market uncertainty. Consequently, it is important to continuously adjust the content or functionality of the product to meet the customer's needs. Figure 5 shows the difference in customer preference across the product types. One interviewee also stated the following about the unknown needs as a result of the connected and digital product type:

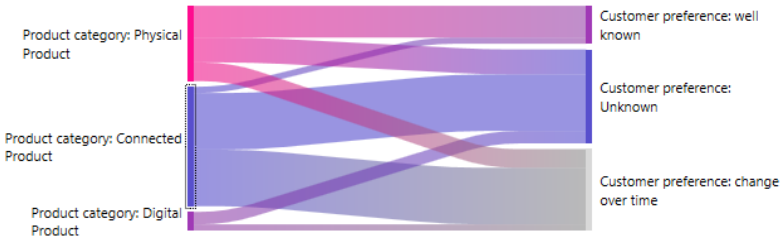

Figure 5 Sankey Diagram - Customer Preference across the different product types

[redacted]

c) Competitive intensity

Findings of the interviews indicated that the Competitive intensity depends on several factors such as the business market combination, competitor landscaping, and overall strategy. Four interviewees mentioned that for their product category there are two major brands with a large market share. Both were considered important brands that drive or lead the market rather than follow the market, meaning they set the trend and challenge each other. Even though there are only two major brands, the interviewees still indicated that there is a high competitive intensity between the two. Other interviewees mentioned that, depending on the business market combination, there are also a lot of so-called "B" and "C" brands. These brands are very competitive in the lower-price segments. One interviewee made the following statement:

[redacted]

Regarding the [redacted] product category, interviewees stated that the competitive landscape is very intense and continues to grow. Because of its wide and diverse portfolio of products, has many [redacted] competitors to compete with. Another important factor influencing Competitive Intensity has been the COVID pandemic. One of the interviewees from [redacted] indicated that the importance of air quality has increased tremendously and as a result, many competitors entered the market. The interviewee reported that there were more than 400 new competitors in the past two years:

[redacted]

In addition to competitive intensity, seven interviewees mentioned several other factors affecting the company's viability. They indicated that it depends not only on competitive intensity, but also on institutional sources such as suppliers, distributors, regulators, or socioeconomic events such as COVID or the Ukraine War. The interviewees indicated that due to a shortage of components, there is a major component lead-time issue which leads to time risks. As a result, pre-agreed volumes cannot be delivered to the markets or, in the worst case, the launch date is delayed. Moreover, the increase in the price of raw materials affects the BC, leading to cost risks during the execution of an NPD. The interviewees made the following statement concerning other factors affecting the company's viability:

[redacted]

[redacted]

2. Internal environmental characteristics

Statements related to the internal environment characteristics were sorted into the two main factors Process Approach and The contribution of Agile. The former relates to the Adaptability & Flexibility of the process, Customer feedback as a data source, and the support for continuous development. The latter relates to the Opportunities& Challenges of Agile as well as Team set-up, Expertise, and Mindset.

a) Process Approach

(1) Adaptability & Flexibility

The interviews revealed that the degree to which the process is adaptive and flexible depends on the moment in the process, which is directly related to a specific Stage or Gate. In this regard, the flexibility to change becomes less as the project progresses. Three interviewees mentioned the fact that even though the Stages and Gates are pre-described, the deliverables can be tailored within each stage. This involves examining the relevance and importance of the deliverable to determine whether or not it is needed. By doing so, the process can be adapted to the complexity of the project. Another interviewee pointed out that, even though the structure can be tailored, it still involves a lot of documentation and approval:

[redacted]

When asked about the flexibility at the Ideation Stage, most interviewees indicate the process to still be linear, while the actual Stages are exploratory. The function or technology has to be developed, causing the function to be not proven yet. Consequently, many uncertainties and risks arise regarding the development of the function and the time required to do so. One of the interviewees made the following statement:

[redacted]

Two interviewees indicated that flexibility depends on the boundary conditions. Since the function is not yet proven, changes can occur in, for example, the technical conditions. If the change is still within the boundaries of what the technical development can handle, it is considered manageable. As soon as the boundary conditions have to be changed due to a major technical change, it is experienced as difficult. One interviewee clearly indicated that the required flexibility is still lacking in this respect:

[redacted]

When asked about the flexibility of the NPD process, most interviewees consider the structure flexible, while the actual execution is to the contrary. Four interviewees emphasized that the low flexibility is due to the commitment of the project plan at the third Gate. Once this is fixed, the freedom to modify, and thereby the flexibility to make changes, is limited. One interview made the following statement:

[redacted]

[redacted]

At the Third Gate, the launch date is set, the design is frozen and the investment costs for the development and tooling are incurred. If changes then need to be made, this becomes very expensive and time pressure. Another interviewee mentioned that once the product is launched, the project is immediately terminated and closed. Therefore, the flexibility in the post-launch period is perceived as limited. Figure 6 shows the degree of flexibility within each stage.

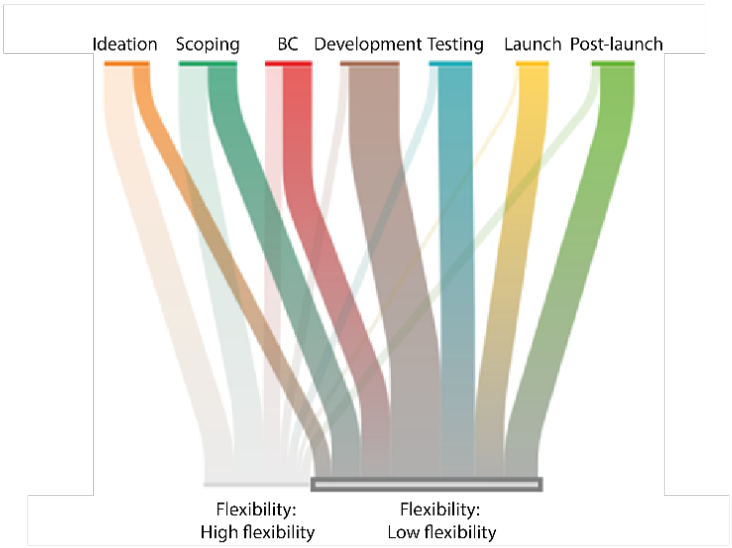

Figure 6 Sankey Diagram – Flexibility within the Stages

(2) Customer feedback as a data source

Most of the interviewees pointed to the importance of the collection of customer feedback during and after the NPD process to understand to which extent the customer needs are being met. This is currently done with a user test, concept validation, [redacted] once launched. A recurring aspect is the actual application of the outcome of the customer feedback. Depending on the timing of customer feedback, the severity of a change and its associated risks, such as time, quality, safety, and cost, a change is either implemented or not.

Two interviewees pointed out the risk of the lagging effect of the customer feedback, referring therewith to the time-consuming collection and interpretation of the data. Consequently, it is not possible to immediately identify how the product is perceived or to what extent it meets the customer's needs:

[redacted]

The interviewees indicated that it is therefore of importance to collect customer feedback early on in the NPD so that the results can still be used for any necessary change(s). Customer feedback collected near launch er even post-launch is often only used as validation and for the development of the next product.

Two interviewees also mentioned that connected products can create a direct data source for customer feedback. Consequently, there is no need to set up pre-established user tests to analyze product usage. The product usage can be continuously monitored, providing real-time insights into the extent to which certain features, functions, or buttons are being used. Doing so, it resolves the uncertainty of the lagging effect. One of the interviewees made the following statement regarding the direct data source:

[redacted]

(3) The support for continuous development

Concerning the actual implementation of the product changes the interviewees pointed out that there are different types of changes, each of which must be assessed with a change request to verify the feasibility. During this assessment, they look at the impact on quality, time, safety, sales, and cost. Based on the impact, the change may be made before launch, after launch or not at all.

