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Reducing Lead Times in Product Development Projects

Master's thesis in Product development, and Management and Economics of Innovation

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A Case Study of a Large Company in the Automotive Industry

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SUMMARY
This study is a qualitative case study using an abductive logic investigating the potential for lead time reductions in product development projects within the case company, a large established European automotive manufacturer, specifically from the perspective of their project management office (PMO). To begin, an initial explorative phase took place with the aim of narrowing down the scope and defining subsequent research questions (RQ). The resulting RQs centered on: First, identifying lead time related issues at the company; second, to apply best practice from relevant literature to each issue and propose corresponding possible actions; and finally, curate the possible actions based on feasibility and potential to reduce lead times.
To find the lead time related issues, 19 semi-structured interviews were conducted. The interviewees ranged across several functions and hierarchical levels. After the interviews, the answers were analyzed with thematic analysis, and the following main issues were specified: Coordination; Teams and organizational structure; Internal supplier; Pre-development; Testing and prototyping; and Software. Specifically, the first two main issues pointed towards a need to increase cross-functional integration at the operational level, as was found in the literature study, which took place in parallel to the above-mentioned activities as aligned with the abductive logic. The issues of the internal supplier were also seen as benefitting from cross-functional integration. For pre-development, more focused and well-defined scopes in combination with more thorough early phase work was suggested. Likewise, more early phase testing and adopting a modularization strategy was deemed favorable. Concerning, testing and problem-solving itself, less reliance on full system tests and more small-scale tests on the sub-system and component level was found promising. Modularization also showed potential here. Finally, the main software related issues seemingly fit into the pre-development and testing issues and their corresponding solutions.
Conclusively, the more detailed proposed actions had already been curated throughout the discussion and also showed a noticeable degree of interconnectedness, hence all proposed actions were recommended, albeit with varying degrees of promise.

Keywords: product development management, time-to-market, new product development, cross-functional coordination

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1. Introduction

The study is a single-case study focusing on a large established European automotive original equipment manufacturer (OEM) and how it can reduce the lead times in development projects, which stretch from initial concept development to start of production, by changing how they manage the execution of these projects. This is motivated by the case company seeing a very high importance of improving the time-to-market for its products due to intense competition, where cheaper and technologically improved products need to enter the market sooner.

1.1 Background

To introduce the context, the importance of speed in product development as described in literature will first be outlined. Following this is a discussion surrounding the ongoing developments in product development speed in the automotive industry. Finally, the case company and its situation will be described.

1.1.1 The importance of speed in product development

Developing new products successfully is vital for the prosperity of businesses, yet it is something associated with many challenges (Knudsen et al., 2023). This increasing importance of product development was described in the 1990s as stemming from the significantly increased competition, which in turn could be traced back to globalization, the fragmentation of markets, more demanding customers and the increasing speed and impact of technological change (Wheelwright & Clark, 1992). Cooper (2019) argue that the situation is even more pressing for today's firms, where for example technological change is faster and competition more global.

To be one of the successful firms, the development needs to be both effective and efficient, meaning that firms need to, as Wheelwright and Clark (1992) describe it, be fast and responsive, have a high development productivity and offer products that are distinct and have integrity. Schilling and Hill (1998) argue that new product development (NPD) is the most important factor for the success of firms in many industries, similarly motivating it through the light of increased competition from globalization and fragmentation of markets, and that the two goals for firms should be to maximize the products' fit with customers' needs and minimize time-to-market (TTM). The definition of TTM can differ between organizations but is generally defined as the time from initial idea of a new product to the first market sales (Bstieler & Noble, Eds., 2023). Development lead time is similar and defined as the time to take a product from concept to market (Thomke & Fujimoto, 2000). Schilling and Hill (1998) motivate the importance of TTM in that it allows the firm to be the one that can offer the newest technology to customers, recoup investments within the shorter timespan than before because of compressed product life cycles and potentially enjoy first-mover advantages. Schilling and Hill (1998) also highlight the expenses that can incur from striving to shorten TTM, emphasizing that it needs to be achieved without compromising quality. This relate to the well-established three performance dimensions in NPD, which are speed, product quality and cost that are all interrelated, and match the triple-constraint in project management (Knudsen et al., 2023). In relation to the urgency of improving development speed, Cooper (2019) emphasize that speed is only an intermediate step to the end goal, as for most companies, of profitability.

