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A Process Development Project For A Case Company

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ABSTRACT:

This paper presents a case study on a process improvement project undertaken by a company in the sustainable energy industry. The project aimed to optimize the gate model for new product development, implement a hybrid-gate model, develop a gate checklist, and create an R&D process flow chart to better manage the R&D process. The study began with a thorough analysis of the existing gate model, which revealed several bottlenecks and inefficiencies. These were addressed through a series of process improvements, including better definition of gate criteria, improved cross-functional collaboration, and enhanced communication with stakeholders. To further improve the R&D process, the company implemented a hybrid-gate model, which integrated elements of both the stage-gate and agile development methodologies. This approach enabled the company to be more responsive to changes in the market and customer needs while maintaining the discipline and rigor of the stage-gate model. In addition, the project team developed a gate checklist, which provided a standardized set of criteria to evaluate project progress at each gate. This allowed the team to identify and address potential issues early in the development process. To provide greater visibility and understanding of the R&D process, the team also created an R&D process flow chart, which outlined the steps involved in new product development and the flow of information and decision-making. The project was successful in improving the efficiency and effectiveness of the R&D process, resulting in faster time-to-market for new products and increased customer satisfaction. The gate checklist and R&D process flow chart provided greater transparency and accountability, helping to ensure that projects were delivered on time and within budget. Overall, this case study demonstrates the importance of continuous process improvement in the sustainable energy industry and highlights the potential benefits of a hybrid-gate model, gate checklist, and R&D process flow chart for managing complex development projects.

KEYWORDS: Process development, R&D process, stage gate process model, Agile-Stage-Gate hybrid process model

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1. Introduction

1.1 Background of the research

The case company (TS) is a fast-growing R&D manufacturing company. Over the years, the R&D process used by the company has become outdated and needs planned reforms to adapt to the increasing project requirements. I was fortunate to get this opportunity to improve the company's R&D process as my graduate thesis project.

While many related discussions and studies have provided some guidance for the company's improvement, the company still seeks to identify the key issues and obtain a tailored improvement plan. This is another reason why I chose this proposition as a research topic.

1.2 Objectives of the thesis

The objective of the research is to assist the case company in gathering information from internal and external sources, such as literature and questionnaire interviews, to identify the benefits and drawbacks of the current product development process. Based on this analysis, the paper will make recommendations to enhance the R&D process.

To guide my research and interviews with the company, I proposed four key questions:

- What are the advantages and disadvantages of the existing PCP process?
- How can we improve the R&D process based on the existing product design process?
- How can a company improve its R&D process?

- How can we use the agile-stage-gate method to develop the R&D process?

1.3 Limitations of the research

Due to the sensitivity of the project, the improvement plan will be based on the company's current situation and the existing process as a basis for improvement. Therefore, the recommendations may be limited to the company's established development route, and the scope for learning from other companies and related topics may be restricted.

2. Literature review

2.1 Stage gate process model

What is stage gate process model?

According to Cooper and Kleinschmidt (1995), "A Stage-Gate System is a conceptual and practical roadmap for taking a new product from concept to market. The effort is divided into discrete phases separated by management decision gates in the Stage-Gate method (gatekeeping). Before getting management clearance to move to the next level of product development, cross-functional teams must successfully complete a defined set of linked cross-functional tasks at each stage."

Each stage has its own gate, which functions similarly to huddles in a football game. Gates are meetings that act as quality control and Go/Kill checkpoints for the process (Cooper and Kleinschmidt, 1995). Senior management scrutinizes the project at these gate meetings: they examine the project's progress, determine if the requirements for moving forward have been satisfied, and either approve the task and resources for the next stage (Go), request additional information (Recycle), or terminate the project (Kill or Hold) (Cooper and Kleinschmidt, 1995). The name "Stage-Gate procedure" comes from the stage-and-gate structure. Other names for phase-gate and phase-review procedures include phase-gate and phase-review processes.

With a little forethought before beginning creation, new items may assist a firm lot more rapidly and efficiently. The basic advantages of the stage-gate system are self-evident. The approach instills discipline in the new product development process and emphasizes quality, which is sometimes lacking in new product initiatives (Cooper and Kleinschmidt, 1995).

According to Koen, Ajamian, Boyce, Clamen, Fisher, Fountoulakis, Johnson, Puri, and Seibert (2001), "Stage gate systems has become a popular method for driving new products to market, and the benefits of using such a clear idea-to-launch system has been well documented. Indeed, many well-managed companies, such as Procter & Gamble (P&G) have prospered and profited from using Stage-Gate systems."

However, as noted by Cooper, Edgett, and Kleinschmidt (2014), "Although theoretically relatively straightforward, as we'll see later, stage-gate methods' design, customisation, and execution are far more complicated because of the dynamics of time, shifting organizational structures, and the transfer of important personnel."

In the 1980s, Robert G. Cooper conducted a study on a wide range of corporate innovation and product development processes, drawing on a wealth of experience and ideas from front-line managers, and incorporating the benefits of the preceding new product development process. Cooper coined the phrase "stage-gate process" in an essay published in the Journal of Marketing Management in 1988. He addressed all components of the stage-gate process in depth and provided actual data gathered through extensive research in his 1986 book "Winning at New Products."

Stages and gates are the two key components of the stage-gate process. The stage definition and layout in the stage-gate process are not new compared to the prior approach. Although previous process models required review or decision-making at the end of each step, the stage-gate process was the first to separate "gates" and "stages" in parallel, and it was created as a critical component of the complete new product development process. After each stage, the gate is placed in an autonomous and conspicuous location, the criteria are enforced, and the gate's decision-making abilities are emphasized. Cooper also developed the gatekeeper's particular duty and a special gate meeting as part of the gateway procedure. The gatekeeper attends the gate meeting and makes decisions at the gate (typically go, no-go, hold, or recycle). Determine and redo the four decisions, prioritize the tasks that have already been completed, and assign the necessary resources.

The number of separate steps in the stage-gate process can vary depending on the scenario. This adaptability also extends to the stage-gate process. As a result, many firms have embraced the stage-gate approach from the start, and it is widely used by corporations in the United States, Europe, and Japan to lead new product development (Cooper, 1990).

The stage is the time between actions and full analysis for delivering outcomes. Each stage usually includes a set of tasks that must be followed to ensure that best practices are implemented. Each stage consists of a succession of cross-functional simultaneous activities carried out by employees from several firm divisions. The project team leader leads the participants in forming a team to work together. The steps of a typical stage-gate process are as follows (Cooper, 1990).

Phase 0: Discovery

The possibilities identified and the ideas generated are the key outputs of Phase 0: Discovery. A skilled product manager has the ability to recognize and capture opportunities, and a great concept often leads to a successful product. Due to the significance of opportunities and ideas for a business, many companies treat the process of discovering opportunities and developing ideas as separate formal stages.

To create a mature and proactive framework for generating and capturing ideas, provide IT support and conduct informative research on fundamental technologies. Collaborate with lead users or work with customers to evaluate the value of innovative technology solutions. Utilize client feedback to identify potential requirements and problem areas. Conduct competitive analysis, reverse engineering, and brainstorming to evaluate rival products. Establish a program to encourage original suggestions from employees. Employ strategic planning activities to identify market interference, gaps with competitors, and opportunities. Collect a variety of sources for fresh product concepts and make these accessible. A straightforward one-page idea submission form is a smart way to make it easy for employees to prepare and submit their ideas. Appoint an innovation advocate who specializes in gathering and assessing ideas (Cooper, Edgett, & Kleinschmidt, 2017).

According to Cooper, Edgett, and Kleinschmidt (2017), one way to establish a mature and proactive framework for generating and capturing ideas is to "establish a creative screening committee to act as the Pass 1 gatekeeper and meet monthly to discuss ideas" (p. 175). This committee should apply uniform criteria, ensure fair decision-making, and provide timely responses to submitters. Additionally, Cooper et al. suggest introducing originality in the first stage and allowing gatekeepers to distribute available staff and resources during the gate meeting. They also recommend giving symbolic awards to successful innovators and creating a creative library accessible to all employees to store and contribute ideas.

Stage 1: Screening

Cooper and Kleinschmidt (1993) stated that the first phase of the Stage-Gate system involves rapid exploratory investigations and preliminary assessments of market potential, technical needs, and capability availability. The main objective of this low-cost phase is to determine the project's technical and market value. A quick market analysis is conducted to determine the market size, potential, and acceptance of the product concept. This analysis can be done using a variety of low-cost survey methods such as internet searches, library access, interviews with key users, distributors, sales staff, focus groups, and quick concept testing of a small number of potential users. The primary deliverables of this phase are the projects that were chosen after the assessments.

According to Cooper and Kleinschmidt (1993), the preliminary technical evaluation of a project includes a rapid and preliminary internal examination of the items to be created. The aim of this evaluation is to assess the technology, manufacturing/operational viability, time frame, and cost of the development and production route (or resource supply). Technological, legal, and regulatory concerns must also be identified and evaluated. Market and technical data are gathered quickly and inexpensively using a rough approach. The financial and business analysis of Phase 1 will serve as input for Phase 2's analysis. A team of multiple people, typically from marketing and technical teams, can manage this stage due to the light workload. However, the necessary preparations must be made according to the project's size.

Stage 2: Business demonstration

The primary deliverable at this stage is the business presentation of the project, which includes product definition, a thorough project demonstration, and a comprehensive project plan (Cooper, Edgett, & Kleinschmidt, 2019). However, despite its significance, this stage is often performed poorly. Therefore, it is crucial to ensure enough preparation is done for this thorough research stage. In-depth experts undertake technical, market, and commercial feasibility studies to precisely describe the product and assess its appeal before spending a considerable amount of money in the latter stages.

The key task at this stage is market research, which helps define an excellent and unique new product by identifying the needs, wants, and preferences of buyers. Competitive analysis is also done at this point, and concept testing is conducted to evaluate the potential client's acceptance of the new product.

According to Cooper, Edgett, and Kleinschmidt (2019), the extensive technical evaluation at this stage focuses on the project's technical feasibility, i.e., transforming client demands and wish lists into technically and economically viable solutions. This conversion may involve some early design work or laboratory experiments, but it is not yet a full-scale development. The business case often includes a manufacturing or operation review that considers manufacturability, supply resources, manufacturing costs, and necessary investment. Concurrently, legal, patent, and regulatory evaluations must be carried out to identify risks and create associated action plans. The business case must also include a thorough business and financial analysis, which employs sensitivity analysis to identify potential risks. The substance of financial analysis usually comprises investment payback duration, net present value, and internal rate of return.

Stage 3: Development

The below passages describe the deliverables and activities involved in Stage 3 of the new product development process. The prototypes developed during this stage are tested extensively through laboratory, internal, and alpha testing to ensure their quality and manufacturability. Additionally, manufacturing, operational, and supply chain strategies are developed to meet project requirements. The development strategy for long-term projects includes milestones and frequent project reviews (Cooper, 2019, pp. 153-155).

Although technical work is the primary focus of this phase, marketing and operational work are also carried out concurrently. For example, market research and gathering customer feedback are done concurrently with technological development. Throughout the development process, customers are continuously asked for feedback on the product as it evolves. To provide the development outcomes, such as the first prototype, to the client for assessment and feedback, these steps are repeated or substituted using a spiral development technique. Comprehensive test plans, market launch plans, production and operation plans, as well as the requirements for the manufacturing facility, are all created at once. Additionally, the financial analysis is updated while resolving regulatory, legal, and patent challenges.