Six interviewees indicated that for physical products, most changes require a long lead-time and are very expensive, whereas for digital or connected products majority of the interviewees indicated that it is easier to continually develop and change it. Nevertheless, one interviewee stressed that continuous development brings challenges concerning the validation and verification. The changed product must be reassessed and validated, which is time-consuming and costly. Moreover, the verification and validation process is not structured to be executed frequently and within a short time span to support continuous development. Moreso, another interviewee clearly stated that the overall structure is not set up to make continuous changes:

[redacted]

a) The contribution of Agile

(1) Opportunities & Challenges

When asked about the actual need for a more flexible, iterative- and responsive process, interviewees mentioned several opportunities for the integration of Agile as well as challenges or modifications needed. Most of them indicated that it depends on the type of product, Stage, uncertainties, and risks within these Stages. Six interviewees indicated that Agile is most appropriate and relevant during the Ideation and Scoping Stages because this is where most uncertainties and risks are. These Stages are still exploratory as the function has not yet been proven and teams are trying and learning from their ideas. At this stage there are also no major commitments or investments yet, making it easier to work in an iterative approach. The interviewees made the following statement with regard to the integration of Agile:

[redacted]

*F*or the Development Stage, most interviewees indicated that it depends on the type of product. For a physical product, four interviewees mentioned that Agile is not well applicable and beneficial. The lead-time of physical product development is long and expensive, making it almost impossible to incrementalize and deliver a new physical prototype in a short period of time. physical product development in an iterative approach would be intensive, time-consuming, and expensive to do:

[redacted]

[redacted]

For the development of a digital or connected product, three interviewees stated that the Agile approach is very applicable. Because most changes involve software, the actual lead time is short and not expensive, which makes the iterative approach suitable. Two interviewees also indicated that the Agile approach would also be beneficial for the post-launch period, thereby implying that the software and electronic components of the connected product can continuously be changed and updated:

[redacted]

[redacted]

(2) Team set-up, expertise, and mindset.

A reoccurring challenge mentioned by the interviewees is the actual team setup and change in culture to embrace Agile within the organization. The interviewees revealed several important factors related to the team set-up, such as the team's expertise, competence, and overall mindset.

One interviewee indicated that the team setup often does not remain intact. For example, a team member leaves the project for which a quick replacement has to be arranged. Because this replacement must be onboarded quickly, they often miss the necessary expertise and knowledge, leading to disruptions (e.g., uncertainties, risks) throughout the project. Another challenge mentioned by three interviewees is the team's mindset. Since the team needs to become more fluid and explorative to be able to navigate quickly and learn fast, a different mindset is needed. This different approach also requires a higher level of knowledge and competence. The following statements were made on the topic:

[redacted]

[redacted]

C. Ethnographic study findings

The following chapter reports the Ethnographic study findings which are based on the Log of Descriptive events and fieldnotes captured over an extended period of time. The structure of this chapter is derived from the dimensions and indicators that emerged from the key decision moments, events, or topics that were identified throughout the project. These indicators are Supplier risks, Volumes of the markets, a Price increase of commodity, The use of different data sources, and Team set-up. Each of these indicators consists of various influencing factors which are divided into two dimensions, categorized into internal or external project factors. These two dimensions are grouped under the concept 'NPD project". See Appendix E for the Concept Indicator Model Ethnographic Study.

1. External project factors

a) Supplier risks

One factor in line with the findings of the semi-structured interviews is the uncertainties and risks from institutional sources such as a supplier. Even before the NPD project started, negotiations were held with several suppliers, resulting in several quotations. Since the negotiation terms with the standard supplier were not realistic within the current market environment, it was necessary to work with a new supplier. The allocation of this new supplier entailed risks in terms of technical maturity, component release, indicative product lifetime, and the supplier's software capabilities. The NPD process allowed some degree of flexibility which made it possible to bring forward the supplier selection and allocation. This resulted in more time to reduce the risks as much as possible. However, eventually, it was decided to move the launch date from March 2023 to September 2023 to timely mitigate the risks and execute the testing and verification and validation on time

b) Volumes of the markets

Another external factor that emerged from the ethnographic study was the uncertainties and risks arising from the markets and their effect on the BC. The Business Marketing Managers are already involved at an early stage to provide the initial volumes for the markets that they are responsible for. Based on this information, the first BC is established. However, since the NPD project takes one and a half year, the economic environment of these market changes, resulting in eventual lower volumes than previously agreed upon. These changes in volumes result in financial uncertainties and risks throughout the project.

c) Price increase of commodity

The observation also revealed several uncertainties and risks regarding the price increase in commodities. The NPD project included a standard product, i.e. a product that drives product penetration to the consumer's home and is also a key driver of profitable growth. Therefore, the project is cost driven and aimed at lowering the FCP as much as possible to increase the Internal Gross Margin (IGM) rate. However, once raw material prices increase, the IGM rate is affected. To compensate for this, changes must be made to either the product's features and functions, or to the financial parameters of the BC.

One change made to the product's feature was [redacted]. While normally user tests are performed for these types of changes, this is not possible for standard products. The reason for this is that for standard products, no budget is allocated for user testing because the products often contain features that are familiar and thus do not need to be verified and validated. However, this change has never been tested and validated by the user. In addition, there is no existing product that can be used as a benchmark to assess usability. Therefore, because of this change risks occurred.

Besides the changes related to the product's features and functions, there were also changes made related to the financial parameters of the BC. Due to the FCP increase, it was determined to increase the recommended retail price, i.e. the price at which the product should be sold proposed by the manufacturer to achieve an acceptable IGM rate. However, the increase in RRP and the low market volume indication from the Business Marketing Manager led to the decision to adjust the entire product proposition, thereby changing the range build-up to achieve a viable BC. This change in product proposition resulted in some re-work, such as a clear differentiation regarding the features and specifications of the two products.

2. Internal project factors

a) The use of different data sources

Several sources being used to collect and generate insightful data during the project were observed. Most data sources used were separated systems without any inter-connection. The data was primarily generated from internal sources. The software used to provide this internal data was a business analytics system that supports the full range of analytics use cases within the organization. This system provides actual, historical, and forecast data regarding volumes, net sales, and IGM rate, which can be filtered on product category, markets, or countries. The internal data was then supplemented with information from external sources. One of these systems provided information and analytics in consumer and retail measurements such as market share and sales from the entire market including the competition. By combining both the internal and external data, insights were created about the competitor landscape, strategy, costs, and demand.

To gather data on the actual functionality of the product, the online rating and reviews of its predecessors was analysed. During the analysis, the most important positive and negative reviews were clustered and ranked according to the number and rating. Since this data is based on the predecessors which were already launched six years ago (i.e., historical data), there is a lagging effect in the data related to the functionality of the product, making the insights irrelevant or invalid.

b) Team set-up

One final finding from the interviews is the disruptions and risks from the team's setup and intactness. Of the 12 team members, two members recently joined the company, while another member left after three months before being replaced. Because the new team members had to be onboarded during the project, the learning and executing of the tasks and deliverables took more time than usual. This led to a disruption in time and knowledge as some expertise and knowledge for the project were missing or lost.

VI. Develop

The Develop phase focuses on the development of the new NPD framework. The first section discusses how the findings from the previous chapter are generalized and translated into concrete modifications and changes for the NPD structure. The second section focuses on the actual development of the NPD framework. This is to eventually deliver a framework in which the necessary adjustments are achieved through the integration of Agile. The third section concludes the Develop phase with the Application on the operational level, including the Team set-up, Defining the Scrum Sprints, Product Requirement Modelling, and the Aggregation of data sources.

A. The translation of the findings into concrete modifications

The findings described in chapters V.B and V.C are translated into concrete modifications and changes for the NPD process and its structure. The following sections will elaborate on each modification, which involves the implementation of Agile in the existing Stage-Gate, the support of continuous development, the utilization of Customer feedback, and the Involvement of institutional sources.

1. Implementation of Agile in the existing Stage-Gate

First, modifications should be made related to the type of approach within each Stage. From the findings, it can be stated that Agile or Stage-Gate may not work equally well within each Stage of the NPD process. Some Stages may require a more predictive and linear approach to improve stability, discipline, and compliance, while other Stages require a more adaptive and iterative approach to respond and adapt accordingly. regarding the former, it is mainly the Development and Launch Stages of the physical product that requires more precision and constrained planning. Since at this point important commitments and investment costs have been made, a more structured and fixed approach is needed to improve the stability, required quality, and accuracy. This makes the Stage-Gate approach within these Stages the most suitable. For digital and connected products, on the contrary, the Agile approach is most suitable for the Development and Launch Stage. This is since the development can be incrementalized and the product can be updated until right before the launch date.