To improve the performance of NPD, there is wide range of recommended practices (Cooper, 2019; Crawford & Di Benedetto, 2011; Wheelwright & Clark, 1992; Schilling & Hill, 1998). Knudsen et al. (2023), while analyzing the 2021 global survey within the Product Development and Management Association (PDMA), describe how none of the most successful firms are strong in just one area, but rather in multiple, and utilize many practices. Furthermore, Knudsen et al. (2023) argue that firms need to continuously adapt their processes to stay competitive. Additionally, Schilling and Hill (1998) highlight the importance of taking the specific context and factors of the firm in account when implementing practices.

1.1.2 Ongoing developments in product development management for speed

The increasing competition driven by globalization, market fragmentation and technological change that Wheelwright and Clark (1992) mention is still present today, if not more so. Cooper (2019) argues for the latter, mentioning how globalization and uncertainty is even greater today. Hence, firms are intensely aiming to improve the efficiency and effectiveness of their product development in order to be competitive. In the automotive industry, practitioners and consultant firms have taken great interest to the short TTM of Chinese OEMs focused on electric vehicles.

McKinsey & Company (Borden et al., 2025) estimates that these types of firms have roughly half the lead time compared to other automotive OEMs with approximately 24 months from concept to launch with platform development included. The report, which has a focus on product development, also highlights the reasons behind this as having a focused product portfolio and modularity with significant component re-use in order to reduce complexity, a high degree of virtual testing compared to physical prototypes, a decoupling of software and hardware development, an efficient development of new tooling for production, a high vertical integration and close relationships with external suppliers that significantly reduce transaction costs, a governance with few decision levels and finally, the use of new advanced technology for overseeing the project management. A report by Arthur D. Little (Schreiber et al., 2026) highlight the advantages these types of Chinese OEMs have from scale, limited legacy in internal combustion engine (ICE) vehicles, government support and the close relationship to the strong Tier 1 suppliers in China. However, it is also brought up that the Chinese OEMs have a software-first thinking, a flat organization with a high span of control, i.e. few managers, parallelized development, decoupled software and focus on modularity. Another report by a consultancy firm, Roland Berger (Roland Berger, 2025), reiterates several of the practices of Chinese OEMs cutting TTM such as emphasis on parallel processes, vertical integration and quick decision-making from how authority is concentrated with a few executives, but also that there is a minimum viable product (MVP) approach. To supplement, Steiber and Teece (2025) describe key differences in management with the Chinese model for automotive development in that it has a higher risk tolerance, entrepreneurial mindset, more emphasis on iteration rather than incremental development, decentralized decision-making and vertical integration.

In summary, the Chinese OEMs have not only been faster and cheaper because of industry dynamics, such as scale, close access to strong suppliers and government support, but also by using different management practices. Several of these practices have been brought up in the literature on product development management through concepts such as concurrent engineering, platforms, modularization, digital prototyping, virtual testing and supplier involvement in product development.

1.1.3 The case company and its situation

The case company is a large established European automotive OEM. The competitive landscape and the accelerated pace of technological development have compelled the company to act in improving its performance. The speed of technological change is especially pressing in the electric vehicles segment, for example due to developments in battery technologies. It is also about developing new products with a lower price for customers, which is important for the company due to customers being highly price sensitive. At the same time, quality is also of high priority, meaning that a reduction of cost and shortened TTM cannot compromise quality. Rather, the company's ambition is to improve quality going forwards. In summary, the situation has resulted in a sense of urgency among the company's top management and consequent commitments to reduce costs and TTM, while improving quality, have been made. This study is tasked with contributing to the efforts by a unit aiming to reduce the lead times in development projects.

The unit in question is the project management office (PMO) located in the technology division at the case company. What PMO means in practice differ between, and within, organizations but in general it refers to a part of the organization with a centralized responsibility for the management of projects and programs (Baker, 2007). This particular PMO is not only overseeing the processes, governance structures and other practices for managing development projects but also house lead project managers and project coordinators. These lead project managers are responsible for the case company's largest development projects, in which they lead a project management group consisting of project managers from different functions as well as representatives from additional functions. Several of these projects are platform projects and their derivative projects. Regarding lead time, the time frame this unit is responsible for is from concept development until start of production, or rather the equivalent phases in their internal process model for managing development projects. Consequently, the lead time of, and between, these stages are what the unit intends to reduce.

Based on early explorative conversations, some of the issues related to lead time in the case company's development projects relate to having many projects in parallel, supplier bottlenecks, late unexpected changes and a degree of inflexibility given by the structured process. All of these together or individually in different combinations, along with some more yet unknown issues, increase the lead time for the PMOs development projects. In light of these issues and motivated by the pressure to reduce TTM, the PMO is now exploring ways of changing how the projects are managed and have already started to take some actions.