According to Cooper, Edgett, and Kleinschmidt (2014), in new product development, technical activities and market activities should be integrated and managed concurrently, as this approach helps ensure that a new product is technically feasible, manufacturable, and marketable. The authors suggest that market activities should be conducted at each stage of the development process to keep the product development aligned with customer needs and preferences.

Stage 4: Testing and Confirmation

In this stage, the primary deliverables are products that have undergone testing and validation. The main objective is to assess the project's overall feasibility, which includes the product, the manufacturing process, consumer acceptance, and the project's financials, and begin external validation of the product and project (Cooper, 2017).

Internal testing, such as laboratory testing and alpha testing, can be supplemented with product field tests or user preference tests to evaluate product performance and quality in real-world scenarios and gauge potential customer response to predict purchase behavior. Trial production or operation can be used to debug and fine-tune the production process, improve cost estimates, and test the operation's capacity (Cooper, 2017).

Market research or test sales can be used to gauge customer opinions, the effectiveness of the launch strategy, and expected market share and revenue. Review financial and business analyses and test the project's economic viability and commercial sustainability using fresh and more accurate income and cost data (Cooper, 2017). If stage 4 cannot meet the requirements, it will revert to stage 3.

Stage 5: Listing.

At this stage, the deliverables are mass-produced and sold products. This marks the beginning of full-scale operations, including manufacturing, marketing, sales, and post-launch monitoring. The phase encompasses tasks such as implementing the market start-up plan, production and operation plan, purchasing and commissioning production equipment, logistics setup, and sales initiation (Project Management Institute, 2017).

Typically, two post-market reviews are conducted. The first review takes place after two to four months of the product launch, during which the team is still learning about the project's details. This mid-term review is an opportunity to assess the project's experience and lessons, evaluate short-term performance, and make critical adjustments to improve outcomes (Cooper, 2017).

The second and final review is conducted 12 to 18 months after entering the market, once the project has stabilized, and the product has become a regular product in the company's product line (Project Management Institute, 2017). This review focuses on obtaining the latest data on product revenue, cost, expenditure, profit, and duration and comparing it with the standards of Pass 3 and Pass 5 to evaluate performance (Project Management Institute, 2017). The project team's responsibility is a core question in this review, where the team's success is evaluated based on whether they have delivered the promised or predicted results (Project Management Institute, 2017).

It is important to note that the project team and the person in charge remain responsible for the project's success during the period after the project is listed until the final review results are released (Project Management Institute, 2017).

"Stage" in the Gate model

The concept of the Gate model is widely used in project management, and it has been extensively researched and discussed in the literature. The model was first introduced by Robert Cooper in the 1980s and has since been modified and adapted by various scholars and practitioners (Cooper, 2014). The Gate model's five stages are well-established in the literature, and each stage's tasks and success factors are based on empirical research and case studies (Cooper, 2014; Englund & Graham, 1999; Lee & Kim, 2000). The importance of cross-functional cooperation and concurrent task execution in the Gate model is also well-documented in the literature (Englund & Graham, 1999; Kim & Choi, 2010).

The Gate model separates the R&D process into five phases, each defining specific tasks that the project team must complete and the information/data to be collected in the current stage. The process only advances to the next phase when the gate is passed, which requires completion of all the necessary tasks and information collection. Although specific stages and gate definitions may differ across enterprises, all stages should possess the following characteristics.

Firstly, cross-functional cooperation is crucial. At each stage, the marketing, R&D, production, and purchasing departments must collaborate to advance the project (Cooper, 2014). Secondly, multiple tasks should be carried out concurrently, with each task assigned to different functional departments. This approach reduces project unknowns and risks (Englund & Graham, 1999). As the project progresses, the cost and resources invested will increase, but the project's risk will decrease. Thirdly, there are key success factors for each stage, based on extensive research and comparisons from successful cases or the company's prior experiences. These key success factors are the focus of each stage and must be completed to ensure the project's success (Cooper, 2014).

The "doorway" in the Gate model

The first is cross-functional cooperation, where the marketing, R&D, production, and purchasing departments collaborate at every stage to advance the project. The second is multitasking, where multiple tasks are assigned to different functional departments simultaneously to minimize risks and uncertainties. Thirdly, there is continuous increase in stage costs, reflecting the increasing investment in resources and effort required as the project progresses, and also the decreasing risk. Fourthly, key success factors/tasks, drawn from previous experiences or successful cases, should be completed in each stage to ensure project success (Cooper, Edgett, & Kleinschmidt, 2019).

At each gate, the main person in charge of the project holds a gateway meeting to decide whether to continue, terminate, or go back to the previous stage. The gateway is the checkpoint of a project and needs to be quantifiable, with a series of standards that determine whether the project meets the corresponding stage's standards. In addition, non-quantitative standards, such as whether the project aligns with the company's strategy and enhances its core competitiveness, also need to be considered. Finally, the plan for the next stage, including resource allocation, time allocation, and task setting, should be outlined (Cooper, Edgett, & Kleinschmidt, 2019).

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Benefits of the stage gate process model

Well-organized innovation and development activities can provide a competitive advantage to organizations by accelerating product development (Cooper, Edgett, & Kleinschmidt, 2020). With the product life cycle shortening continuously, adopting a stage-level process approach is necessary (Kriz & Nason, 2014). This approach can help improve the market success rate of new products by identifying bad product development projects early and correcting their development direction (Kriz & Nason, 2014). It also helps in reasonably subdividing the complex product development process of large companies, providing a development outline that helps prioritize projects and processes (Song & Lee, 2019). The approach is cross-functional, integrating market factors and incorporating the participation and input of people from different functions within the organization (Khan & Lew, 2017). Although there is no separate R&D or marketing phase, a discovery phase has been added (Cooper, Edgett, & Kleinschmidt, 2020). This approach can be effectively integrated with various performance management tools, making it a comprehensive and efficient method for innovation and development (Kriz & Nason, 2014).

Limitation of the stage gate process model

Although the Gate model involves carrying out tasks in parallel in each stage, it is still essentially a sequential approach like a waterfall model (Cooper, 2021). Some experts in product innovation have suggested that product development activities should follow circular and parallel structures (Leifer, McDermott, O'Connor, Peters, Rice, & Veryzer, 2000). For a long time, the stage-level process approach lacked a process for market discovery and generating innovative ideas (Brown & Eisenhardt, 1997). This created tension between the development organization and the creative process, neither of which alone is sufficient for successful product innovation (Biemans, Fisscher, & Frese, 2008).

Applicability

The stage gate system is best suited for companies with relatively simple new product technology, high market risk, and rapid product updates. It leverages flexible market opportunities to drive new product development (Cooper, 2008).

The importance of processes in R&D projects can be traced back to the first-generation portal-style process proposed by NASA in the 1960s. In 1972, Rothwell conducted a theoretical study of the SAPPHO project and found that 41 factors, including process, have a statistically significant effect on R&D project success (Rothwell, 1972). Similarly, in the subsequent Stanford innovation research project, Maidique and Zirger identified eight conditions for new product success, one of which is "good process planning and execution" (Maidique & Zirger, 1984).

Building on these research efforts, Cooper and Kleinschmidt (1987) conducted an in-depth investigation of 203 new product development projects, including 123 successful and 80 failed projects. Based on their findings, they identified nine experiences related to shortening new product development time and improving project success rates. These experiences formed the basis for the second generation portal management process model, which breaks down the entire product innovation process into successive stages with audit points between them to supervise and control the entire process.

The early version of this model proposed five linear portal processes: preliminary investigation and research, in-depth investigation and research, development, testing, and formal production and launch. Since the 1980s, many leading companies in Western countries have successfully applied this portal process to actual R&D projects.

As business competition intensifies, satisfying customer needs better and faster has become the ultimate goal of new product development projects. However, the early portal management process had its own limitations, including a long management cycle, high time costs, bureaucratic factors, lack of flexibility, and a lack of program/project portfolio management. To address these issues, the third-generation portal management process was developed. It improves upon the second generation process by incorporating more flexibility and portfolio management, among other improvements (Cooper, 2008).

2.2 Agile process model

History of Agile

Agile methodology was first introduced in 2001 by a group of 17 software development experts who met to discuss a new approach to software development that would reduce development time and documentation requirements (Highsmith, 2002). At that time, traditional software development methodologies were slow and failed to meet changing business requirements. The experts created the "Agile Manifesto," which emphasized faster product delivery and continuous feedback as keys to software development success (Beck et al., 2001).

However, the agile methodology that exists today has evolved significantly from the original conception. The current methodology is considered "lightweight" and fast, enabling continuous feedback and reducing the need for later rework (Conboy & Fitzgerald, 2004). The original goal of creating a more flexible and responsive approach to development has been achieved through the adoption of Agile principles and practices.

In summary, the Agile Manifesto was developed to address the shortcomings of traditional software development methods and to create a more flexible and responsive approach that emphasizes continuous feedback and faster product delivery. This approach has been refined over time to become the Agile methodology used by software development teams today.

Agile Challenge

Existing waterfall techniques at the time were too cumbersome to provide feedback until the final product was ready for delivery (Chowdhury, 2017). The waterfall model of development is named so because the team completes one step first and then moves on to the next. This means that there is no room for required corrections, and the customer has no view of progress until the entire product is ready (Royce, 1970). These were the exact issues that the experts who came up with Agile wanted to avoid. They sought a solution that allowed for continuous feedback to reduce the cost of rework at a later stage. Agile is all about adaptation, continuous improvement, and speed of delivery.

Agile goes beyond just applying set practices to software development. It brings about a change in the team's mindset, encouraging them to build better software, work together effectively, and ultimately satisfy the customer (Nerur, Mahapatra, & Mangalaraj, 2005). The Agile values and principles shift the team's focus and thought process towards building better software. Agile is not a set of rules, guidelines, or even a methodology. It is a set of principles that encourage flexibility, adaptability, communication, and working software over plans and processes, succinctly captured in the Agile Manifesto.

Agile software development enables teams to work together more effectively when tackling complex projects. It involves the practice of iterative and incremental techniques that are easy to adopt and show great results. There are a variety of Agile-based methodologies available to meet the needs of the software development industry, from software design and architecture to development and testing, project management, and delivery.

Agile methods and methodologies also provide a scope for process improvement as an integral part of every delivery (Singh, 2017). Agile is a practical philosophy of software development that builds a self-sufficient and cross-functional team committed to continuous delivery through iterations and development throughout the process by collecting feedback from end users.

The most popular Agile-based methodologies are Scrum, Kanban, and Extreme Programming (XP) (Beck et al., 2001). All of these approaches focus on Lean software development and help build better software efficiently and effectively.

Advantages and disadvantages of agile methodology

The client receives continuous updates on the progress of the project at the end of each iteration/sprint (Khuong & Lethbridge, 2018). Each sprint delivers working software that meets the customer's expectations as defined in the completion criteria they provide (Beck et al., 2001). The development team is responsive to changing requirements, adapting even in the advanced stages of development (Schwaber & Sutherland, 2017). Continuous two-way communication with clients keeps all stakeholders, both business and technology, informed of project progress (Dikert et al., 2016). The product design is efficient and meets business needs. The use of comprehensive documentation, which is not needed in agile, should be avoided. Instead, teams should constantly ask themselves if they have enough information (Martin & Martin, 2002). At the beginning of a project, requirements may not be clear, and the client's vision may change, requiring the team to integrate many changes, making it difficult to measure the end result (Highsmith, 2002).