For the early Stages, (i.e., Ideation Stage and Scoping Stage) modifications must be made to provide an adaptive and iterative approach that supports the exploration and development of technologies and functions for the use of new solutions. The Agile approach is considered most appropriate since it allows employees to explore, experiment, and test options in an iterative manner to ultimately arrive at the right solution in a short time span.

Finally, Modifications must be made to the last Stage and Gates of the NPD process. Where normally the project is terminated and closed immediately after the launch, the findings indicate that this limits the required flexibility, iterative- and adaptiveness after launch. As a result, it is not possible to make changes and update the product easily. To solve this, a Post-launch Stage should be added in which an Agile Approach is implemented. Also, the last Gate should be removed so that the project is not terminated and closed. This allows for continuous development throughout the product life cycle.

2. Supporting the continuous development

To facilitate continuous development post-launch (i.e., throughout the product life cycle), it is important to modify the other processes and Stages accordingly. From the findings, it can be stated that the current Validation Stage is not structured to be performed so frequently and in such a short time span to support continuous development. Therefore, it is important to streamline the Validation structure to allow for frequent updates, changes, and releases throughout the product lifecycle. Because the Validation process requires precision and discipline, the Stage-Gate approach is most appropriate. The structured approach and planning allow changes or updates to the physical or digital product to be verified and validated in a short time frame, supporting the Agile approach in the post-launch Stage.

3. Utilization of the Customer feedback

Another change is related to the collection and interpretation of customer feedback data. While during the NPD process there are several pre-established user tests that serve as data sources for customer feedback, after NPD there is only one data source, which is the online rating and reviews. Consequently, it is not possible to immediately determine how the product is perceived or to what extent it meets customer needs, resulting in a lagging effect. To solve this, the actual data sources and type of analysis used to interpret the data should be modified and improved. This can be achieved by making use of the digital and connected products as a direct data source for continuous customer feedback. By monitoring the product usage, real-time insights can be provided reading the functionality and usage of the product. These insights do not only relate to software functionality, but also the hardware features and general usages of the product, for example, which features customers prefer to use, or how often they use it. This new data source can thereby contribute to new function development or hardware improvements.

4. Involvement of institutional sources

One final modification is the frequent and early involvement of institutional sources within the NPD process to mitigate the uncertainties and risks related to suppliers, distributors, and regulators. It is important to monitor and be up-to-date on the component availability, lead time, and commodity costs to establish a realistic BC. As these aspects evolve over time, it is important to be transparent and regularly inform external parties and key stakeholders about the latest status. The NPD process should support frequent and early involvement and transparency throughout the project to be able to react timely and quickly to the risks and uncertainties that arise during the NPD process, for example by adjusting the sales strategy accordingly.

B. Development of a new NPD Framework

The development of the new NPD framework is based on the proposed modifications from the previous section. The final NPD framework, which is presented within this chapter, is derived after many iterations. The first section will explain the general framework and its structure, thereby explaining each Stage and Gate. Where after, in the second section, the final framework is presented. Finally, in the third section, the use of the framework is illustrated by means of an example project.

1. Structure of the NPD framework

The NPD framework is derived from the t standard Stage-Gate system of R. G. Cooper (2008). By integrating Agile within certain Stages, a so-called 'Hybrid model' is established (R. G. Cooper et al., 2016). Within this hybrid model, the Stage-Gate structure act as the strategic level framework, facilitating the coordination of the project throughout the process. While at the operational level, either the Stage-Gate or Agile approach is implemented to obtain the necessary structure or adaptability during the execution of that specific Stage.

The NPD framework consists of seven Stages and nine Gates. See Figure 13 for the NPD Framework structure. The six Stages are Ideation, Scoping & Business Case, Physical Development & Testing, Digital Development & testing, Final V&V & Launch, and Post Launch. Each Stage has an icon indicating either the Agile or Stage-Gate approach. Whereas these Stages are executed linearly and sequentially, the Digital Development & Testing Stage is simultaneously executed. With the use of the Gates, it is secured that the next Stage only can begin once the previous Stage has been completed. In the following section, each Stage and Gate is reviewed in detail.

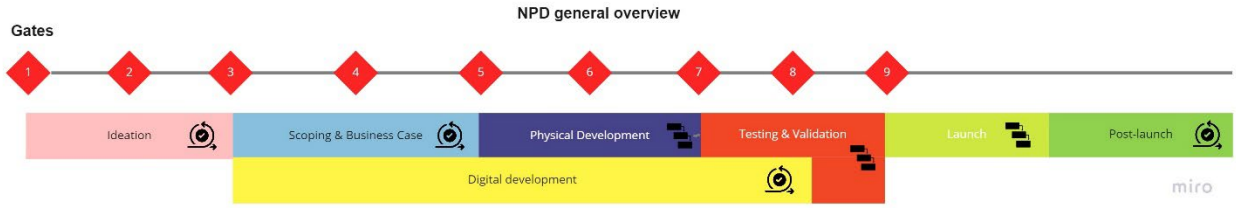

Figure 7 Overview of the Stages and Gates within the NPD framework

2. NPD framework Stages and Gates

a) Stage 1: Ideation

The first stage of the NPD framework is the Ideation Stage, for an Agile approach is used. At this stage the project is kicked off, meaning that the project team is set up, the project planning is created and the project is initiated. During the Project Initiation, a Product Backlog is created and a Product Goal is set. This Product Backlog consists of requirements that are related to both physical and digital products. Therefore, two distinctive Backlogs are created, namely the Physical Product Backlog and the Digital Product Backlog. Chapter VI.C.3 provides a further explanation regarding Product Requirement Modelling and the creation of both Backlogs.

After the first Gate, concepts and embodiments get developed. To do this, a series of Sprints, which are timeboxed, will be executed. At the start of each Scrum Sprint, a Sprint planning and Sprint Backlog is established, which composes of a Sprint Goal, several Product Backlog items, and a learning plan. At the end of each Scrum Sprint, a concept is presented. This concept will then be reviewed and demonstrated to the customers during the concept validation. These Sprints allow the project team to explore, experiment, and test concepts in an iterative manner to ultimately deliver the final concept at second Gate. This same Scrum Sprint approach will be used for the development of the embodiment, which will ultimately be delivered at the third Gate. At the end of the Ideation Stage, multiple physical

and digital embodiments are delivered which can be used for the new solution going forward in the process.

b) Stage 2: Scoping & Business Case

After the Ideation Stage, the second Stage, Scoping & Business Case, is initiated. While simultaneously the third Stage Digital Development Stage is conducted. The Second Stage uses the same Agile approach as explained in the previous section. During the Scoping & Business Case Stage, the development of the proposition takes place, in which the proposition in terms of the offer to the consumer is developed. Consequently, an initial BC is created together with the input from the Business Marketing Manager. This BC is continuously updated during the project execution and will be reviewed at every Gate. In addition, the backlogs are updated and new requirements regarding institutional sources are added to both the Digital and Physical Product Backlog, such as the supplier allocation and an initial list of long lead-time components, which is made to set priorities for resourcing.

At fourth Gate, the proposition is clearly stated and the aesthetic physical design direction is chosen. For the digital product, the MVP is established and the Epic and Themes structure is clearly stated. However, this structure can still evolve and adapt over time, based on the solution. Chapter VI.C.3 provides a further explanation regarding Epic and Themes structure.

After the VPA Gate, the solution development takes place, in which the 3D CAD file is created iteratively based on the aesthetic design. This file is then used for the initial mold creation and manufacturing design so that the tool costs can be estimated. Also, the first prototype and MVP are validated with the customer by doing another user test. During this test, both the physical product as well as the digital product are reviewed and demonstrated to validate and identify needed changes.

The stage is concluded with the fifth Gate which can be seen as a joint commitment for both the physical and digital products. During this milestone the development of the Physical Product is frozen and the final technical design is confirmed, while for the digital product the MVP and Sprint Planning are confirmed. This concludes the development phase for the physical product to start the Physical Development & testing Stage, while the development phase for the Digital Product continues until the eight Gate.

c) Stage 3: Physical Development

Within the physical development Stage, a Stage-Gate approach is used to ensure a structured approach to the development of the manufacturing design and tooling design. This is because the development requires precision and accuracy and any subsequent changes are time-consuming and costly. An iterative approach, where prototypes are delivered in a short period of time, would be nearly impossible in terms of time and cost and therefore does not produce the desired results.