1.2 Aims

The purpose of the study is to identify how the case company can change their practices to improve future development projects' lead time, without compromising quality or cost, in order to ultimately increase competitiveness.

1.3 Specification of the issue to be investigated

To identify what the PMO should do differently, first the current situation at the case company regarding the management in development projects and their lead times will be investigated (RQ1). This will then be followed by a comparison with applicable best practice as gathered through literature study to identify opportunities for improvement (RQ2). Finally, recommendations will be selected from these opportunities based on their feasibility and potential to reduce lead times (RQ3). This is formulated in the following research questions.

RQ1: *What are the main issues affecting the lead times in development projects that the case company is facing when managing the execution in development projects?*

RQ2: *Based on the identified issues, combined with insights from relevant literature and industry best practices, what potential actions exist for the case company to reduce future development projects' lead times?*

RQ3: *Which of these actions should the case company pursue based on feasibility and potential to reduce the lead times of future development projects?*

1.4 Scope

The scope is limited to what lies within the actionable frame of the PMO overseeing development projects at the case company. In other words, what they are in direct control of or have significant influence over. These are the processes, governance structures and other similar practices used for managing development projects.

Studying the development processes of the case company's external suppliers are not included. However, they are to be considered in a contextual regard and in terms of the case company's processes for collaboration. Moreover, decisions related to the type and number of projects and their prioritization, are not included for the recommended actions as even though it partially falls within the PMO's tasks, it is at a strategic level outside of the scope. However, as it was a reported issue during data collection, it was still mentioned in findings.

To emphasize, the focus is on how the execution in development projects is managed, not e.g. portfolio management or direct engineering work. Furthermore, with regard to the potential actions not compromising cost or quality, the essence is that recommendations are not distinctly impacting these parameters significantly. This is due to estimating cost or quality effects is both outside of scope and highly complex given the circumstances.

Among the development projects, an ongoing platform project and its derivative platform projects will receive more attention in order to attain an in-depth view into how specific projects are managed. These projects were chosen based on their perceived importance for management, which include that similar projects will be undertaken in the future. However, as not any project is alike to another and to receive an understanding of the systemic factors at the case company, the study is not only focusing on these projects. To emphasize, this is a not a project case study but rather a case study of the PMO.

2. Methodology

This chapter introduces the research approach, design and process that was used for the study. Additionally, the ethical implications are discussed.

2.1 Research approach & design

The study is a single case study with an abductive logic and qualitative methodology with semi-structured interviews as the main data collection method.

In a case study the emphasis is on in-depth investigation of the subject and the complexities of it (Bell et al., 2022, chapter 3). Dubois and Gadde (2002) argue that when the problem to be studied is complex with several interdependent variables, a single case study is favorable over multiple cases due to the increased depth of analysis. Reducing lead times of projects is of high complexity, making the single case study design a suitable approach. The study also followed the systematic combining approach by Dubois and Gadde (2002), which uses abductive reasoning. Systematic combining is a process of going back and forth between theory and reality, matching them and redirecting the study upon new insights. This approach, along with abductive logic underpinning it, is according to Dubois and Gadde (2002) useful for developing upon existing theory. Abductive logic can be contrasted with deductive, which focuses on testing existing theory on reality, and inductive, which generates entirely new theory from reality. In practice, the systematic combining approach meant that we iteratively developed our analytical framework based on our findings both empirically and in literature throughout the study.

For similar reasons why the case study design and systematic combining approach are suitable for this problem, qualitative methods were used for data collection. The qualitative methodology involves viewing the topic from peoples' own perspectives, focusing deeply on context and process with detailed descriptions and flexibility in the investigation (Bell et al., 2022, chapter 17). The main source of data was semi-structured interviews, which was supported by documents, field notes and immersion in the research setting by regularly spending time in the office of the case company while attendings meetings, conversating with people and similar. This allows for contextual understanding, triangulation and as Dubois and Gadde (2002) highlights a greater potential to discover new aspects than when only using data collection methods that are focused on searching.

The study falls under what Schwarz and Stensaker (2014) describe as phenomenon-driven research, as compared to theory-driven research. This means that it investigates a managerial or organizational phenomenon and aims to contribute to a body of knowledge, in the process drawing from multiple theories rather than one specific theory. This holds for this study as well, including that a variety of theories was explored during the literature review.