Agile emphasizes value-driven delivery and encourages delivering high-value, high-risk requirements first, followed by high-value, low-risk requirements, low-value, high-risk requirements, and finally low-value, low-risk requirements (Beck et al., 2001). This approach allows the highest risk requirements to be tackled first, ensuring the product's feasibility can be determined within the first 1 to 4 weeks (Sutherland et al., 2009). If the project fails for any reason, it can be stopped early to reduce risks (Schwaber & Sutherland, 2017). Agile promotes accepting changes late in the iteration to respond to changes in the market, user expectations, and customer needs quickly, ensuring competitiveness in a constantly changing market (Highsmith, 2002).

Agile advocates high-frequency delivery of valuable products, with daily regular meetings, iteration planning, review, and retrospective meetings (Schwaber & Sutherland, 2017). These meetings allow the team to check the quality of deliverables layer by layer, discuss and solve problems, and invite project stakeholders to participate in the iterative review meeting to accept and provide feedback on deliverables (Martin & Martin, 2002). Agile encourages continuous adjustment and optimization through iteration retrospective meetings, where the team analyzes, discusses, and summarizes agile iterative development to identify areas for improvement in the process (Beck et al., 2001).

Agile promotes servant leadership, with the Scrum Master guiding and supporting team members, eliminating work problems and obstacles, valuing and respecting team members' ideas and opinions, empowering the team to self-organize and manage themselves (Schwaber & Sutherland, 2017). Team members decide what, how, and when to do the work, monitor and manage progress, and take responsibility for the results (Beck et al., 2001). They can discuss and confirm work agreements together to ensure everyone's input is considered, and the SM promotes collaboration among team members, making them more efficient, improving the quality of work and delivery, and increasing team member satisfaction (Schwaber & Sutherland, 2017).

Agile's project scope is flexible, allowing project stakeholders to continuously adjust requirements, changes, and priorities in response to market feedback (Highsmith, 2002). Agile encourages frequent communication with teams and customers, allowing for constant adjustments to management methods, development processes, and acceptance criteria based on feedback and opinions (Beck et al., 2001). The Definition of Done (DoD) can be adjusted according to the actual situation (Schwaber & Sutherland, 2017). In summary, Agile is based on value-driven delivery, flexibility, and constant adjustment and optimization, resulting in high-quality, successful products and early business ROI.

Limitation

One significant challenge of agile is that the team does not know the final product's look from the outset, but rather gains a gradually deeper understanding of it by exploring user needs throughout the development process. This presents great difficulties for early planning, particularly with regards to cost, time, and resource allocation, especially in more extensive projects with greater complexity (Ambler, 2018).

Agile emphasizes software over documentation, meaning that documentation only occurs "just-in-time" during the development process, and is often simple and placed at the end of the process (Schwaber & Sutherland, 2017).

Although incremental delivery can help bring products to market faster, it is also a major drawback of agile methodologies. When individual components are developed at different times, the overall output can become fragmented, rather than a cohesive and integrated set of components. This challenge becomes more significant when projects have higher UI and UX requirements (Stenbeck & Axelsson, 2016).

Agile requires minimal planning at the outset, which makes it easy to veer off course when delivering new, unexpected functionality (Martin & Osterling, 2017). Furthermore, since agile is delivered incrementally, there is no defined endpoint, and progress tracking requires looking across cycles. Setting KPIs at the beginning of a project is difficult, and measuring progress becomes relatively challenging, considering the long game of agile (Boehm & Turner, 2018).

2.3 Agile-Stage-Gate hybrid process model

Based on several case studies from Denmark, Sweden, Germany, and the United States, Agile-Stage-Gate can provide several benefits that can be grouped into five areas (Cooper & Sommer, 2016). Research has shown that many new products fail to deliver their promised value, mainly due to a lack of understanding of customer needs and the product not meeting those needs (Ulrich & Eppinger, 2020). Even with the adoption of new product systems like Stage-Gate, there is still room for improvement. However, by using iterative sprints that involve many user tests and market validations in the early stages of a project, the chances of getting the product right are greatly improved, increasing the odds of success (Cooper & Sommer, 2016).

For many companies, selecting the right projects, defining winning product concepts early on, getting market feedback, and maintaining focus are challenges that come with going public (Sahlman, 1990). The highly iterative, time-bound, and rapid approach of Agile-Stage-Gate is a promising solution for addressing these time-to-market challenges. The use of a dedicated team focused on one project can also increase speed to market (Cooper & Sommer, 2016).

The success rates and development time improvements from implementing Agile-Stage-Gate can vary by industry and organization type. However, a Danish study of five manufacturing companies showed positive results on several performance indicators, such as adaptability, better team communication, higher team morale, and most importantly, faster time-to-market (Geraldi et al., 2011).

Agile-Scrum provides an easy way to integrate Agile into Stage-Gate, making the innovation process more flexible, iterative, and ensuring user feedback and measurable output (Cooper & Sommer, 2016). Working in a sprint format emphasizes speed and fixed time, and this applies to all stages of the innovation process. The greater content flexibility inherent in Agile-Stage-Gate is well-suited for an innovation process that may have a lot of uncertainty and ambiguity (Wohlin et al., 2012).

The Agile-Stage-Gate methodology was developed based on several case studies from Denmark, Sweden, Germany, and the United States, as noted in a previous section. Research has shown that many new products fail to deliver their promised value due to a lack of understanding of customer needs and the product not meeting those needs (Cooper, 2021). Agile-Stage-Gate is an iterative process that involves many user tests and market validations in the early stages of a project to increase the odds of success (Kock et al., 2018).

The definition of a "product increment" in Agile-Stage-Gate has been adapted by early adopter manufacturing companies to include any tangible deliverable that is the result of work done by a project team, including market research results, product concept drawings, detailed design drawings, agreements between concepts and prototypes, rapid prototyping, and Early Work Models (Kock et al., 2018).

The Agile-Stage-Gate methodology can be applied to both technical stages and the earlier "fuzzy front-end" stages of innovation, such as ideation, concept development, and building business cases (Dennis & McDonald, 2017). User stories are essential to the backlog in the early stages when new solutions are unknown, identifying customer needs, pain points, or work to be done, and illustrating how users solve challenges with the new solution and the benefits they gain (Kock et al., 2018).

Danfoss, a Danish company, exemplifies "participatory innovation" by co-creating new solutions with users (Kock et al., 2018). The approach is part of a second idea sprint, guiding subsequent concept sprints (Dennis & McDonald, 2017). Top management buy-in is crucial for the project's success, and the sprints consist of several repetitive actions within the Scrum framework (Kock et al., 2018). The methodology involves sprint checks after each sprint and gates that serve as comprehensive assessments of all the increments completed in the project so far (Dennis & McDonald, 2017).

The Agile-Stage-Gate approach is commonly used during the technical stages of development and testing, but it can also be applied to the fuzzy front-end stages of innovation, including ideation, concept development, and building business cases (Cooper, 2019). Early iteration sprints, such as Idea sprints and Concept sprints, are followed by Development sprints, each consisting of several sprints before entering the gate. Each sprint check is a mini gate that evaluates the increment completed. In contrast, each gate is a more in-depth assessment of all increments and execution or investment decision points completed in the project so far (Liu et al., 2021).

In the Ideation and Concept phase, there are several sprints that typically last 1-4 weeks and involve repetitive actions within the Scrum framework. Before the first sprint, management defines the "why" and "vision," and top management buy-in is critical for the project's success (Cooper, 2019). User stories are crucial to the backlog in the early stages when new solutions are not yet known, as they guide the initial idea sprint in two ways. Firstly, they identify customer needs, pain points, or work to be done, which are derived from customer voice user research. Secondly, they illustrate how users solve challenges with the new solution and what benefits they will gain from it (Liu et al., 2021).

Innovation challenges expand the project's scope by grouping reasons, visions, and user stories. While there are pros and cons to the waterfall approach, developers and customers agree on what will be delivered early in the development lifecycle, making planning and design simpler (Bassil & Knuppertz, 2019). Since the full scope of the work is known in advance, it is easier to measure progress, and various team members can participate or continue other work depending on the active phase of the project. However, the validity of requirements is often lacking, and clients may have difficulty visualizing applications from written requirements, wireframes, and mockups (Kaur & Singh, 2020).

The approach is suitable for projects that require multiple software components to be designed and integrated with external systems, as the design is done early in the development life cycle. This leads to better software design and reduces the possibility of "piecemeal effects" (Bassil & Knuppertz, 2019). Client presence is not strictly required after the requirements phase, except for reviews, approvals, and status meetings. Nonetheless, gathering and documenting requirements in a way that makes sense to the customer is often the most challenging part of software development (Kaur & Singh, 2020).

To expand the scope of the project, reasons, visions, and user stories are grouped into innovation challenges. While there are pros and cons to the waterfall approach, it allows developers and customers to agree on what will be delivered early in the development lifecycle, making planning and design simpler (Rouse, 2020). Measuring progress is also easier since the full scope of work is known in advance, and team members can participate in other work depending on the active phase of the project (PMI, 2017). Testers can prepare test scripts during the coding process, and business analysts can understand and document what needs to be done while developers work on other projects (Duggal, 2019). Client presence is not strictly required after the requirements phase, which is suitable for projects that require multiple software components designed to integrate with external systems (Erdogmus et al., 2013).

However, one potential issue with the pure waterfall development approach is that customers may be dissatisfied with the software product delivered. By then, implementing changes can be difficult and costly (Boehm, 1988). In contrast, Agile development allows for frequent opportunities for clients to see the work being delivered and make decisions and changes throughout the development project, resulting in a strong sense of ownership. Agile produces working software faster, with a basic version built in successive iterations, and is more user-focused due to frequent coaching by clients (Beck et al., 2001).

Agile development requires a high level of client engagement, which can be problematic for clients with limited time or interest. It is most effective when team members are fully committed to the project, and additional sprints or functionality may increase overall time and cost (Ambler & Lines, 2012). Close working relationships are easiest to manage when team members are in the same physical space, but this can be resolved through various tools (Nerur et al., 2005). The iterative nature of Agile development can also lead to frequent refactoring, which is crucial to consider in the initial architecture and design of large-scale implementations or systems with a high degree of integration to avoid overall quality degradation (Kaur & Sohal, 2020).

The traditional way of software development involves a large up-front design that sets requirements, specifications, and design documents in stone before any code is written. Changes in scope become difficult because each stage is a prerequisite for the next, making it inflexible and unsuitable for moving and growing with the business (Boehm, 1988).

On the other hand, Agile is a successful methodology that accepts the fact that requirements and designs change as the product is developed. Changes are welcomed and easily incorporated, even in the final stages of development (Beck et al., 2001). Agile is an adaptive form of process management that allows businesses to achieve short-, medium-, and long-term goals while modifying them as needed.

Iterative development is a key component of Agile, as it allows for validation of the product and getting something physical in front of customers early, often, and cheaply. This approach deals with changing requirements through fast revisions and experimentation, which allows for trial and error in exploring and testing solutions both technically and with the customer. Understanding the requirements becomes a part of finding the solution (Ambler & Lines, 2012).

Once a sprint begins in Agile, its duration is fixed and cannot be shortened or lengthened. Project teams commit to certain deliverables at the beginning of each sprint and are under self-imposed pressure to deliver within the agreed time frame. This approach improves project efficiency and focuses teams on delivering quality results. Scrum, a popular Agile framework, places great emphasis on this approach, leading to its success in many major projects (Beck et al., 2001).