At the beginning of the third phase, the 2D CAD files are created, starting with items with a longer lead time. Then the tooling designs are created and the final asset creation task is completed. These aspects are completed along with the production design at the sixth Gate. After this Gate, the molds are built and the tools are tested and validated. Because of the structured approach, high stability, accuracy, and quality can be achieved for these molds and tools. Finally, at the nineth Gate, the actual final production is verified.

d) Stage 4: Digital Development

The fourth Stage, Digital Development, starts simultaneously with the second Stage and runs in parallel. During this stage, the digital product is developed and tested. Since this is Stage is entirely software-related, an Agile approach is applied, in which the digital product is continuously developed with the use of Scrum Sprints.

The fourth Stage starts off with the Experience proposition design, in which User stories are created (See Chapter VI.C.3 Product Requirement Modelling). These User stories are categorized into features, which are grouped under a specific Epic or Theme. These Epic and Themes are converted into requirements, which are put in the Digital Product Backlog. The experience proposition is concluded at the fourth Gate, in which the MVP is established and the Epic and Themes structure is stated. After the fourth Gate, the Experience solution design is started, as well as the App and Content development. Here the content strategy is determined and the application wireframes are created. These wireframes are derived from the storyboards and User stories and contribute to the establishment of the MVP, which get validated with a user test. After the MVP and Sprint planning is confirmed at the fifth Gate, several more Scrum Sprints are conducted to further develop the digital product. This is then done until the eight Gate, at which the digital product and its processes are finalized and stable.

e) Stage 5: Testing & Validation

The fifth Stage, which is the Testing & Validation, uses a Stage-Gate approach. At this stage, both the physical and digital products are stable and are verified and validated. This includes longer-lead-time verification and validation such as a Home Placement test (HPT), where the physical product and the app are tested. At the eight Gate, the production processes of the physical product are verified and released, which means that production can begin. For the digital product, the application and its content are verified and released. Then, at the ninth Gate, the product is launched into the market.

f) Stage 6: Post Launch

After the ninth Gate, the product is launched in the markets. This marks the time of the Post-launch Stage. In this Stage, the project is handed over to the life cycle management team. This team takes care of the product portfolio in which this project is placed. It handles the marketing introduction process, meaning that they gradually roll out the new product to the market. However, the initial NPD project team is still closely involved during the Post Launch Stage to follow up on the launch and evaluate the success in the market and in terms of how the product works. In doing so, several data sources are aggregated to gain a deeper understanding of the product and its usage. Two such data sources during this Stage are the online rating and reviews and Continuous User Feedback (CUF). Chapter VI.C.4 further explores the topic of Aggregation of Data Sources. These insights are then used to make possible modifications or changes. Once a change or modification is proposed to the physical or digital product, a change request is required to verify feasibility. Therefore, the changed product must be reassessed and validated during the validation processes. This includes a short comprehensive validation and verification process so that the change can be implemented in a short period of time to continuously improve and develop the product.

3. Final NPD framework

The Stages and Gates described in the previous section, as well as the activities within them, are visually presented in Figure 14 below. At the top of the figure the overall structure, consisting of the six Stages and ten Gates, is shown. Below that, the stages are segmented on the operational level, covering specific processes. A distinction has been made between the processes related to the physical product and digital product. This is because some are performed simultaneously, start at a different time, or use a different approach.

The Gates are visually represented by a red diamond-shaped icon, whereby joint commitments and Gates are represented by a dotted line starting from the red diamond-shaped icon. The type of approach per Stage is represented by an Agile or Stage-Gate icon. Finally, the customer feedback moments during the process are represented by a dark blue triangle.

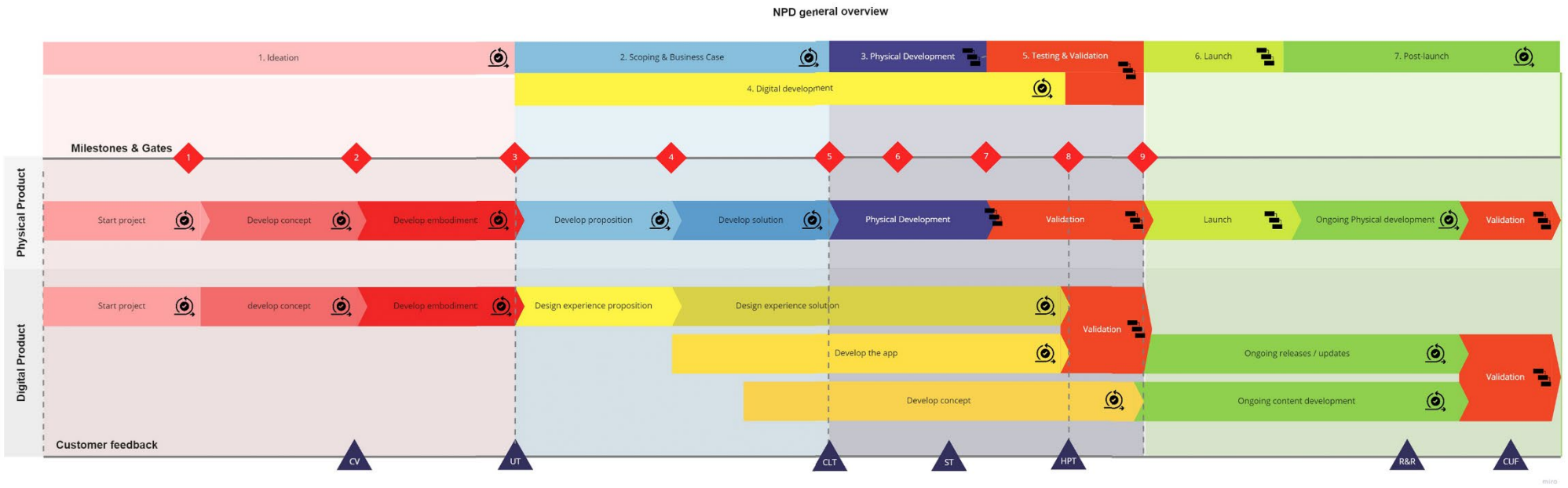

Figure 8 NPD Framework

C. Application on the operational level

Although the scope of this study is focusing on the NPD processes and therefore the modifications are mainly focused on the strategic level, some important modifications are at the operational level and are also important for the final development of the NPD framework. In this chapter, some of these important aspects are elaborated such as, in the first section, the composition of the team. Then, in the second section, changes to the Scrum Sprint are explained. In the third section, Product Requirements Modeling is explained. Finally, section four explains the aggregation of data sources.

1. Setting up the team

One of the topics that emerged from the semi-structured interview and Ethnographic Study findings is the importance of the team set-up, its expertise, and mindset. To employ an Agile approach during an NPD project, it is important to compose a dedicated team that has the right skills and knowledge to execute short sprints, hold Daily scrum meetings, and deliver quick deliverables. The product development will thereby not only include mechanical engineering, but a large portion will be software related. This includes the embedded software, operating system, and UI, as well as the overall network, and Digital Backbone to provide deeper insights. Therefore, it is important to have the necessary knowledge and expertise in software engineering both within the company and within the project team. Consequently, a Digital team organization should be established that consists of Digital R&D, App development Team, Digital Content Team, Digital Product Research, Digital Quality and Reliability, and Embedded Development. This organizational setup should support the newly developed NPD framework.

Finally, the overall mindset within the company must shift to Digital Product Development. To run this hybrid model, a so-called 'Bimodal' work style must be established. This Bimodal approach is introduced by Gartner in 2014 and is defined as the practice of managing two separate but coherent work styles, where one is based on predictability and the other on exploration (Mingay & Mesaglio, 2014). The former is related to the Stage-Gate approach and this work style is optimal in mature markets with well-known technologies. The latter is related to Agile and this work style is most optimal in uncertain, rapidly growing markets with many unknowns and technical risks. For both styles, different techniques, skills, and tools are needed, which need to be reflected within the Digital Team organization.

2. Defining the Scrum Sprints

A second important topic is related to the actual execution of the Scrum Sprints. Since these Sprints are also used for physical products, some modifications are needed. One of them is determining the length of a Sprint. This is since the development of a physical prototype, for example, the development of a new coating for a soleplate is time-consuming and cannot be created in the fixed timebox of one month. Therefore, the actual length of the Scrum Sprint should be scalable so that it can be made longer or shorter to fit different types of increments or prototypes.