The core quality criteria in qualitative business research are trustworthiness and authenticity (Bell et al., 2022, chapter 17). Trustworthiness in turn consists of credibility, transferability, dependability and confirmability. Credibility is about the match between the empirical observations and the theoretical concepts that are then derived. To ensure credibility, Bell et al. (2022, chapter 17) mentions triangulation, which means using multiple sources of data, and validating findings with those that have been studied by sharing it with them and ensuring that the descriptions are correct. For transferability, which is about generalization, the recommendation is to provide a thick description of the social setting so others can assess whether the findings could hold in other settings. Dependability requires documenting the research process extensively so that others can evaluate it. Finally, confirmability refers to limiting the effect on the research that the researchers' personal values and inclinations have, i.e. striving for objectivity.

2.2 Research process

The study had two main phases: an explorative phase culminating in defining research questions and a main study phase where the research questions were studied in-depth. First the process of these will be described (see Figure 2.1) and then the process of the components in each phase, namely literature study, data collection and conceptual analysis, will be outlined.

2.2.1 Explorative phase

The explorative phase involved being introduced to the context and issues through conversations, documents and observation, and was accompanied by brief literature review. Note that they were not formal interviews, but rather conversations with 10-15 people around the PMO of explorative character. These were akin to unstructured interviews (Bell et al., 2022, Chapter 20) in that there was no interview guide nor were recorded, but brief notes were taken. The length varied greatly from just 15 minutes in some cases, up to 2.5 hours for the longest. The aim of the literature review, in both phases of the study, is to become knowledgeable about what is already written, such as the relevant concepts, methods and gaps, in order to be able to build upon it (Bell et al., 2022, Chapter 5). In line with the systematic combining approach, we moved back and forth between theory and reality to develop our analytical framework for the study. The explorative phase ended with defining preliminary research questions for the main study phase, in which the scope had been narrowed down.

2.2.2 Main study phase

The main study phase began with a more extensive literature review than in the earlier phase, but following a similar process, in order to refine our analytical framework and to support the preparation of the interview guides. This was then be followed by the main data collection phase that focused on semi-structured interviews, but was complemented by documents, immersion in the research setting and field notes.

Despite the linearity of how this process is presented in text we continued to iteratively collect empirical data, review literature and refine the analytical framework as we went with the aim of matching theory and reality. For example, if a concept that had not yet been considered was mentioned in an early interview, a brief literature review would then follow along with an adjustment of the analytical framework. This is also similar to the process of qualitative business research described by (Bell et al., 2022, chapter 17) where the researcher moves between interpreting data, doing conceptual and theoretical work, refining research questions and collecting additional data.