In summary, Agile is a flexible and adaptive approach to software development that allows for changes in requirements and designs. Its iterative development process enables businesses to achieve their goals while modifying them as needed, leading to improved project efficiency and quality results (Beck et al., 2001; Boehm, 1988; Ambler & Lines, 2012).

2.4 R&D and product development

Research and development (R&D) is an essential process for companies to create and improve new goods and services (Ireland, Hitt, & Sirmon, 2003). During the research phase, new product concepts are generated and feasibility is tested, which involves acquiring new scientific knowledge that can be applied to developing novel goods (Kline & Rosenberg, 1986). The process of transforming acquired scientific knowledge into practical products that a business can market and sell is called development (Chiesa & Frattini, 2011).

R&D activities can vary between businesses and industries, and can be delegated internally or to third-party contractors, depending on the size of the organization and its goals (Dodgson, Gann, & Salter, 2005). Many businesses prefer to keep their R&D efforts in-house to safeguard intellectual property (Chiesa & Frattini, 2011).

Product development encompasses the entire process of developing, marketing, and distributing new items (Cooper, 2017). Although R&D is a fundamental initial step in creating a new product, product development involves the entire product life cycle, from design to sale (Cooper, 2017). This includes creating, developing, and marketing new goods or updating older products to add new features or improve sales. Product development occurs whenever a new product is developed, sold, or when an existing product gets new features added to it and is resold (Kotler, Kartajaya, & Setiawan, 2010).

In conclusion, R&D and product development are both important for businesses to thrive and succeed over the long term. R&D is the stage of the product life cycle when ideas are first conceived, whereas product development is the complete process of developing, producing, and selling new goods or current products with new features (Cooper, 2017).

3. Case company introduction

3.1 Background

The company in question, TS, is a supplier of drive train technology, specializing in key components for renewable and industrial applications. Its main focus areas are wind, marine, and special industrial applications. TS has independently developed its product portfolio, including full power converters and permanent magnet generators. To achieve rapid ramp-up and ramp-down manufacturing capabilities, TS has implemented a model factory manufacturing concept. This concept not only ensures manufacturability but also enables on-time delivery and consistent quality.

Moreover, TS provides comprehensive product life cycle maintenance and after-sales services, as well as training for product and software usage, servicing, commissioning, and maintenance. Established in 2006, TS is headquartered in Helsinki and operates factories in Finland and China. The company also has sales offices in 7 countries, including Finland, China, and Japan.

TS employs a product creation process (PCP) based on the stage-gate model, which was initially created by its electrical machine functional unit and later transferred to the high power converter. The PCP process consists of six or seven different phases, typically following the waterfall development model. Iterations are only performed within individual phases, and Gates are used to control transitions between them. Each Gate has specific criteria that must be met before transitioning to the next phase.

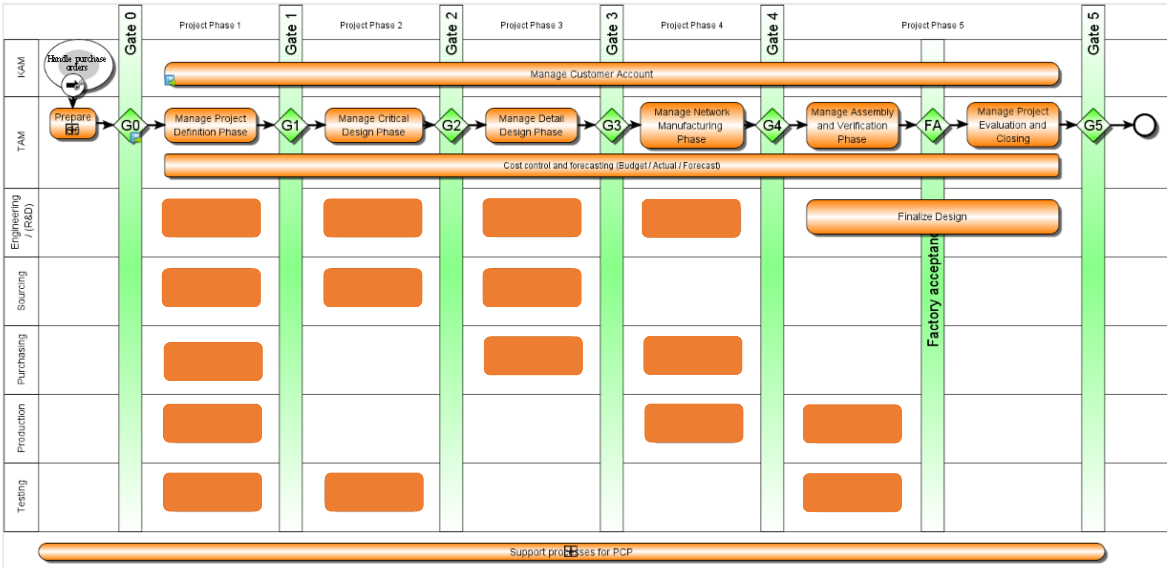

Figure 1. PCP model from the case company

The TS product creation process (PCP) is based on the stage-gate model and consists of six or seven different phases. These phases ensure the successful development of a new product and a smooth transition from one phase to the next.

Phase 0: Project Preparation and Kick-Off

Preliminary specifications and delivery terms are agreed upon with the customer during this phase. The kick-off meeting is conducted to review project information and establish mutual understanding on project organization, schedule, and other PCP-related matters.

Phase 1: Concept Design

The final concept design is collaboratively developed by the project team and the customer, with the aim of obtaining customer acceptance. This phase concludes upon customer approval of the final concept design.

Phase 2: Overall Technical Design

During this phase, the primary emphasis is placed on critical design matters, including electromagnetic dimensioning, main mechanical designs, cooling arrangements, and other fundamental design aspects. The overall design phase concludes upon customer approval of the technical design and completion of documentation for purchasing time-critical main components.

Phase 3: Detailed Technical Design

In this phase, the technical design and documentation are thoroughly finalized, resulting in a comprehensive bill of materials and detailed description of the prototype product for the ERP system.

Phase 4: Prototype Assembly and Testing

In this phase, meticulous preparation is carried out to ensure that the prototype assembly and testing conditions are well-planned, including the subcontractor plan, assembly plan, and testing plan.

Phase 5: Assembly and Testing

During this phase, the final assembly and type testing of the product take place. Upon successful completion of the type testing, a factory acceptance test is conducted.

Phase 6: Commissioning, Project Evaluation, and Closing

The primary objective of this phase is to ensure customer satisfaction and collect valuable information for the continuous improvement of the company.

3.2 Benefits of the current status of the PCP

The PCP was developed by the EM functional unit and has been mostly applied to EM side projects. This is because the nature of projects is different between EM and HPC, as EM develops new machines while HPC mainly modifies existing products.

For customer delivery projects in HPC, PCP is effective and typically starts with a purchase order (PO) that already provides customer specifications and requirements at the first stage. This limits changes and iterations during the process.

PCP also works well for projects such as product cost optimization and product design improvement, where products or platforms already exist, and project teams only need to focus on making small changes to limit iterations.

PCP also acts as a quality checklist to ensure that all necessary documents are prepared and checked before moving to the next gate. This is crucial for quality control to ensure that essential documentation is not overlooked, ensuring the final products and deliveries are of high quality.

3.3 Limitations of the current status of the PCP

The PCP was originally designed for customer delivery projects where clear product specifications and customer requirements are provided at the start of the project. However, for R&D projects, which may start from an idea or indication from key customers, there are no clear customer specifications or requirements. This can create challenges for the project team, especially when there are a lot of changes and iterations during the project. This is particularly true for converter platform design projects for HPC, where most mechanical, electrical, and software designs need to start from scratch.

While the PCP is based on the stage-gate model, which iterates from the waterfall model, it is not suitable for TS and has limitations for R&D projects where change and iteration are the nature of the project. Therefore, the current PCP model is not well-suited for R&D projects where there is no customer and the nature of the project requires a lot of changes and iterations.

However, the PCP model works well for most customer delivery projects where customer specifications and requirements are specified. In these cases, the PCP serves as a quality checklist to ensure that all necessary documentation is prepared and checked before moving to the next stage, ensuring high-quality final products and deliveries.

4. Methodology

This thesis work was an empirical case study that aimed to explore the implementation of the Stage gate process model and the agile-Stage-Gate hybrid process model in R&D process development. The study used a mixed-method approach that involved conducting interviews with selected professionals from the case company and analyzing relevant literature. The Stage gate process model is a widely used framework in product development, while the agile-Stage-Gate hybrid process model combines the benefits of both agile and Stage-Gate approaches. The interviews provided valuable insights into the challenges and benefits of using these models in R&D process development. The findings of this study can be useful for companies seeking to improve their R&D processes and develop successful products.

Empirical case study methodology is a research approach that involves in-depth investigation of a specific phenomenon within its real-life context. This methodology involves collecting data from multiple sources such as interviews, documents, and observations to understand the intricacies of the case being studied. The author then analyzes the data to draw conclusions and develop theoretical frameworks that can be applied to similar cases.

According to the book "Building Theories from Case Study Research" by Kathleen M. Eisenhardt (1989), the empirical case study methodology is an effective way to build new theories and understand complex phenomena. Eisenhardt argues that case studies are particularly useful when the research questions require an in-depth understanding of a specific context or when the phenomenon being studied is not well understood. She also notes that case studies can be useful for testing and refining existing theories and models.

Overall, empirical case study methodology offers a unique and valuable approach to research, allowing researchers to gain deep insights into real-world phenomena and develop theories that can guide future research and practice.

Based on the discussions with the case company, the research will provide an improvement plan for the company's current process. The plan will be based on academic research from the dissertation and internal company interviews, with the aim of recommending the best direction for process improvement that aligns with the company's goals.

Qualitative research methods will be used in the form of carefully designed and selected interview questions. The purpose of these questions is to gain a thorough understanding of the advantages and disadvantages of the company's current R&D process, as well as to explore expectations for future process improvements and directions for optimization.

Interviewees will be selected in advance through negotiations with the steering group, and interviews will be conducted in a one-on-one manner. The questions will focus on evaluating the current PCP gate model within each department, as well as exploring potential improvements to the R&D process. The following questions will be asked during the interviews:

Interview Questions:

1. Benefits and Positivity of the current PCP:
    a. In which kind of projects or circumstances does the PCP process run well and smoothly?
    b. Please describe at least three satisfying functions of the PCP process.
1. Limitations and Challenges of the current PCP:
    a. In which kind of projects or circumstances does the PCP process run problematically?

b. Please describe at least three unsatisfying functions of the PCP process.

2. R&D process development
    a. In your experience, what are the key differences between R&D and product delivery processes?
    b. In your experience, what are the most critical functions to be developed in the next version of the R&D process?

3. Including R&D process into current PCP framework
    a. What are the challenges and risks associated with including the R&D process into the current PCP framework?

Research questions	Data	Analysis
What are the advantages and disadvantages of the existing PCP process?	Interviews: 6 persons, average length 120 minutes Document: 20 internal documents	Content analysis Thematic analysis
How can we improve the R&D process based on the existing product design process?	Interviews: 6 persons, average length 120 minutes Document: 20 internal documents	Content analysis Thematic analysis
How can a company improve its R&D process?	Interviews: 6 persons, average length 120 minutes Document: 20 internal documents	Content analysis Thematic analysis
How can we use the agile-stage-gate method to develop the R&D process?	Interviews: 6 persons, average length 120 minutes Document: 20 internal documents	Content analysis Thematic analysis

Firstly, the research methodology used in this thesis was an empirical case study approach. This approach involved collecting data from multiple sources such as interviews, documents, and observations to gain an in-depth understanding of the R&D process development in a company.