Second, it is important to modify 'the definition of done'. The current Scrum framework assumes that each Scrum Sprint delivers a result that contains an increment or prototype that can be tested with the user to get valuable feedback. However, in the new NPD framework there are also Scrum Sprints that do not contain an increment or prototype as result, but other types of results such as a proposition, plan, or BC. As a result, the 'Definition of Done' should be modified so that it also includes these types of results. These results are then not tested by the user, but validated by key stakeholders.

3. Product Requirement Modelling

The third topic relates to the combination of the different types of requirements within the Product Backlog. Whereas a normal Product Backlog, which is defined in section IV.A.2.a) Scrum, as an emergent, ordered list of what is needed to improve the product (Schwaber & Sutherland, 2020), consist of User stories, it should now also comprise the traditional technical requirements for the physical product.

To do so, modifications to the Product Backlog are needed. To distinguish the two type of requirements (i.e. User stories or traditional technical requirements) the Backlog consists of two lists, namely the Digital Product Backlog and the Physical Product Backlog. The former consist of User stories that identify a user role and include various business and consumer values. In addition, the User Stories have Acceptance criteria that the digital product must meet. These user stories are then converted into specific features that fall within an Epic or Theme. See appendix F for the Epic and Theme Requirement Hierarchy. Although the Physical Product Backlog can also consist of User stories that relate to physical features, it also includes a detailed and fixed development plan, consisting of technical and development-related requirements. Since these requirements cannot be converted to User Stories, they are still documented and captured in the traditional method.

4. Aggregation of data sources

The fourth and final topic relates to the aggregation of the data sources. In addition to the traditional internal and external sources used to collect data, this can now be supplemented by a third source, the connected product. As explained in section VI.A.3, data can be collected on the functionality and use of the product through connectivity. However, it is important to note that the connected product source only provides data about the result of an action, rather than the purpose, action, or belief behind this action. This only provides basic insights into the usage patterns. Therefore, the main challenge is to aggregate the connected product data with the data from internal and external sources to reveal deeper insights into the actual rationale of an action. An example of this is to aggregate the data from the connected product with the data from a user test, to find out the purpose behind certain actions or beliefs.

Since the disparate data streams cannot be processed with conventional approaches such as spreadsheets or tables, sophisticated data analysis tools are needed to process and analyze the big data. These tools can be Descriptive, Diagnostics, Predictive or Prescriptive (Porter & Heppelmann, 2015). The descriptive analysis provides a deeper understanding of the state of the product, its environment, and general usage, while diagnostic analysis provides insight into the underlying causes of product performance. In addition, predictive analysis detects patterns that predict specific usage situations. Finally, the prescriptive analysis identifies aspects or factors that can improve overall performance. Each of these tools provides deeper insights into the product and the rationale behind the actions and usage of the consumers, thereby contributing to the exploration and establishment of new customer compositions. The deeper insights can be used for the development of new functions and features or even the creation of entirely new product categories that better match the composition of the customer and their type and scope of needs.

VII. Deliver

The Deliver Phase focuses on the Implementation Strategy, Discussion, and Conclusion. In the first section, the Implementation Strategy is presented, in which the implementation plan is explained. The second section describes the Discussion, which includes theoretical implications, as well as the limitations of the findings and suggestions for further research. The third section concludes the Deliver phase with the overall conclusion & Practical Implications, which answers the primary and secondary research questions

A. Implementation Strategy

Chapter VI.A identified the modifications and changes resulting in the development of the new NPD framework. The next step is to establish an actual implementation strategy that describes the necessary steps needed to integrate the NPD framework. The strategy which is used for implementation is classified as an Implementation Process Strategy (Leeman et al., 2017). Within this strategy, the implementation of the framework is planned and delivered in multiple phases. These include assessing the context, involving key stakeholders, monitoring implementation, and making improvements.

1. The Goal of the Implementation Process Strategy

Before the project plan is established, a clear goal for the implementation strategy must be established. This goal must be approved by key stakeholders such as the CEO and Management team. The goal related to this Implementation Strategy is to improve the NPD process by integrating the NPD framework and its processes. In addition to the vision, clear strategic objectives must be created. These objectives must be related to the goal. One such objective can for example be to improve the performance or meet the customer needs. After the objectives have been formulated, KPIs must be defined which relate to at least a single objective. The following objectives and associated KPIs related are proposed, see Table 4 Strategic Objectives and their KPIs. These KPIs will be used as standard metrics for the KPI dashboard, thereby supporting the Implementation Strategy by measuring the performance.

Objective	**KPI**
Process performance	- On-time Completion % - Milestone and Gates on Time % - Control Chart (MIP) - Time-to-Market
Project Management	- Estimate Project Completion - Sprint burndown chart
Adaptive and Responsiveness	- Cumulative flow - Adjustment to planning - Change requests
Meeting customer needs	- Continuous user feedback - Rating & Reviews - Net Promotor Score

Table 4 Strategic Objectives and their KPIs

2. The implementation plan

The implementation plan consists of two phases. Whereby the first phase can be seen as the preparation phase, in which important activities are executed to prepare for the second phase. The second phase can be seen as the pilot testing phase, in which a project is executed and monitored. Both phases are explained in the following sections.

a) Preparation Phase

At the start of first phase, the framework and its structure and processes must be digitalized in an innovation management platform and system. Initially, this will be used as a pilot platform, but once fully integrated, it can serve as a standard internal and external communication system between departments, project team members, or even external institutional sources. This supports cross-functional collaboration and early institutional sources involvement such as the supplier. In addition, the organizational structure must be expanded with a Digital team. Once the Digital team is established, a Digital Backbone must be created, composed of an IT infrastructure with cloud-based services and intelligent systems. This Digital Backbone will run in the background alongside the existing systems during this pilot phase. Once all these activities in the first phase have been completed systems are running, and the right level of management commitment is achieved, phase 2 can start.

b) Pilot Testing Phase

The second phase mainly focuses on the development of a pilot project and its documentation, to see to what extent the framework and the process meet the objectives and the overall goal. At the beginning of the second phase, a cross-functional team is put together, in which employees with the most knowledge and expertise within their field of expertise are selected. In addition, several team members from the Digital Team work within this cross-functional team.

As soon as the project is started, the project team is briefed about the goal of this pilot project, the new framework, its processes, and different type of approaches. Then the project is run through the usual Stages. However, the process performance is closely monitored with the use of the KPIs mentioned above. In addition, the opinions and insights of the team members are weekly documented. The project team thereby reflects on the framework itself and the way of working during the project. At the end of the project, these insights will be generalized and shared to further improve the NPD framework.

In addition to the process performance during the project, the success of the product after launch is also monitored. During the management meetings, the Project Management KPIs, as well as the Sales and Marketing KPIs, are presented to provide insights into the progress towards the defined goal. This disciplined structure ensured that lessons are learned and improvements, changes, or insights are identified for the future. After the product has been launched, and several change requests have been implemented in the Post-launch phase, the pilot project will be evaluated. First, the team will deliver an individual reflection report in which they reflect on the project, the process, the tasks and actions as well as the results. Afterward, a group evaluation will take place to see which improvements or possible alternatives can be applied during the execution of the project to improve the overall process. This knowledge is then generalized and documented. The insights are then applied to further optimize the framework and processes, after which, if necessary, another pilot project can be started.

Once the required process performance and product launch effort are achieved and the process proves to be more advantageous than the current process on these KPIs, the transfer to the other project teams takes place. The documented knowledge is transferred, after which the framework, processes, and working method are implemented in each next initiated project. By using the different phases and pilot projects, an incremental implementation plan is carried out, minimizing risks and disruption to ongoing NPD projects and activities.

B. Discussion

The main aim of this study was to identify the challenges and needs for the actual integration and modifications required to implement Agile-Stage-Gate. This is done by examining the required flexibility, iterative- and responsiveness for the environmental characteristics that change the market environment. The TA of the semi-structured interviews as well as the additional and confirmatory information from the Ethnographic Study provided new insights and knowledge of these challenges and needs required to clearly define the integration of this approach. The meaning of the findings and their relationship to previously performed research are explained in this chapter. Subsequently, the limitations of the findings are presented, including limitations regarding the methodology and the sample selection in this study. The chapter concludes with suggestions for further research.