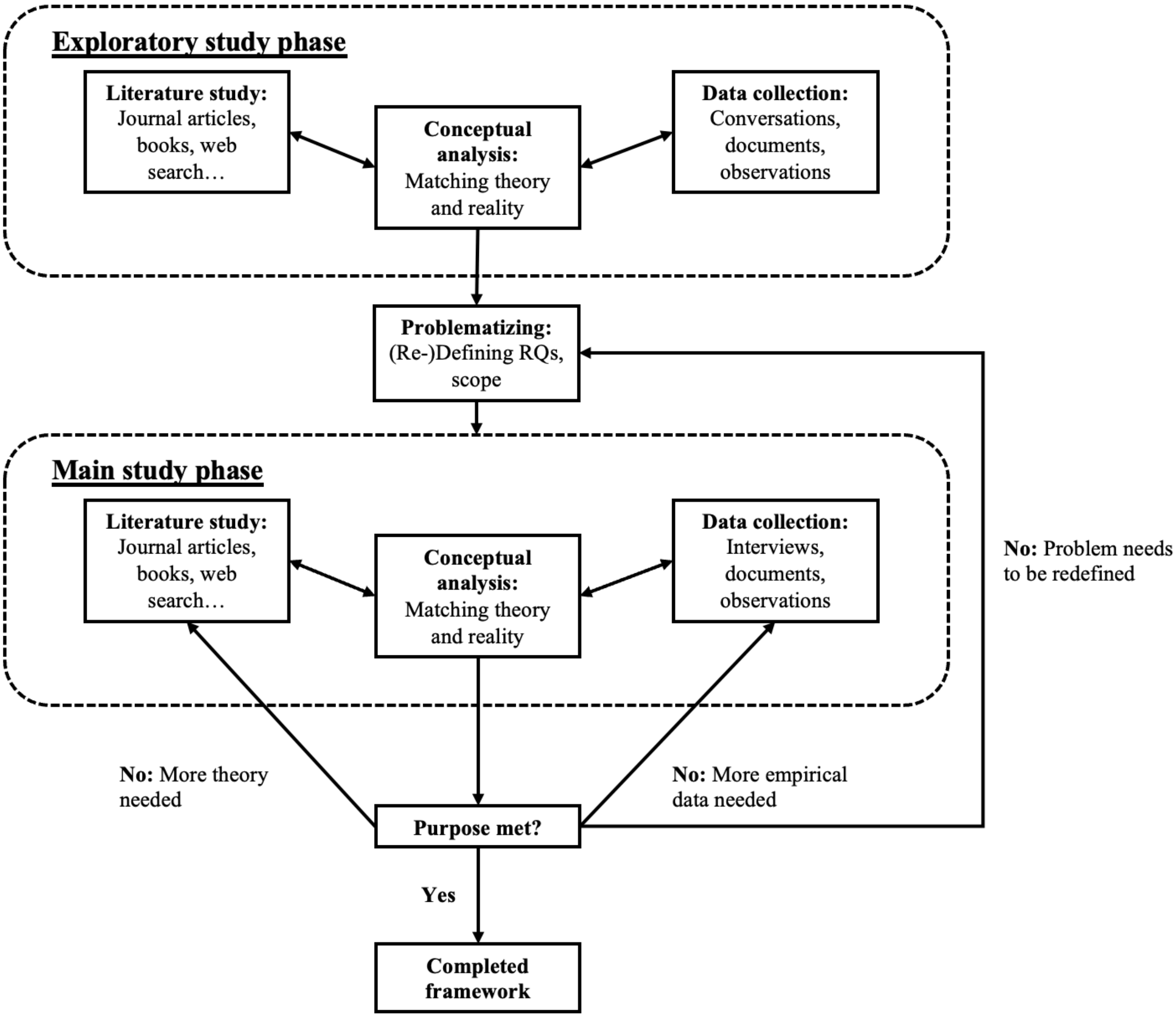


Figure 2.1: A flow chart of the research process.

2.2.3 Literature review

The literature review was conducted mainly by using online databases such as Scopus, searching with relevant keywords and using both forward and backward snowballing with the help of the databases' features to find relevant theory. This was then complemented by reviewing course literature of relevant courses that the researchers have taken and finding other material, such as management consultant reports and similar, with Google search. As mentioned earlier, the study is phenomenon-driven which involves the use of multiple different theories (Schwarz & Stensaker, 2014). Consequently, there was a wide array of keywords used in the searches and in different combinations, an example being: "Product development" AND speed. During the review, notes were taken about relevant literature in order to capture the knowledge and track references.

2.2.4 Data collection

Interviewees were selected using generic purposive sampling, meaning based on how well the data that they provide could contribute to answering the research questions (Bell et al., 2022, chapter 18). In this study, this meant that several people from the PMO unit was interviewed, such as managers and the lead project managers. Due to the extensive cross-functional collaboration in the management in development projects, functional project managers were also selected along with their functional project leaders. People from other functions, such as sales and product planning, were also of great interest. The process of sampling was also sequential (Bell et al., 2022, chapter 18), which means that more people were added to the sample as the study evolved, for example after asking initial interviewees about other people who could have relevance. The latter is also called snowball sampling (Bell et al., 2022, chapter 18). The total sample size was not pre-determined, rather the criterion was to achieve saturation. In other words, where more interviews would not change the answers to the research questions significantly. Later interviews were in large agreeing on the main issues mentioned by previous interviewees, meaning that the data was relatively saturated. However, the study's time-constraints also affected the final sample size, but more in relation to detailing some specific areas rather than the main issues. The total number of interviews in the main study phase were 19, ranging from 45 to 90 minutes length, albeit the majority were around 60 minutes (see Table 2.1).

Table 2.1: List of interviewees

ORDER	TITLE	LENGTH (MIN)
1	Lead project manager	60
2	Project Manager Product Development	60
3	Manager PMO	60
4	Lead project manager	60
5	Project coordinator	60
6	Project Manager Product Development	80
7	Project Manager Manufacturing	60
8	Project Manager Manufacturing	60
9	Manager Manufacturing	60
10	Project Manager Aftermarket	50
11	Project Manager Purchasing	60
12	Manager Purchasing	55
13	Manager Aftermarket	45
14	Senior Manager PMO	60
15	Manager Verification and Validation	55
16	Product Planner	60
17	Lead project manager	90
18	Representative of Sales	60
19	Lead project manager	55