To begin, identify a company or organization that has an R&D process in place and is willing to participate in the study. Once you have identified the company, schedule interviews with key personnel involved in the R&D process, such as R&D managers, engineers, and product managers. During these interviews, ask open-ended questions that allow the interviewees to provide detailed information about their role in the R&D process, their experiences, and their thoughts on the process.

In addition to the interviews, gather relevant documents such as project reports, meeting minutes, and product specifications. These documents will provide further insights into the R&D process and its outcomes.

Finally, observe the R&D process in action, if possible. Attend meetings, participate in discussions, and take notes on the process as it unfolds. This will provide a more complete picture of the R&D process and its challenges.

Once all data has been collected, analyze it to draw conclusions and develop theoretical frameworks that can be applied to similar cases. Use qualitative data analysis techniques such as coding and theme identification to identify patterns and themes in the data.

In summary, to replicate this thesis work, identify a company with an R&D process, conduct interviews, gather relevant documents, observe the process, and analyze the data to draw conclusions and develop theoretical frameworks.

5. Results

5.1 Interview summary

Following a detailed conversation with the interview team, the key points from the results were summarized. The current PCP process is well-suited for improving and optimizing mature products, including product cost optimization, component replacement and upgrades, and performance improvement. It is also considered appropriate for the supply process of mature products, from receiving the customer's purchase order to final shipment. However, it is not suitable for the R&D process of new products, as it is too rigid and inflexible to handle frequent iterations and changing progress in the product development process. This view was consistently expressed by all interviewees. It was surprising to learn that the PCP process is not widely implemented in the company, including in critical departments. Below is a summary of each interview, which will serve as a reference for the upcoming process improvement.

Product Manager A

The transfer of responsibilities between gates is a critical aspect of project management that requires clear definitions and guidelines. In particular, sourcing and purchasing responsibilities in the gate model are not well-defined, and gate owners should not make decisions in these areas. It is also important to set deadlines between gates. Currently, G0 is scheduled one week after PO, and engineering is ready eight weeks before assembly starts. However, IAT and FAT are missing from the process, and critical document deadlines are not reflected in the PCP model, making it difficult to track and manage project progress. Waiting until everything is fully engineered to start placing orders is too late, and the current PCP process has limitations in moving steps back when necessary.

In the R&D process, creating something entirely new for the market can provide advantages such as increased sales, competitiveness, and reputation, but it also requires heavy technology creation or modification. R&D creates the foundation, while product development adjusts and refines it for specific needs. Implementing minus gates could be a suitable way to include the R&D process into the current PCP process. However, sourcing brings limitations to the R&D process as the selection of materials is highly dependent on price, and R&D doesn't have the freedom to purchase the exact parts needed for necessary testing. Therefore, sourcing needs to ensure a second source for the most critical components to facilitate product delivery. Additionally, although the high-level framework may be the same, the details can deviate significantly between different operational units.

Product Manager B

After a detailed conversation with the interviewee, it was concluded that the current structure for normal delivery projects is satisfactory. However, challenges arise due to the pressure from the management team to proceed without proper gates, lack of standardization in quality management, and undefined engineering processes. The PCP model only provides a checklist, making it difficult to create certain documents, estimate project length, and allocate resources. When the starting point is undefined, or changes occur after the process has begun, estimating resources and allocations becomes more challenging.

To improve the next generation process, a requirement management process and a standard template for all the documents in the PCP checklist are needed. The verification process also requires improvement. Additionally, the nature and target of the current PCP and R&D processes differ, with the former serving delivery projects and the latter providing engineering solutions and approved libraries to engineering. The challenge lies in harmonizing the different requirements in product design across different business units and industries.

The responsibility transfer between gates is critical in project management, and the sourcing and purchasing responsibilities in the gate model need clear definitions and guidelines. Deadlines between gates are important, but critical document deadlines are not reflected in the PCP model, making it difficult to track project progress. Implementing minus gates could be a suitable way to include the R&D process into the current PCP process, but sourcing brings limitations as material selection is highly dependent on price. A second source for critical components is needed to facilitate product delivery.

Overall, standardization and harmonization are crucial in the next generation process, along with clear definitions and guidelines for responsibilities transfer and document management.

Lead Engineer

The Product Creation Process (PCP) is a system used for normal delivery projects, but it may not be suitable for Research and Development (R&D) projects due to its rigidity and complexity. The R&D process involves creating documents that are only used in meetings, with little content. The R&D team is only involved in the first few gates, and the final gate has not been organized for the projects they have been involved in. Proper introduction and education of the PCP process throughout the company is lacking, including training and workshops. Furthermore, there is no management or supervisory level follow-up of the usage and implementation of the process.

While the PCP process works well for machine development projects, it may not work as effectively for converter-side projects. The PCP process is beneficial for mutual design projects that require only minor adjustments. The advantages of the PCP process include improved documentation, better traceability, and standardization of different projects. However, it is difficult to evaluate if the problems come from the process itself or from people who have not been using and managing the process properly.

To improve the R&D process, it should be clearly defined, including what should and should not be included. The definition of the R&D process should recognize that there will be a lot of failures, mistakes will be allowed, and the time required can be quite long, possibly more than two years. Additionally, a requirement management process should be developed for the next generation process, and a standard template for all documents in the PCP checklist should be created. The verification process also needs improvement. Finally, organizational roles and responsibilities should be harmonized, as different business units and industries have different requirements in product design.

Engineering Manager

The Product Creation Process (PCP) is a quality management tool developed for engineering-to-order processes, primarily focused on delivery rather than developing new products. It works very well for well-specified delivery projects with a defined scope. The PCP includes a comprehensive checklist and is not suitable for standard product delivery. In contrast, Research and Development (R&D) is focused on exploring and developing new ideas with a scope that is not fixed. The R&D process begins with a feasibility study and has the ability to halt the project immediately if it is deemed too risky.

It is essential to understand that the PCP and R&D processes have different objectives and scopes, and therefore, they require different approaches. While the PCP process is ideal for delivery projects, the R&D process is better suited for developing new ideas and exploring uncharted territories. Therefore, it is essential to have a clear definition of the R&D process, including what to include and what to exclude. The R&D process should allow for experimentation, mistakes, and a longer timeframe, possibly extending beyond two years.

To conclude, the most important thing that emerged from the interviews was the need for a clear R&D process development that incorporates feedback loops to ensure continuous improvement. The interviews revealed different opinions regarding the effectiveness of the Stage Gate process model versus the Agile-Stage-Gate hybrid process model. Some interviewees expressed a preference for the Stage Gate model, citing its structure and predictability, while others preferred the Agile-Stage-Gate hybrid model, citing its flexibility and ability to adapt to changing market conditions. However, all interviewees agreed on the importance of customer feedback and involvement throughout the R&D process, as well as the need for effective communication and collaboration among cross-functional teams.

The interviews had different opinions on the level of detail required in the initial proposal stage of an R&D project. Some interviewees felt that a high level of detail was necessary to justify the investment of resources, while others believed that a general overview was sufficient to proceed to the next stage.

Additionally, there were different opinions on the ideal number of gates and iterations in the R&D process. Some interviewees believed that a higher number of gates and iterations allowed for better verification and decision-making, while others felt that it increased complexity and hindered progress.

On the other hand, the interviews had the same kind of opinions regarding the importance of a NOGO decision and the need for a clear decision-maker in the R&D process. All interviewees agreed that it was essential to have a clear and straightforward NOGO decision, and that the decision-maker should be identified and held accountable for the decision.

Furthermore, everyone agreed on the importance of having a well-defined product description and a clear business case to justify investing resources in an R&D project. The interviews also highlighted the need for continuous review and improvement of the R&D process to ensure its effectiveness and efficiency.

5.2 R&D gate checklist

The following is an R&D gate checklist that has been developed based on interviews and related studies. The documentation has gone through many iterations, and a method similar to Sprint has been used to refine it. The iteration interval is one week, and the goal is to have a new releaseable version after four weeks. At the start of each weekly sprint, the Steering group sets the goal for the next week. At the end of the sprint, the results are presented to the Steering group, and the achievement of the goal is reviewed. The goal for the next week is then set, and the process repeats.

The checklist comprises four gates: initiation, gate-3, gate-2, and gate-1. As shown in the table 1 below, the initiation phase outlines the necessary approvals and preparations needed before starting an R&D project. The required documents include the R&D project plan, which should cover project scope and objectives, staffing, project investment and budget, and other relevant information. These documents will be evaluated by the product and technical direction management team, who will either pass, be prepared to iterate, or fail the project.

Table 1. R&D process document checklist, initiation

					Initiation		Initiation	
	R&D Process				PTDB decision		CTDB decision Assessors: Panu or Teemu	
No.	Contents	Meeting organizer and minimum participants	Goals / Deliverables	Responsible	Decision	status	Decision	status
1	Prepare for PTDB							
1.1	Prepare proposals to PTDB			Proposer				
	PTDB decision		- Go or no go decision		21.11.2019, GO Next checkpoint on 28.11.2019			
2	Prepare for CTDB							
2.1	Standard proposal template To include initial critical elements to support decision making and idea selection, e.g. scope, resource plan, investment, profitability, rate of return, selection criteria against technological or commercial.			Proposer				
2.2	Risk and opportunity evaluation							
2.3	Background analysis (innovation disclosure, business case)							
	CTDB decision		- Go or no go decision - Go back and iteration				28.11.2019 Risk evaluation missing Next review on 05.12.2019	
							05.12.2019, GO PM Teemu to start R&D gate	
	Gate Acceptance							

After passing the initiation gate, the project will move forward. Table 2 below shows an overview of Gate 3, Discovery & Ideation. In this gate, the project team will reflect on the intention and significance of the R&D project through more detailed analysis and reports. This includes analyzing the target market, creating technical specification sketches, conducting analysis of existing technology, and more. At the end of the gate, the product and technical direction management team will review the provided documents and make the final decision for the gate.

Table 2. R&D process document checklist, G-3

					G-3 DL: give DL here	
	R&D Process				Discovery & Ideation Gate assessor: TDB chariman	
No.	Contents	Meeting organizer and minimum participants	Goals / Deliverables	Responsible	Decision	status
	G-3					
1	Phase planning meeting on 30.08.2019	Organizer: PM P: Eng. manager, CTO and BU director				
1.1	Overall project goal and schedule set together with BU					
1.2	Overall schedule and output definition for G-3		- 12 weeks between next CTDB - Give deadline to G-3			
1.3	KPI introduction					
1.4	Project organization and responsibilities					
1.5	Establish project in system using general reporting number					
1.6	VS current product & technology portfolio analyse					
1.7	Analysis of target markets, customers and competition assessment					
1.8	Technical specifications draft					
1.9	Scope of development					
1.10	Project budget & cost estimation					
1.11	Project schedule					
1.12	Quality Assurance					
1.13	Project risk & mitigation and opportunities assessment		...			
1.14	Future trends VS prior art analyze		...			
	Gate meeting on xx.xx.xxxx	Organizer: PM P: Eng. manager, Prod. manager	*- Repeated sprint - define duration, deadline and requirements* *- Decision to go forward*		06.09.2019 - Better definition for customer protentional analysis - Next review on 16.09.2019	
					16.09.2019, GO	
2	Preparation for CTDB					
2.1	Summary report					
2.2	Risk and opportunity evaluation review					
2.3	Share result with BU					
	CTDB meeting on xx.xx.xxxx	CTDB	*- Repeated sprint, define duration, deadline and requirements* *- Decision to go forward*		24.09.2019 - GO forward to next phase - Next phase planning meeting on xx.xx.xxxx	
	Gate Acceptance					

If G-3 is successfully passed, the project will then move forward to G-2 Concept Design. In this gate, the project team will undertake more detailed prototype design steps, and provide a more comprehensive overview of the new product, including mechanical design, electrical design, software design, product price estimation, and risk assessment. Various factors will be described in detail. At the end of this gate, the management will make an investment decision on whether to allocate funds for purchasing and assembling the prototype, and to carry out the next series of prototype testing. Table 3 below illustrates the detailed checklist for G-2 Concept Design.