1. Theoretical Implications

Similar to the findings from the study of Kohli & Jaworski (1990), several factors influence the rate of change concerning Technological Turbulence, Market Turbulence, and Competitive Intensity. However, the results also indicated that not only the rate of change but also the magnitude and effect of these aspects lead to uncertainties and risks. As for the Market turbulence, it does not only depend on the rate at which the composition of the customer and their preference change, but also on the exploration of new customer compositions, with their type and extent of needs. While the Competition intensity, as (WP Barnett, 1997) implies, depends on the number of brands, the result also indicated the importance of the size and impact of a brand on its competitor. In addition to the three environmental characteristics (Kohli & Jaworski, 1990), the analysis also revealed institutional sources such as suppliers, distributors, regulators, or socioeconomic events that lead to uncertainties and risks.

The findings related to the contribution of Agile confirmed but also enriched the study of R. G. Cooper & Sommer (2018) which addresses where to implement Agile and for which projects. The following section elaborates on this statement. The findings, first of all, confirmed that the implementation of Agile is suitable for the early Stages, such as the Ideation and Scoping Stages. This is because these Stages are still exploratory and therefore require a certain degree of flexibility, iterative- and responsiveness. To date, the NPD process within the company still uses a linear approach that effectively limits these aspects. Second, while the study by R.G. Cooper & Sommer (2018) indicates that most manufacturing companies are integrating Agile principles into the Development and Testing phases to address technical and design-related uncertainties and risks, the results of the findings suggested the contrary. At these stages, precision is required and the planning is more constrained, which means that an iterative approach for the creation of a prototype is not tolerable. It is especially for the Physical Product Development- and Test Stage that a clear structure and fixed approach is needed to achieve the required quality and accuracy, thereby making the Stage-Gate approach best suited. Third, For digital and connected products, the Agile approach is applicable and even beneficial throughout the entire NPD process. Moreover, the results indicated that the Agile approach is needed in the Post-launch Stage since the current process within the manufacturing company does not cater to this, thereby not fostering continuous development. Last, the results corroborated and enriched the findings of the early study of R. G. Cooper & Sommer (2016) to identify the challenges and needs for the actual integrations and modifications required to implement Agile-Stage-Gate. While several challenges, such as determining the length of a Sprint, or creating a concrete prototype, are similar to the ones that had been identified in this study, the findings also described several other challenges. These include the Validation for continuous development, the actual application of the customer feedback and most importantly the challenges regarding the team set-up & expertise. This confirmed what R. G. Cooper & Sommer (2016) argued; namely that the Agile approach requires high expertise team with generalist capabilities. However, the

results from this study indicated that it is challenging to establish and keep intact such a team with the necessary expertise.

2. Limitations of the findings

The findings of the study provided insights and knowledge regarding the integration and modifications needed for implementing Agile-Stage-Gate, thereby providing a foundation that can be continued as part of an ongoing research on this topic. However, these findings must be considered in light of the methodological limitations of the study.

First, the main limitation is related to the retrospective aspect of the Semi-structured Interviews which makes the findings dependent on the interviewees' recall of previous projects. To limit this aspect, an Ethnographic Study was conducted. This is to record events and observations that might have been neglected during the semi-structured interviews because the interviewees considered them insignificant, took them for granted, or forgot them. However, due to the compressed time approach, the ethnographic study observed only the first two Stages, which may have resulted in incomplete selective reporting. Second, there is a limitation regarding the Ethnographic Study and the social role the researcher had, and the type of social relationships that came with it. Through the role of an active participant, a close relationship or friendship was developed with each team member. While this provided in-depth knowledge, it also affected the reliability of the study. This is because the ethnographic findings are based on the social role and relationships of the researcher. In order to limit the effect on reliability, an attempt was made to build a professional and general relationship with the team members, in which no profound friendly relationships were established with the assumption that other researchers can build up the similar professional and general relationship in order to achieve the same results. However, it cannot be excluded that other researchers will not have exactly the same social roles or relationships and therefore will not be able to obtain similar findings. Third, the diversity of perspectives that have been captured in the interview sample was useful to identify common and fundamental challenges and needs across the different product categories and departments. As a consequence, however, the need to provide a general comprehension of these results might have led to a simplification of it. In other words, the challenges and needs specifically related to a product category or even a department might have been lost. Fourth, the design of the study necessitated the selection of the sample within the company. While this provides in-depth insights and understanding of the market environment in which the company operates, it can distort the overall interpretation of the result. Although understanding and examining the perspective of companies operating in a different market environment may provide interesting insights into this subject, this was beyond the scope of this study. After all, like all qualitative research, the results regarding the integration of Agile within Stage-Gate across different companies cannot be generalized (Braun & Clark, 2013).

3. Suggestions for further research

Despite the limitations, the use of a qualitative approach appeared to be essential to clearly define the challenges and needs for the integration of Agile-Stage-Gate. It is expected that these aspects would not have emerged without applying a qualitative approach. The findings suggested practical knowledge and new research questions. This knowledge should give project managers direction and guidance for integration, leading to an improved NPD process.

In terms of research questions, three important questions arise. First, it would be insightful to identify and research the actual increase in the overall success of the product launch efforts. For example, how much improvement is there during NPD execution? And how much faster is the response to the changing market environment? Applying a quantitative method for this purpose can achieve methodological triangulation, using multiple methods to increase the validity and reliability of the findings. Second, how will this new approach affect the other functional units within the value chain? Such as HR, Finance, Marketing, and Sales. Third, what kind of change in the organizational structure and

culture is needed to support this new approach? These research questions represent a broad and interesting research potential to gain more knowledge about the further development of Agile-Stage-Gate.

C. Conclusion & Practical Implications

The objective of this research was to examine the required flexibility, iterative- and responsiveness within the current NPD process to determine the need for Agile. In doing so, several secondary research questions were established. This chapter presents the answers to these research questions.

What are the environmental characteristics that change the market environment and thereby create uncertainties and risks?

Using the environmental characteristics defined by Kohli & Jaworski (1990), it appeared that the emerging trend of connectivity can be seen as the greatest contribution to Technological Turbulence. In this regard, it is not the maturity or the pace at which the technology is changing, it is the integration of this technology, and thus the creation of connected and digital solutions that leads to Technological uncertainty and risk.

In terms of Market Turbulence, the most important factor is the exploration of new customer compositions. It can be concluded that there are still unexplored customer compositions with new types and extents of needs, which create Market uncertainty. An example is generation Z, or the millennials. In addition, the Market Turbulence depended on the type of product. For connected products, the digital application broadens the customer experience, which means there are more unknown customer needs that also change over time, resulting in Market uncertainty. Since more products will become connected, it can be concluded that this will also increase the Market Turbulence within other product categories.

Finally, the Competitive Intensity, in the higher segment is mainly due to the size and impact of a single brand, while in the lower segment the Competitive Intensity is due to the large number of B- and C-brands that create intensity through their low price strategy. In addition, it can be concluded that there are other factors besides the competitors that influence the company's viability. These are for example institutional sources such as the supplier, or socioeconomic events such as COVID or the Ukraine War. These factors lead to uncertainties and risks regarding the lead-time of components or financial uncertainties such as the price increase of commodities.

How can Agile contribute to solve or reduce the challenges, uncertainties and risks?

While some of these uncertainties and the associated environmental change impacts can be well predicted or anticipated, thereby making the current Stage-Gate approach quite suitable, several uncertainties are unpredictable, meaning the effect on the change in the market environment cannot be predicted. In this case, the Agile approach would be beneficial to address risks that arise later on in the NPD process or even post-launch. Finally, it can be stated for the digital and connected products the Agile approach can contribute throughout the entire NPD process. This since these require a more iterative and flexible approach to support continuous development.

Which modifications are needed within the NPD processes?

It can be concluded that several modifications are needed that relate to the structure and approach within the NPD process. Regarding the former, some Stages require a predictive and linear approach to improve stability, discipline, and compliance, while other Stages require an adaptive and iterative approach to

respond and adapt to the changing market environment. Regarding the latter, the current NPD process is terminated and closed off once the product is launched, limiting the continuous development of the products after launch. Therefore the structure needed to be changed and extended with a Post-launch Stage to support the continuous development. In addition, the validation structure were modified and streamlined to allow for frequent updates, changes, and releases in the post-launch Stage.