Qualitative interviews are flexible by being less structured, allowing follow-up questions and following the direction of the interviewee to a certain extent as compared to quantitative data collection methods (Bell et al., 2022, chapter 20). Within qualitative interviewing, there are two main approaches: unstructured or semi-structured interviews. An unstructured interview is similar to a conversation. The interviewer only has one or a few questions, which can be written down or not, before the interview. Meanwhile, in semi-structured interviews the interviewer has an interview guide with a list of topics and questions that will mostly be followed, though the order can vary and follow-up questions are allowed. As Bell et al. (2022, chapter 20) describe, there is variability in the degree of structuredness even between these two types of qualitative interviews. This is reflected in our study as well. Due to the study being phenomenon-driven and the complexity of the topic, where various theories could be of use and various factors be identified, the level of detail in the interview guides between interviewees varied. In other words, all the interviews were semi-structured, but for some interviews the core interview guide was supplemented with detailed questions for the specific interviewees dependent on role, function and similar. In terms of creating the interview guides, Bell et al. (2022, chapter 20) recommends, among others, to always have the research questions in mind, not formulating leading question and to ask for demographic information and similar to have context for the answers. This influenced the structure of the interview guides where there was a core interview guide that began with background questions about the interviewee and their current role. This was then followed by two main questions aimed at supporting both answering the first research question, i.e. the main issues in relation to the lead times in development projects, and the second, i.e. what potential actions there are from their perspective. Due to the complexity of the problem, such as the plethora of potential factors affecting the lead times, a diagram of topics related to managing development projects was constructed where the aim was to have it neutral to not act as leading. The four major topics were process, organizational structure, collaboration and soft factors. All of these had several sub-topics. The diagram was shown stepwise, first process and its sub-topics, then organizational structure and its sub-topics etc. The interviewees were reminded by the purpose of the study of finding the main issues affecting the lead times in development projects and potential actions to improve the situation. The diagram also allowed for comparability between interviewees as they also touched upon the same topics. See Appendix A, B and C for the full interview guide. The timing of the detailed questions varied, such as more descriptive questions being asked before the main two questions, while questions more directed at lead time was after the main two questions in order to not influence the answers.

When conducting qualitative interviewing Bell et al. (2022, chapter 20) describe that recording and transcribing is strongly preferred among researchers as it achieves the optimal accuracy and detail, which in turn supports the analysis of the data much better. However, as will be described in more detail later, care needs to be taken to the ethical principles of research (Bell et al., 2022, chapter 6). Thus, if the interviewee did not consent or for other reasons could not be recorded, detailed notes were taken. If recorded, the transcription was made automatically within the Microsoft Office environment but reviewed afterwards to verify its accuracy. A majority of the interviews were recorded and transcribed. Interviews were conducted in English or Swedish dependent on the interviewee. There are some considerations with conducting interviews in a different language than the study's that need to be considered. Bell et al. (2022) mention that translating is a sensemaking process, in which the researchers need to be well-versed in the language and culture to make an accurate interpretation of what is said. Finally, the interviews were done either face-to-face or through online video meetings, such as Microsoft Teams, where most were face-to-face.

The qualitative interviews were used as the main data. However, as mentioned earlier it was complemented by documents, immersion in the research setting and field notes. This is similar to other case studies, which often use documents and participant observation as additional data to semi-structured interviews according to Bell et al. (2022, chapter 23). The main type of document in the study was organizational documents that contributed to the contextual understanding of the case company and the research problem. Bell et al. (2022, chapter 23) highlight that all documents need to be assessed based on authenticity, credibility, representativeness and meaning. Regarding the immersion in the research setting in this study, it is of the type labeled as observer-as-participant as it describes when the researcher is mainly an interviewer (Bell et al., 2022, chapter 19). The field notes were brief and for memory about important things that have been said or have happened. And to emphasize again, the main data were the semi-structured interviews, while documents, immersion and field notes acted as support for contextual understanding, triangulation and, as Dubois and Gadde (2002) highlight, exploration.

2.2.5 Conceptual analysis

As stated earlier, the main data was from the semi-structured interviews in the form of transcripts, which are often large and very detailed. There are different ways to analyze such qualitative data, but the two most common approaches according to Bell et al. (2022, chapter 25) are thematic analysis and grounded theory, which both share coding as the foundation in their process. This study used thematic analysis due to its flexibility compared to grounded theory, which is a more rigorous process with clearly defined steps. Thematic analysis involves finding themes in the data, which could be, among others: repetitions, similarities and differences, or theory-related material (Bell et al., 2022, chapter 25). The process begins with reviewing initial interviews transcripts, developing codes and then begin coding transcripts. Bell et al. (2022, chapter 25) describe how it is common to have codes of different levels, ranging from basic concepts to broader themes. This study followed a similar process, and it was well-aligned with the research questions where issues and potential actions related to the topic were to be identified. Once again, the study followed an abductive approach with systematic combining (Dubois and Gadde, 2002) meaning that the data analysis was done iteratively and aiming to match theory and reality.