Table 3. R&D process document checklist, G-2

					G-2 DL: give DL here	
	R&D Process				Concept Design Gate assessor:	
No.	Contents	Meeting organizer and minimum participants	Goals / Deliverables	Responsible	Decision	status
	G-2					
1	Phase planning meeting on xx.xx.2019	Organizer: PM P: Eng. manager, Prod. Manager				
1.1	Overall schedule and output definition for G-2		- xx weeks			
1.2	Project organization and responsibilities, review					
1.3	KPI, review and evaluation					
1.4	Technical specifications draft, review					
1.5	Scope of development, review					
1.6	Future trends VS prior art analyze, review					
1.7	Project schedule, review					
1.8	Project budget & cost estimation, review					
1.9	Quality Assurance, review					
1.10	Project risk & mitigation and opportunities assessment, review		...			
1.11	Manufacturing and testing capability analysis					
1.12	Establish project in system and open specific project number					
1.13	3D model, concept design					
1.14	Single line drawing with main circuit components					
1.15	Concept design simulation					
1.16	Cooling performance calculations					
1.17	Air circulation design					
1.18	Protection system design					
1.19	Lifetime design					
1.20	Mechanical performance design					
1.21	Electrical performance design					
1.22	Control SW design					
1.23	Application SW design					
1.24	Competitor product benchmark					
1.25	Product competitiveness analysis					
1.26	Product cost estimation					
1.27	Alliance partnership research					
1.28	Key components and key suppliers list					
1.29	Applicable standard specifications					
1.30	Certification bodies evaluation					
1.31	Certification requirements					
1.32	Environmental requirements					
	Gate meeting on xx.xx.xxxx	Organizer: PM P: Eng. manager, Prod. Manager	*- Repeated sprint - define duration, deadline and requirements* *- Decision to go forward*			
2	Preparation for BU decision					
2.1	Simulation report					
2.2	Opportunity evaluation review					
2.3	Technological risk evaluation					
2.4	Commercial risk evaluation					
2.5	Product budget evaluation					
2.6	Technical specification					
	BU decision meeting on xx.xx.2019	Organizer: PM P: Eng. manager, Prod. Manager, BU dir.	*- Repeated sprint - define duration, deadline and requirements* *- Decision to go forward*		Decision to build minimum viable prototype	
3	G-2 project closure output					
3.1	Technical specification, draft					
3.2	Commercial specification, draft					
3.3	Risk and opportunity evaluation report, draft					
3.4	Project summary report					
3.5	Sale or not sale decision evaluation					
	Gate Acceptance					

In the final gate of the research and development process, the prototype of the product will be presented in more detail. Based on the accumulation of knowledge from previous gates, the project team will provide a more comprehensive overview of the product's technical specifications. They will also start preparing for the productization of the new product, which includes negotiating with factories for product assembly, constructing the product supply chain, and proposing product listing plans. At the end of the research and development process, the project team will provide a detailed project summary that includes venture capital, future prospects, and other relevant information. This information will be presented to management for evaluation as the research and development project comes to a close and the subsequent connection process begins.

Table 4. R&D process document checklist, G-1

					G-1 DL: give DL here	
	R&D Process				Concept Verification Gate assessor:	
No.	Contents	Meeting organizer and minimum participants	Goals / Deliverables	Responsible	Decision	status
	G-1					
1	Phase planning meeting on xx.xx.2019	Organizer: PM P: Eng. manager, Prod. Manager				
1.1	Overall schedule and output definition for G-1					
1.2	Project organization and responsibilities, review					
1.3	KPI, review and evaluation					
1.4	Technical specifications draft, review					
1.5	Scope of development, review					
1.6	Future trends VS prior art analyze, review					
1.7	Project schedule, review					
1.8	Project budget & cost estimation, review					
1.9	Quality Assurance, review					
1.10	Project risk & mitigation and opportunities assessment, review		...			
1.11	Manufacturing and testing capability analysis, review					
1.12	Communication plan/matrix					
1.13	BOM					
1.14	LLT components list					
1.15	Testing specification, draft					
1.16	Design documentation plan					
1.17	Application SW, review					
1.18	Control SW, review					
1.19	Production documentation plan					
1.20	Production plan					
1.21	Testing plan					
1.22	Sourcing plan					
2	Prepare deliverables for BU					
2.1	Prototype verification report					
2.2	Technical specification					
2.3	Commercial specification					
2.4	Risk and opportunity evaluation report					
2.5	Project summary report					
	Gate Acceptance					

5.3 R&D process flow chart

Along with the checklist, the process introduction diagram is another critical document for the R&D process. The flowchart is created using a similar approach, setting goals in advance and going through weekly sprints, reviewing results, and setting new goals for the following week. The final version is released after a four-week sprint. The flowchart provides a visual representation of the R&D process, illustrating the different gates and stages of the project. The diagram helps to ensure that everyone involved in the project understands the process and their roles, promoting transparency and collaboration. With clear and well-defined steps, the R&D team can work more efficiently and effectively towards achieving their goals.

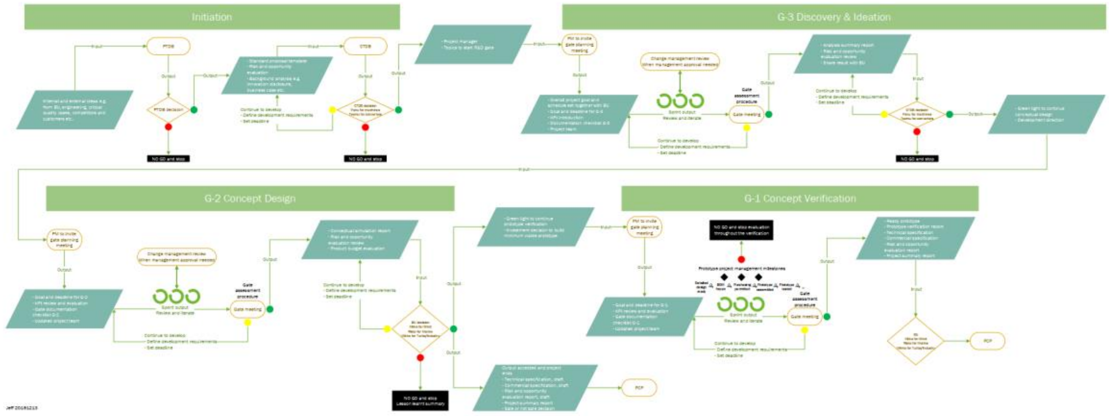

Figure 2. R&D process flow chart, overview

The flow chart provides a more detailed description of the R&D project process in a visual format that corresponds to the checklist. The standardization of the process is emphasized, including the input and output of each certification meeting. The chart defines the required work goals, sprint deadlines, personnel involved, and specific goals to be achieved. Because R&D projects are inherently uncertain, the management reserves the right to terminate the project if it is deemed too risky or not aligned with the company's development strategy. In such cases, the management must provide clear and detailed reasoning for the termination decision. The terminated project will be immediately stopped or returned for reconsideration, and the decision will be discussed at the meeting.

After the release of the flow chart, a round of interviews was conducted to introduce and promote it, as well as to collect feedback. The feedback was then used to carry out the final iteration of the flow chart. The figures below depict the final version, which provides more detailed information about the various gates in the process.