Another modification concerned the utilization of Customer Feedback. It can be concluded that, with the current data sources, it is not possible to immediately determine how the product is perceived and to which extent it meets customer needs. To solve this, the data sources and type of analysis to interpret the data needed to be modified. This is achieved by using the connected product as a data source. In doing so, continuous real-time insights can be provided. These insights can also contribute to the exploration of new customer compositions, thereby lowering the Market Uncertainty.

One final modification is related to the involvement of institutional sources such as the supplier. Since various aspects, such as the component availability and lead-time or commodity costs, evolve over time, it is important to be up-to-date about these aspects. Therefore, modifications were needed to support the frequent and early involvement of the institutional sources to respond in a timely and prompt manner to the uncertainties and risks that arise from these sources.

How can a framework be developed in which the required adjustments are achieved through the integration of Agile?

.

The development of the new NPD framework is based on the proposed modifications from the previous section. The final NPD framework was derived after many iterations. The framework can be seen as a hybrid model, in which the Stage-Gate structure act as the strategic level framework, facilitating the coordination of the project through the process. On the operation level, either the Stage-Gate or Agile approach is implemented to obtain the necessary structure or adaptability. The processes are divided into the physical product and digital product since some Stages are performed simultaneously, start at a different time, or use a different approach.

The framework consists of seven Stages and eight Gates. The seven Stages are Ideation, Scoping & Business Case, Physical Development, Digital Development, Testing & Validation, Launch and Post-launch. Within all Stages is an Agile approach implemented, except for the Physical Development, Testing & Validation Stage and Launch Stage, Within these three Stages, a Stage-Gate approach is implemented to ensure a structured approach is used for the development of the manufacturing design and tooling design. This is since the development requires precision and accuracy and any subsequent changes are time-consuming and costly.

How can Agile contribute to the required flexibility, iterative- and responsiveness within the current NPD process?

The five secondary research questions together answer the primary research question. Based on these results, it can be stated that the current NPD process does not provide the required flexibility, iterative- and responsiveness to respond to the environmental characteristics that create uncertainties and risks within the market environment in which the company operates. To achieve this, modifications were needed concerning the structure, approach, utilization of data sources, and involvement of institutional sources. These modifications resulted in the establishment of the final new NPD framework. The flexibility, iterative- and responsiveness required in certain stages were sought through the implementation of an Agile approach. This allows the NPD process to respond to uncertainties and risks, which ultimately contributes to the success of the product launch.

When these changes are generalized and linked back to the current literature, it can be concluded that within the traditional Stage-Gate format of R. G. Cooper (2008) more flexibility, iterative, and responsiveness is required in the Ideation, Scoping & Business Case, and Post-launch Stage. Regarding the Ideation Stage, it is especially important to generate new ideas, discover gaps in the market, and exploit business opportunities. However, the current Stage-Gate approach is too linear and pre-established that it does not facilitate this. By adopting an Agile approach at this stage, it is easier for the project team to conduct the exploration in iterations or time-boxed design-build-test cycles to explore, experiment and test new ideas in order to arrive at the right solution in an iterative manner in a short time. Finally, Agile can contribute in the Post-Launch Stage. By implementing Agile in this Stage, it is easier to make adjustments and changes that respond to the change in the market environment. For example, software or hardware modifications can be made during the Post-Launch Stage, in which, for example, a new chip set is implemented.

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IX. Appendices

A. Topic list Semi-Structured Interview

Topic list

<table>
<tr><td colspan="2">Aim interviews: Understand the current fit of the NPD process on the rapidly changing market and customer needs to determine the need for implementing Agile.

Provide insights in the challenges which arise during the execution of the NPD process concerning the changing market environment.</td></tr>
<tr><td>Introduction: voorstellen + uitleg onderzoek (5 min.)</td><td>Introduction:
Introduce myself, the reason of this research

- The research aims to provide insights and in-depth knowledge on the current NPD process; its shortcomings, challenges, risks opportunities, and needed improvements
- Eventually offering direction and guidance on the adaptations and reconciliations needs within a firm to implement Agile.
- The interview will be audio-recorded and transcribed within teams. I therefore kindly ask for your permission to proceed.
- Date / time / location.

The interview will be recorded and remains anonymous. It will take about 45-60 minutes.
As an expert from your role, who is familiar with the NPD process end execution, I would like to hear you speak, from the perspective of your function/department. so please take your time to think about your answer. Kindly speak loud and clear so that Teams can directly transcribe the words.
Starting Question
- - What is your name?
- - What is your exact function?
- - How long have you been working as.....
- - How long have you been working within this industry?
- How are you involved in NPD?
- Is everything clear? If yes, let's begin.</td></tr>
<tr><td>Topic 1: Current NPD process status (20</td><td>Introduction: I am outlining a situation in which a new NPD process is being started. I would like to get a rough picture of</td></tr>
</table>

minutes) **Aim = Find out how team members go through the NPD process (From their perspective)**	*how you go through this process from your functions perspective.* **1. Question: How is the length of an NPD project determined? (NPD cycle)** ~~1.1~~ What effect do external factors (such as market environment, emerging technologies and customer needs and wants) have on the NPD cycle? *The next question is about the content and execution of the Stages and related activities* 2. What kind of uncertainties/risks arise at the start and throughout the execution of NPD? *(Open question first, possibly supplemented by sub-questions later):* 2.1 How do you resolve these uncertainties/risks? - 2.1 How would you describe the adaptability, and flexibility of each stage? (*note*: adaptability refers to.., keywords?) **3. Question: Could you describe how the deliverables are validated and committed at the gates?** - 3.1 In what way/extent are the deliverables continuously /evolving over time? - 3.2What is the latest moment these deliverables are committed/frozen (Latest Responsible Moment) - 3.2.1 why at this moment? - 3.3 How do you ensure that the deliverables validated at the beginning of the NPD cycle are still valid later in the process (i.e. at the end of the NPD cycle)? - 3.3.2Could you describe the market validation and valuable feedback from the user/customer throughout the process? - 3.3.3 How does the NPD process support this evolvement of the deliverable?
Topic 2 : Market environment: External environmental factors **Aim = Insights into**	**4. Could you describe how the market environment (for example innovations, promotions/pricing, globalization, focus on service, erosion, commoditization) changes during the execution of the NPD process?** -4.1 How do these changes in the market environment affect

how the current NPD responds to the most important environmental factors which change the market environments	the initially validated requirements and deliverables earlier in the NPD process? **Question How do you respond to the change in *customers' product preferences* over time during NPD? (Market Turbulence)** - 5.1 How much change is there over time? (often, little, etc) **7. Question Could you describe the competitive intensity within the business? (Competitive intensity)** - 7.1 How much change is there over time? (often, little, etc) - 7.2 How do you respond to these changes during NPD? **8. Question How would you describe the technological turbulence? (Technological turbulence)** - 8.1 How much technological development is er within the industry? - 8.2 How do you respond to these changes during NPD? 8.3- How do you see the change in technological turbulence due to the integration of software within the physical products?
Topic 3: Experiences, Challenges, needs, and Preferences (8min) **Aim: to gain insights into the experiences, needs, preferences, and challenges of carrying out an NPD process**	*Introduction: Now that we know more about the current process, market environment, and its factors, I am curious about your experiences, challenges and preferences during the executing of an NPD.* **9. Question Can you share what your experiences are while going through and working out an NPD?** *(We are interested in the adaptability, flexibility, ridigity, iterativeness of the process and how this affects the success of the new product)* 9.1 Can you describe the flexibility and adaptability of the process with regard to these uncertainties and changes? - In which way does this cause inefficiency/rework? **-9.1 How do you experience the change in market environment reflected in the evolvements of the requirements at the beginning?** - 9.1 To which extent do these requirements evolve / get revised? **11. Question If you have delivered activities or deliverables that have been approved – locked-in / frozen, do you encounter challenges later on in the process?** -11.1 if yes, which challenges? -11.2 How do you handle encountering these challenges during NPD? **12. Question Could you tell me how you prefer to go through the NPD process?** - 12.1 What would be the ideal process? -12.1 How do you see the Software team playing a role in this ideal NPD process? - How do you prefer the collaboration / communication with the software team. - How is this aligned with the NPD process and its

	gate and decision moments?
Topic 4: Approach (10 min.) aim: to find out the approach to improve the process.	Introduction: Scenario There are several ways that could possibly contribute to the improvement of the NPD process, one of them is a hybrid approach; implementing Agile methods within the existing Stage-Gate to make it more adaptive, flexible, iterative, ensuring a quicker response to the changing market environment. - Show image of framework; explain **13 Question How do you think Agile can contribute to the improvement of the current NPD process and thereby the final success of the new product?** - 13.1 What kind of challenges would be solved? **16. Culture changing? Can Manufacturing make this change?** **15. In what way / on which level do you see Agile being implemented within the current Stage-Gate?** - 15.1 How would it differ between shorter/longer risky-less risky projects and why? - 15.2 Which Stages would be most suitable? (one specific, several or all of them) and why?