2.3 Ethical considerations

There are four main ethical principles in business research: avoidance of harm, informed consent, privacy and preventing deception (Bell et al., 2022, chapter 6). Harm is not only about physical harm but rather all types of harm. Bell et al. (2022, chapter 6) highlights the researchers' responsibility in caring for the risk of harm of participants and taking steps to ensure that it is minimized, as well as the importance of agreeing on the level of confidentiality and anonymity together with the research participants. To reach informed consent, the participants of the study must receive sufficient information before participating and the researchers must inform when using techniques or tools related to data collection, such as audio recordings. Privacy ties in with the previously mentioned aspects of informed consent, confidentiality and anonymity, and additionally to respect the participants' private and personal life. Preventing deception is about honesty and transparency to the participants about what the research is about. These ethical principles were adhered to in this study. For example, it affected how the empirical findings were presented more aggregated as to not reveal which interviewee said what, i.e. maintain anonymity.

We saw no direct effects on societal and ecological aspects from our study, and they are therefore not considered further.

3. Literature review

The literature review that will be presented begins with briefly setting the scene in this section of the general steps in a development project and the fundamental challenges in product development. This is then followed by a review of previous discussions on ways to reduce the lead times in development projects, which is independent of the empirical findings. Meanwhile, the sections after are presented due to its relevance for the case as aligned with the abductive logic and systematic combining approach (Dubois & Gadde, 2002) of the study. To emphasize, more areas in literature have been explored but these are the ones connected to the main issues found during data collection, as aligned with RQ2. The literature review is finalized with a synthesis of the literature that has been presented in the previous sections, summarizing the theoretical framework. However, as mentioned, first some fundamentals will be covered.

A development project typically begins with product planning and concept development, in which various sources of information is distilled into a product architecture (Wheelwright & Clark, 1992). This is then followed by a phase of detailed engineering, which has a twofold purpose of reaching a final design and developing tools and equipment for the subsequent manufacturing. The former is done through repeated design-build-test cycles, where virtual and physical prototypes are tested against requirements. The next stage of a typical development project is pilot production where everything is brought together to finalize the system and prepare for the final stage of ramp-up production.

The two fundamental challenges underpinning development projects are uncertainty and complexity (Wheelwright & Clark, 1992). Uncertainty largely relates to time as things change between when a product is conceived and its release, such as the market or customers' preferences. The complexity is multifaceted and can relate to the product having many parts or be challenging to manufacture. It can also stem from the company having a wide variety of customers with different preferences. Wheelwright and Clark (1992) also emphasize the complexity of integrating the various skills, resources and capabilities needed for the development project, such as the interactions between different functions and the dependencies between different projects. Wheelwright and Clark (1992) describe how these issues of uncertainty and complexity make managing large development projects effectively highly challenging.

3.1 Reducing lead times in development projects

There is a plethora of ways to reduce lead times in development projects and there has been several discussions on the topic before. This section of the literature review will begin with outlining the practices mentioned by a selection of important references and will be followed by synthesis summarizing the common themes in the literature.

3.1.1 Previous discussions on ways to reduce lead times

There are several authors who bring forward lists of practices. Cooper (2019), best known for developing the Stage-Gate model (Cooper, 1990), is one of those, outlining 20 success drivers in new product development (NPD), seven of which are highlighted in relation to reducing TTM: adequate front-end homework; high quality-of-execution; effective cross-functional teams, parallel processing; spiral or iterative development; prioritizing and limiting number of projects to ensure resources are not spread too thin; and, using an agile approach.