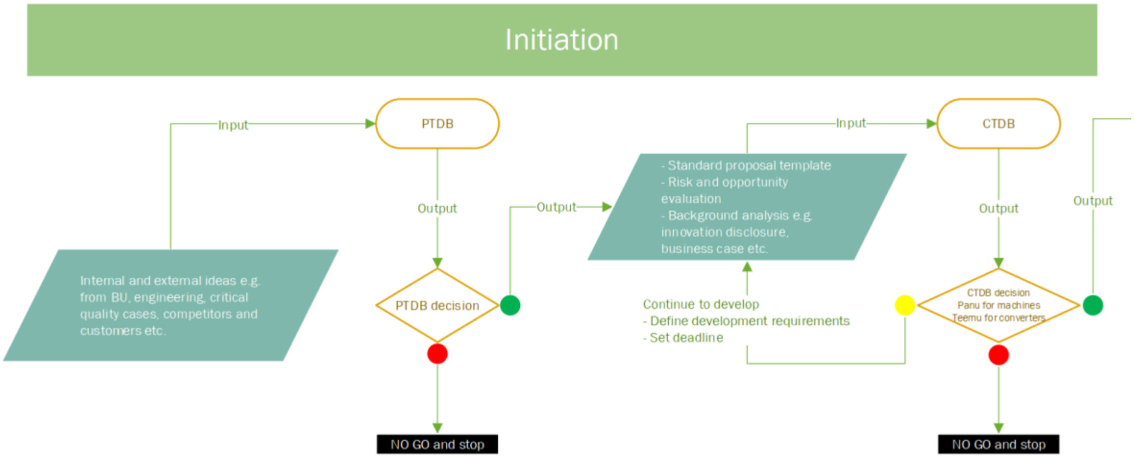

Figure 3. R&D process flow chart, initiation

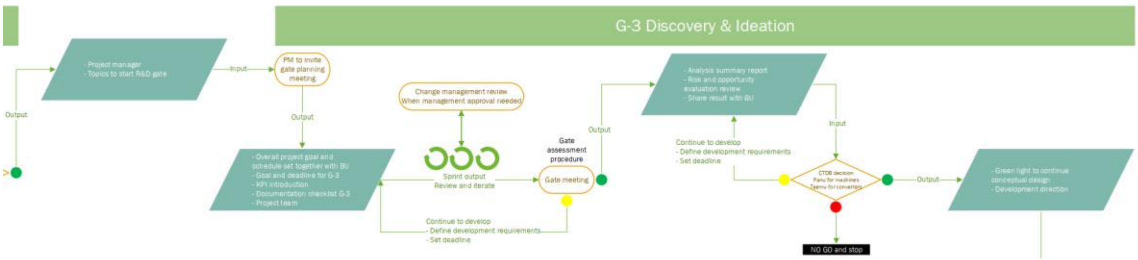

Figure 4. R&D process flow chart, discovery & ideation

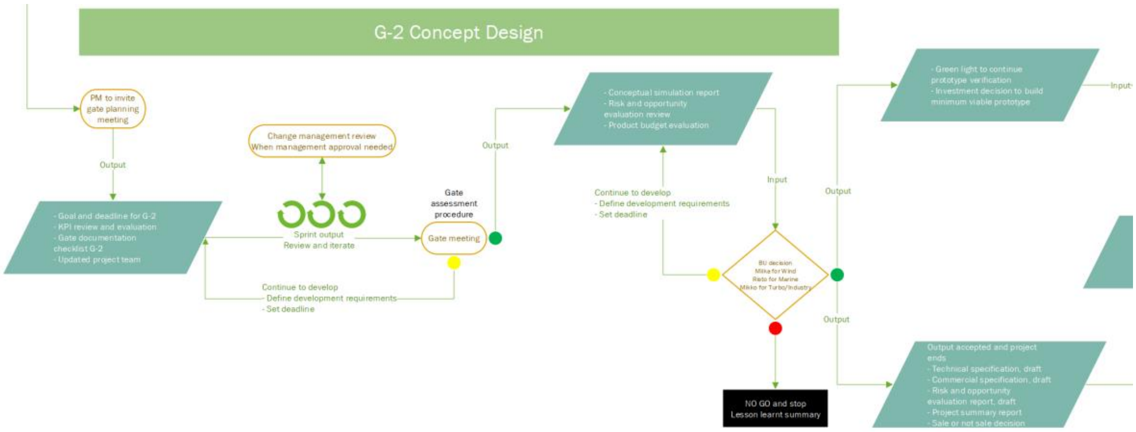

Figure 5. R&D process flow chart, concept design

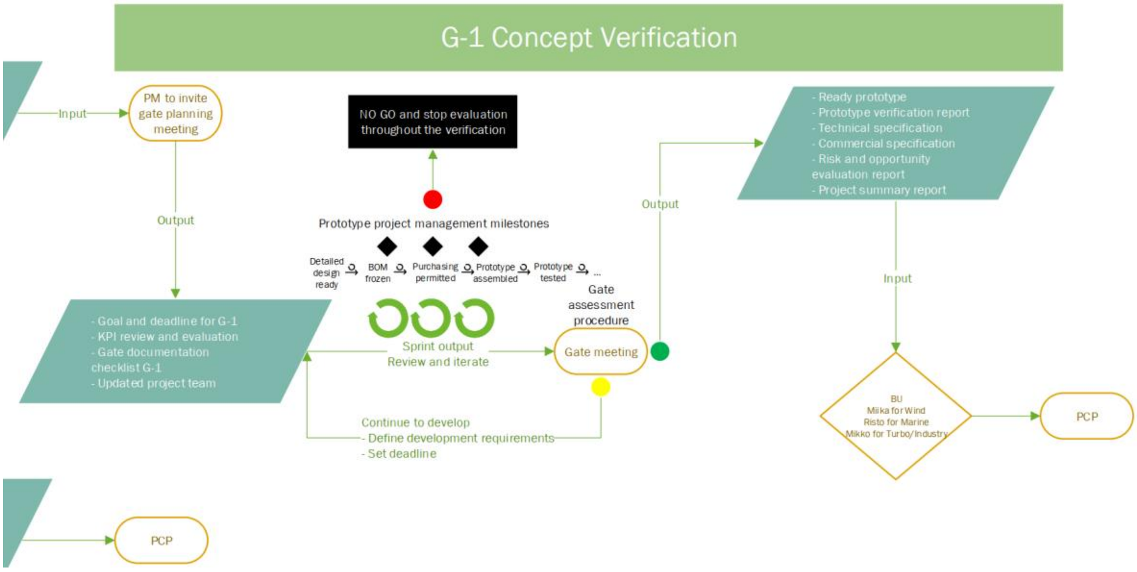

Figure 6. R&D process flow chart, concept verification

During the interviews, the importance of the flow chart as a tool for standardizing the R&D process was emphasized. Feedback was collected on the clarity and comprehensiveness of the chart, as well as on specific areas that needed improvement. Based on the feedback, the final iteration of the flow chart included updates such as more detailed descriptions of the gates and the addition of specific tasks to be completed at each gate. The minutes of each interview are presented below, along with the updates made during the final iteration of the flow chart.

Overall, the final version of the flow chart was well-received and seen as a valuable resource for managing R&D projects.

<u>Interview with the head of engineering</u>

The R&D process flow chart is well received initially, as it facilitates the planning meeting before each gate to ensure readiness. Additional document templates can be created to standardize results and enhance efficiency, but they should remain flexible and adaptable to accommodate different project requirements.

In R&D, solutions should be developed not just for specific customers but for potential markets, applications, and customers. Collecting more practical data through real case piloting can improve the process by providing insights for further refinement and development.

Interview with the head of marketing

The initial impression of the R&D process flow chart is positive, and it's important to have a clear and straightforward NOGO decision in the process. This is necessary when project conditions don't allow us to proceed further, even after the concept design is ready. However, even in such situations, the efforts made can be worthwhile as valuable insights can be gained for the next project.

To start process piloting, it would be ideal to begin with high-speed machine and converter projects, and finalize the estimated project timeline within the next six months. Real case piloting can also help to collect practical data, which will further refine and develop the process. The next step is to review the process feedback with business unit (BU) directors and product managers by the end of next week, and agree on the next steps with CTO and Engineering director.

To improve the process, additional document templates can be created for repeatable work to standardize results and make the process more efficient. However, it's essential to keep these templates flexible and easily modified to meet the needs of different projects. Developing solutions not only for a specific customer but also for potential markets and their various applications and customers will help to improve the process further.

Interview with the head of key account manager (KAM)

To initiate an R&D project, it is crucial to provide an initial proposal that not only focuses on technical aspects but also includes a comprehensive business case, highlighting the reasons and drivers behind the project to justify resource investment. It is equally important to carefully evaluate all the feedback from the sales director and modify the flow chart accordingly. It is recommended to use SwitchOn, the primary platform associated with the process chart, and consult with the quality director if necessary.

Interview with KAM

After reviewing the R&D process flow chart, the initial impression is positive. However, there are some areas that need clarification and improvement. Firstly, it is necessary to clearly define who is responsible for presenting the meeting for the product technical directive board (PTDB). Secondly, a more specific product description, such as "Converter TDB" and "Machine TDB", could be considered to better define the TDB. To improve cooperation at a higher level, other operating units, such as Norway and China, should be more involved in the process. It is important to note that sharing resources between R&D and customer delivery projects will become more demanding and should be carefully managed. Overall, the process shows promise and can be further refined with input from all relevant stakeholders.

Interview with product manager A

The initial impression of the new R&D process is positive, but it's essential to ensure that the process is not only created but also followed correctly. Therefore, the product manager will review the flow chart in detail and provide additional comments to further refine the process.

Interview with product manager B

Consider adding an iteration loop to the PTDB review stage as the process may not always proceed in a straightforward manner in reality. Finalizing the entire prototype verification process within just one gate can be cumbersome. Therefore, it is important to have milestones to advance the project. Additionally, consider having a separate gate process or gate model specifically for prototype verification projects.

Interview with product manager C

The initiation phase of an R&D project can be time-consuming, especially when it comes to preparing all the necessary analyses. It is important to consider the level of detail in the contents to avoid wasting time on irrelevant information. Therefore, having a general flow chart that can be applied to different types of R&D projects, such as component or software development, is beneficial.

During the prototype verification process, it is crucial to make a decision on whether or not to sell a product or prototype that has not been thoroughly verified. This decision should be based on facts, and the decision-maker should be clearly identified. It is recommended to consider adding an iteration loop into the PTDB review stage to allow for more flexibility in the process, as finalizing the entire verification process within one gate can be cumbersome.

To further improve the flow chart, it is important to take into account the review comments in the PDF and update it accordingly.

6. Conclusion and discussion

6.1 Conclusion

The aim of this thesis work was to find answers to the following research question: 1) What are the advantages and disadvantages of the existing PCP process? 2) How can we improve the R&D process based on the existing product design process? 3) How can a company improve its R&D process? 4) How can we use the agile-stage-gate method to develop the R&D process? As an answer to the first research question, the advantages of the existing PCP process may include its ability to systematically manage the R&D process from idea generation to product launch, its focus on customer needs and market trends, and its use of clear criteria for evaluating project success. However, some disadvantages may include its tendency to prioritize short-term goals over long-term innovation, its rigid structure that can stifle creativity and flexibility, and its potential for bureaucratic delays and inefficiencies.

To address the second research question, there may be several ways to improve the R&D process based on the existing product design process. One approach may involve incorporating more user feedback and involvement throughout the process, from initial concept development to prototype testing and product launch. This can help ensure that the final product meets the needs and preferences of the target market. Another approach may involve adopting more agile development methodologies, such as rapid prototyping and iterative testing, to allow for greater flexibility and faster adaptation to changing market conditions.

Additionally, companies can improve their R&D process by investing in training and development programs for employees, fostering a culture of innovation and risk-taking, and providing the necessary resources and support for R&D initiatives. Finally, using the agile-stage-gate method can help companies develop their R&D process by combining the benefits of agile development with a structured, stage-gate approach for managing projects and ensuring their alignment with overall business objectives.

I have completed my study assignment and research on the R&D project process. After consulting with the company, the checklist will serve as a reference for creating the R&D checklist in the future. The flow chart was well received by the company's management and will be updated to the company's internal process and tested on actual projects. Going forward, I will continue to apply the excellent experience I gained in the Agile system to my daily work.

I would like to express my gratitude to my university thesis supervisor, Ville Tuomi, colleagues in the company, and management team for their help and encouragement throughout this project. Without their support, I would not have been able to complete this project alone.

Most of the research results are based on the real environment and real situation within the company, and therefore, they are specific to the company to some extent. However, they can serve as a valuable reference for other companies facing similar challenges and problems. Through this study and research, the company was able to sort out its internal R&D process and pave the way for subsequent improvements. In the future, I will continue to provide relevant improvement suggestions for the company.

Through the analysis and discussion of the interview questions, as well as the targeted documents and flow charts created from the discussion results, the company now has a comprehensive and clear understanding of the necessary improvements to the R&D process.

6.2 Discussion

Validity refers to the extent to which a study measures what it intended to measure. Reliability refers to the consistency and stability of a measure or a study over time and across different settings. Based on my own evaluation, it appears that the thesis has taken measures to ensure validity and reliability. The research questions were clearly stated, and the methods used to collect and analyze data were described in detail. Additionally, the study employed multiple sources of data, such as interviews and surveys, to increase the validity and reliability of the results.

However, as with any study, there may be limitations that affect the validity and reliability of the results. For example, the study was conducted in a specific company and industry, which may limit the generalizability of the findings to other contexts. Additionally, the sample size and selection process may have limitations that could impact the validity and reliability of the study. Therefore, while the results of the study may provide useful insights, it is important to consider the limitations and potential sources of bias when interpreting the findings.

The generalizability of the results of a case study depends on the scope and focus of the study. Since case studies typically focus on a specific organization or situation, the results may not be fully generalizable to other organizations or contexts. In this particular thesis, since the study focused on a single organization, the results may only be partially generalizable to other companies in similar industries or situations. However, the insights and recommendations provided may still be valuable for other organizations looking to improve their R&D processes.

Based on the research questions and findings of the thesis, there are several areas that could benefit from further research. Here are a few potential research ideas:

1. Investigating the effectiveness of the agile-stage-gate method in improving the R&D process: While the thesis suggests that this method can be effective, more research could be done to further test and refine the approach.

2. Exploring the impact of PCP on other aspects of product development: The thesis primarily focused on the advantages and disadvantages of the PCP process itself. However, future research could look at how PCP impacts other areas of product development, such as cost, time-to-market, and customer satisfaction.