B. Interview characteristics list

	Function	Gender	Product Category/segment	Location	Years of experience	Length of interview
1	Senior Project Manager	Male	[redacted]	China	10 years	49m 43s
2	Project Manager / Segment Team Lead	Female	[redacted]	China	17 years	52m 40s
3	System architect Product Architect	Male	[redacted]	China	22 years	47m 34s
4	R&D Project Manager	Male	[redacted]	Germany	16 years	56m 23s
5	Project Manager	Female	[redacted]	China	10 years	54m 11s
6	System Architect	Male	[redacted]		25 years	49m 34s
7	Project Manager Segment lead	Female	[redacted]	China	10 years	48m 33s
8	Quality Project Leader	Female	[redacted]	China	22 years	45m 24s
9	Business Category Lead & Venture Lead	Male	[redacted]	China	15 years	49m 28s
10	Digital innovation Lead	Male	[redacted]	China	15 years	1h2m 56s
11	Venture Lead	Male	[redacted]	Amsterdam	20 years	54m 25s

C. Concept Indicator Model Semi-structured Interviews

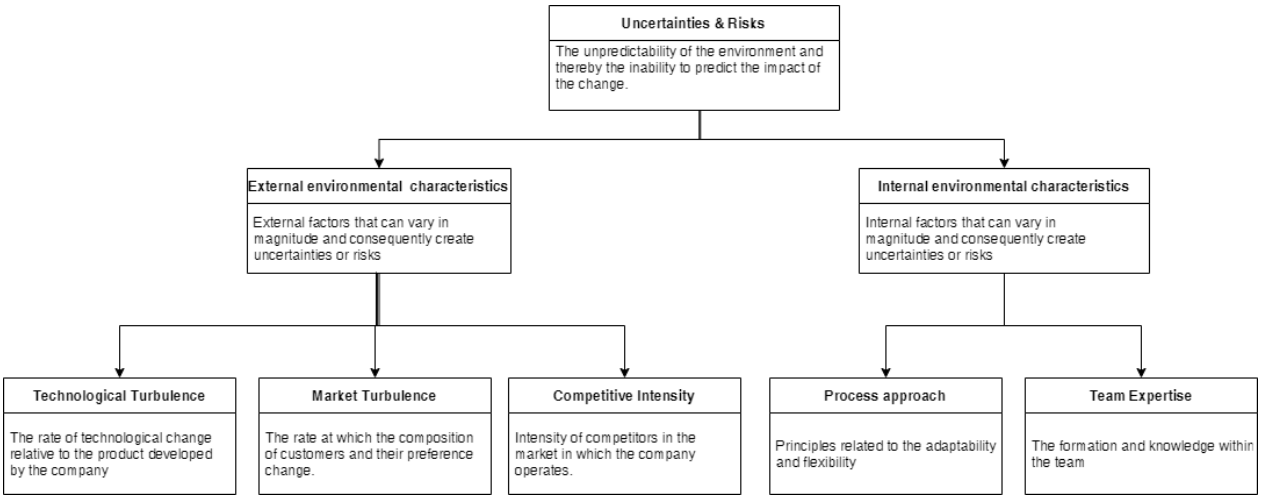

Figure 9 Semi-Interview CIM

D. Hybrid Coding Scheme

Category	Code	Sub-code	Description
Internal environmental characteristics	Process Stage	Type of Stage	*I.e. Ideation, Scoping, Business Case, Development, Testing, Launch* (R. G. Cooper & Cooper, 2008).
	Process approach	Principles	*Understanding of the principles and fundamentals that serve as the foundation of the system.*
		Adaptability / Flexibility	*Examination of the adaptability & flexibility of the NPD process.*
		Validation	*Understanding of the validation process.*
		Team expertise	*Analyzing the required high-level needed expertise from the team and thereby the team set-up.*
	Risk & Challenge	Type of Risk & Challenges	*Identify and categorize the risks and associated challenges.*
Project type	Scope	Small scope	*Few required processes and resources needed to complete the project or deliver the product.*
		Large scope	*Many required processes and resources needed to complete the project or deliver the product.*
	Complexity	High complexity	*Involvement of many unmature or proven technologies.*
		Low complexity	*Involvement of mature platforms or technologies.*
	Budget	Maintain segment	*Segment with general growth rate.*
		Growth segment	*Segment with the highest compounded growth.*
Product aspects	Product category	Physical Product	*Product which is tangible: i.e. the consumer can hold it in its hand.*
		Digital Product	*Intangible asset, content, app or software that is online available.*
		Connected Product	*Product that has both physical and digital components, connected to a platform.*
	Product Type	Modification	*Reference to a product improvement, modification.*
		Initiative	*Reference to an innovative, higher-risk initiative.*
External Environmental Characteristics (Milliken, 1987)	Customer preference	Well known	*Known customer needs which are stable over time.*
		Unknown	*Many unsolved customer problems and unresolved needs, are unstable over time.*
	Competitive Intensity	Low	*Low intensity, large mature market.*
		High	*Existing, growing rapidly*
	Technological Turbulence	Mature	*Well-known, existing technologies*
		Emerging	*New innovations / technologies*

Implementation Strategy	Hybrid Principles	Culture / Mindset	*Understanding the environment underpinned by an organization's core values, behavior and mindset.*
		Validation	*Examine the changes in the validation process.*
		Suitability	*Determine the suitability for implementation.*

Table 5 Hybrid Coding Scheme

E. Concept Indicator Model Ethnographic Study

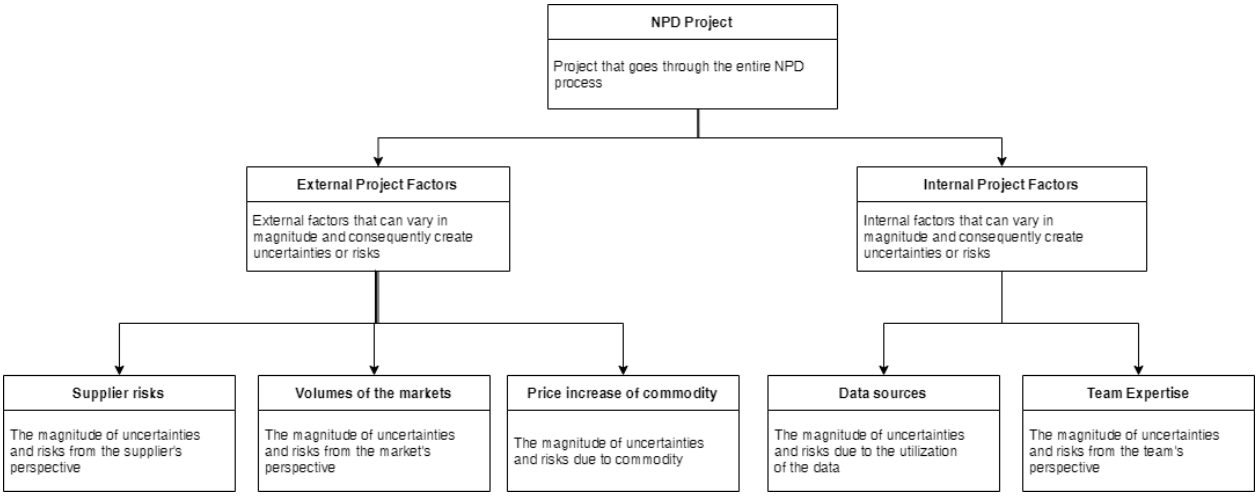

Figure 10 Ethnographic Study CIM

F. Epic and Theme Requirement Hierarchy