3. Comparing the effectiveness of different R&D process improvement methods: The thesis identified several potential ways to improve the R&D process, such as using the agile-stage-gate method and implementing cross-functional teams. A comparative study could be conducted to assess the effectiveness of these methods and identify the most efficient ways to improve the R&D process.

4. Examining the factors that influence successful R&D process improvement: While the thesis provides some insights into how companies can improve their R&D process, more research could be done to identify the key factors that lead to successful process improvement initiatives. This could help companies develop more effective improvement strategies.

5. Investigating the impact of organizational culture on R&D process improvement: The thesis notes that a supportive organizational culture is important for successful R&D process improvement. Future research could explore how different types of organizational culture impact the success of improvement initiatives, and identify ways to create a culture that is more conducive to innovation and continuous improvement.

References

Ambler, S. W., & Lines, M. (2012). Disciplined agile delivery: A practitioner's guide to agile software delivery in the enterprise. IBM Press.

Ambler, S. W. (2018). Disciplined Agile Delivery: A Practitioner's Guide to Agile Software Delivery in the Enterprise. IBM Press.

Bassil, Y., & Knuppertz, P. (2019). Pros and cons of the waterfall and Agile project management approaches in software development projects. Information Systems and e-Business Management, 17(4), 685-713.

Beck, K., Beedle, M., Bennekum, A. V., Cockburn, A., Cunningham, W., Fowler, M., ... & Sutherland, J. (2001). Manifesto for Agile Software Development. Agile Alliance. Retrieved from http://agilemanifesto.org/

Biemans, W. G., Fisscher, O. A., & Frese, R. W. (2008). Innovation processes in small high-tech firms: An empirical exploration. R&D Management, 38(4), 357-369.

Boehm, B. W. (1988). A spiral model of software development and enhancement. Computer, 21(5), 61-72.

Boehm, B., & Turner, R. (2018). Management challenges to implementing agile processes in traditional development organizations. IEEE Software, 35(2), 74-81.

Brown, S. L., & Eisenhardt, K. M. (1997). The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations. Administrative Science Quarterly, 42(1), 1-34.

Chowdhury, S. (2017). Agile software development methodologies: An overview and comparison. 2017 IEEE Calcutta Conference (CALCON), 1-6.

Chiesa, V., & Frattini, F. (2011). R&D and the market value of firms: a review and meta-analysis. European Management Journal, 29(6), 341-361.

Conboy, K., & Fitzgerald, B. (2004). Toward a conceptual framework of agile methods: A study of agility in different disciplines. Information and Software Technology, 46(4), 255-274.

Cooper, R. G. (1986). Winning at new products: Accelerating the process from idea to launch. Addison-Wesley.

Cooper, R. G., & Kleinschmidt, E. J. (1987). New products: What separates winners from losers? Journal of Product Innovation Management, 4(3), 169-184.

Cooper, R. G. (1988). The new product process: A decision guide for management. Journal of Marketing Management, 3(3), 238-252.

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. Business Horizons, 33(3), 44-54.

Cooper, R. G., & Kleinschmidt, E. J. (1993). New products: What separates winners from losers? Journal of Product Innovation Management, 10(1), 64-75.

Cooper, R. G., & Kleinschmidt, E. J. (1995). New product development: The Stage-Gate system. Journal of marketing management, 11(8), 469-486.

Cooper, R. G. (2008). Perspective: The stage-gate® idea-to-launch process—Update, what's new, and NexGen systems. Journal of Product Innovation Management, 25(3), 213-232.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2014). Portfolio management for new product development: Results of an industry practices study. Research-Technology Management, 57(5), 12-25.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2014). New product portfolio management: Practices and performance. Journal of Product Innovation Management, 31(2), 125-142.

Cooper, R. G. (2014). Winning at new products: Accelerating the process from idea to launch. Basic Books.

Cooper, R. G., & Sommer, A. F. (2016). The Agile-Stage-Gate hybrid model: A promising new approach and a new research opportunity. Journal of Product Innovation Management, 33(6), 681-696.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2017). Portfolio management for new products (4th ed.). Basic Books.

Cooper, R. G. (2017). Winning at new products: Creating value through innovation. Basic Books.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2019). Portfolio management for new products: Second edition. Basic Books.

Cooper, R. G. (2019). Winning at new products: Creating value through innovation (6th ed.). Basic Books.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2019). Portfolio management for new products: Second edition basic and advanced methodologies. Product Development Institute Inc.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2019). Portfolio management for new products. Basic Books.

Cooper, R. G. (2019). Agile-Stage-Gate™: A new idea-to-launch methodology for hybrid agile and waterfall development environments. Research-Technology Management, 62(3), 16-29.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2020). Portfolio management for new products: Second edition. Basic Books.

Cooper, R. G. (2021). Winning at new products: Creating value through innovation (6th ed.). Basic Books.

Cooper, R. G. (2021). Product leadership: Pathways to profitable innovation. Basic Books.

Dennis, A. R., & McDonald, D. D. (2017). Agile-Stage-Gate: A flexible framework for managing new product development in highly uncertain environments. Journal of Product Innovation Management, 34(5), 646-662.

Dikert, K., Paasivaara, M., Lassenius, C., & Ståhl, D. (2016). Challenges and success factors for large-scale agile transformations: A systematic literature review. Journal of Systems and Software, 119, 87-108.

Dodgson, M., Gann, D. M., & Salter, A. (2005). The management of technological innovation: Strategy and practice. Oxford University Press.

Duggal, A. (2019). Agile methodology in software development and testing. International Journal of Computer Science and Information Security, 17(12), 104-108.

Englund, R. L., & Graham, R. J. (1999). From experience: Linking projects to strategy. Journal of Product Innovation Management, 16(1), 52-64.

Erdogmus, H., Morisio, M., & Torchiano, M. (2013). Agile methods in open source software development. IEEE Software, 30(4), 28-35.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of Management Review, 14(4), 532-550.

Geraldi, J., Söderlund, J., & Thuesen, C. (2011). Exploring the combined effects of uncertainties in the early phases of product development projects. International Journal of Project Management, 29(6), 712-723.

Highsmith, J. (2002). Agile software development ecosystems. Addison-Wesley.

Ireland, R. D., Hitt, M. A., & Sirmon, D. G. (2003). A model of strategic entrepreneurship: The construct and its dimensions. Journal of Management, 29(6), 963-989.

Khan, M. S., & Lew, Y. K. (2017). Cross-functional integration and new product development performance: An empirical analysis. Journal of Innovation & Knowledge, 2(3), 130-138.

Kim, H., & Choi, B. (2010). The effect of cross-functional cooperation on new product development in the Korean high-tech industry. International Journal of Innovation Management, 14(6), 1027-1043.

Khuong, P. T., & Lethbridge, T. C. (2018). An empirical study of agile teams using Scrum or Kanban. Empirical Software Engineering, 23(2), 707-749.

Kock, A., Gemünden, H. G., & Killen, C. P. (2018). Agile-Stage-Gate: A new product development methodology for highly uncertain environments. Journal of Product Innovation Management, 35(6), 941-964.

Koen, P., Ajamian, G., Boyce, S., Clamen, A., Fisher, E., Fountoulakis, S., Johnson, A., Puri, A., & Seibert, R. (2001). Fuzzy front end: Effective methods, tools, and techniques. PDMA Toolbook for New Product Development, 151-192.

Kaur, H., & Singh, H. (2020). Evaluating requirements engineering practices in Agile and waterfall software development methodologies. Journal of Software: Evolution and Process, 32(1), e2170.

Kaur, K., & Sohal, A. S. (2020). Agile software development: A review of literature. International Journal of Information Management, 52, 102093.

Kriz, A., & Nason, R. (2014). Cross-functional product development teams, creativity, and the innovativeness of new consumer products. Journal of Product Innovation Management, 31(2), 319-333.

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. In R. Landau & N. Rosenberg (Eds.), The positive sum strategy: Harnessing technology for economic growth (pp. 275-305). National Academy Press.

Kotler, P., Kartajaya, H., & Setiawan, I. (2010). Marketing 3.0: From products to customers to the human spirit. John Wiley & Sons.

Lee, H. W., & Kim, C. (2000). A stage-gate system for product development. Journal of Product Innovation Management, 17(3), 169-184.

Leifer, R., McDermott, C., O'Connor, G. C., Peters, L. S., Rice, M. P., & Veryzer, R. W. (2000). Radical innovation: How mature companies can outsmart upstarts. Harvard Business School Press.

Liu, J., Li, J., Li, L., & Li, Y. (2021). Agile-Stage-Gate™: A hybrid approach to managing new product development projects. R&D Management, 51(1), 87-101.

Maidique, M. A., & Zirger, B. J. (1984). A study of success and failure in product innovation: The case of the U.S. electronics industry. IEEE Transactions on Engineering Management, 31(4), 192-203.

Martin, R. C., & Martin, M. (2002). Agile principles, patterns, and practices in C#. Prentice Hall.

Martin, R., & Osterling, M. (2017). Agile Estimating and Planning. Pearson.

McDowell, W. C., Hamilton, R. W., & Cohn, J. M. (2018). New product development: Process benchmarks and performance metrics. Product Development Institute.

Nerur, S., Mahapatra, R., & Mangalaraj, G. (2005). Challenges of migrating to agile methodologies. Communications of the ACM, 48(5), 72-78.

Project Management Institute. (2017). A guide to the project management body of knowledge (PMBOK guide) (6th ed.). Project Management Institute.

Rothwell, R. (1972). Factors which influence the success of R&D projects. R&D Management, 3(3), 149-160.

Royce, W. W. (1970). Managing the development of large software systems: concepts and techniques. In Proceedings of Wescon (Vol. 26, pp. 1-9).

Rouse, M. (2020). Waterfall model. Retrieved from https://searchsoftwarequality.techtarget.com/definition/waterfall-model

Song, X. M., & Lee, H. (2019). Exploring the impact of process-oriented organizational culture on product development performance: A cross-level examination. Journal of Product Innovation Management, 36(3), 324-340.

Singh, A. (2017). Agile software development: An overview of principles, methodologies, and practices. International Journal of Computer Applications, 166(10), 40-44.

Schwaber, K., & Sutherland, J. (2017). The Scrum guide. Scrum.org. Retrieved from https://www.scrum.org/resources/scrum-guide

Schwaber, K., & Sutherland, J. (2017). The Scrum guide: The definitive guide to Scrum: The rules of the game. Scrum.org.

Sutherland, J., Schwaber, K., & Sutherland, J. (2009). Agile development: Lessons learned from the first Scrum. Cutter Consortium.

Stenbeck, L., & Axelsson, J. (2016). UX design and agile: How do they fit together? In Proceedings of the 9th Nordic Conference on Human-Computer Interaction (pp. 1-10). ACM.

Sahlman, W. A. (1990). The structure and governance of venture-capital organizations. Journal of Financial Economics, 27(2), 473-521.

Ulrich, K. T., & Eppinger, S. D. (2020). Product design and development. McGraw-Hill Education.

Vignesh, G., & Kumar, V. (2019). Agile methods for product development in highly uncertain environments: An empirical study. Journal of Engineering and Technology Management, 52, 70-87.

Wohlin, C., Aurum, A., & Durango, C. (2012). The Agile-scrum process used in game development: An empirical study. Empirical Software Engineering, 17(6), 729-759.