To set a foundation, it is worth expanding briefly on the meaning of these practices and more in-depth in later sections as several of these topics will be important later. Front-end homework refers to the pre-development work, such as making market and technical assessments, financial analysis and setting project scope and product specifications. Cooper (2019) also argue that it is the area where quality-of-execution is most insufficient in most firms, bridging to the second point. As for ensuring quality-of-execution throughout the project, Cooper (2019) highlights the need for competent personnel with sufficient training and enough time for the project, support from management and clear process, including the stage-gate approach that provide quality checks. Cross-functional teams and parallel processing, both relate to cross-functional coordination, which is a fundamental aspect to manage in product development. Spiral or iterative development is about working iteratively with build-test-feedback-revise cycles in which simple representations of the product are built, whether virtual or physical, to gather customer feedback. The purpose is to deal with the fact that market information is changing throughout the project and ensure fit with customer needs. Cooper (2019) mention that this iterative and experimental approach can also be used for technical purposes, wherein solutions are e.g. built with rapid prototyping. In essence, the same as Wheelwright and Clark's (1992) description of the design-build-test-cycles. Portfolio management lie outside of the scope of the study, but being overcommitted is an issue in most firms and makes important projects suffer when the firm's limited resources are tied elsewhere (Cooper, 2019). Finally, when advocating for an agile approach, Cooper (2019) refer to taking elements of Agile into the stage-gate process model, labeling it Agile-Stage-Gate. Cooper (2019) argues that the model's positive aspects are the timeboxed sprints, dedicated team that communicate well through co-location and daily scrums, and the iterative process with frequent customer feedback that was described earlier. Another important consideration of this model mentioned by Cooper (2019) is that while the aim of a sprint in software development is to have demonstratable and working product, physical products, as they are not divisible, does not have to be working but still demonstratable through some sort of representation. It is also worth mentioning that Cooper and Sommer (2016) describe that the main benefit may lie in the dedicated and co-located team, which is a discussion that will be returned to. Outside of the seven success factors especially linked to improving speed, one of the most notable according to Cooper (2019) is the organizational climate, labeling it a top three success factor when developing new products.

Crawford and Di Benedetto (2011) also give a list of recommended practices but beforehand reference five methods mentioned by Cooper (1993), which are; a clear product innovation charter that includes sharp definitions to avoid having to go back in the process; parallel processing; portfolio management to avoid spreading resources too thinly; quality at each step to avoid re-work; and, empowered cross-functional teams that follow along the project to support parallel processing and improve coordination to avoid "over-the-wall" product development. In other words, Cooper's (2019) principles have remained relatively stable over time.

The subsequent list by Crawford and Di Benedetto (2011) comprise of 29 techniques and some additional considerations for improving TTM. These are grouped under the headers of organization phase, intensifying resource commitments, designing for speed, preparing for rapid manufacturing and preparing for rapid marketing. The main topics relating to the organization phase are using small, dedicated and empowered cross-functional teams and transferring knowledge across projects. Intensifying resource commitments refers to integrating and involving suppliers, users and other types of stakeholders, as well as having concurrent engineering, i.e. parallel processing in Cooper's (2019) terminology. Designing for speed and preparing for rapid manufacturing refer, in short, to using digital tools, such as CAD, designing with consideration for the manufacturing and testing process, and re-using components. Rapid marketing is for example about using rollouts instead of test markets and having service capabilities ready. Crawford and Di Benedetto (2011) complement this list with several other considerations for reducing lead time. These include quality in early stages to avoid rework, extensive training, effective communication, flexibility in processes, structures and attitude, quick decision-making, prioritizing what to eliminate well, and finally, top management commitment that involves not only words but also significant resource investments. Crawford and Di Benedetto (2011) also highlight some potential pitfalls to avoid when aiming to reduce TTM such as making the new products too simple or too low quality resulting in disappointed customers.

Finally, Thomke and Fujimoto (2000) do not provide a list of practices but a brief categorization of the main ways to reduce lead time based on previous discussions as background to introducing the concept of front-loading, an approach argued as one of the ways to do it. The grouped topics are parallelizing tasks, cross-functional teams, work done before the development starts, re-use of platforms and components, and the degree of human resources, i.e. the number of people assigned to a development project.

Thus, at this point, cross-functional teams, parallelized processes and adequate pre-development work are aspect mentioned by all three of these references. Implicitly the iterative development is also shared due to it being a core concept in front-loading (Thomke & Fujimoto, 2000) and in designing for speed and preparing for rapid manufacturing (Crawford & Di Benedetto, 2011). Furthermore, there are several topics that overlap between two of the articles. Re-use of components is mentioned by both Thomke and Fujimoto (2000) and Crawford and Di Benedetto (2011). Meanwhile, Cooper (2019) and Crawford and Di Benedetto (2011) share quality-of-execution, customer involvement and aspects of organizational climate. Important differences are Crawford and Di Benedetto (2011) highlighting supplier involvement, knowledge transfer and digital tools, albeit Thomke and Fujimoto (2000) do focus on the latter two as the core approaches in front-loading. Additionally, Cooper (2019) has more emphasis on focus through prioritization, though dedicated teams are mentioned by the others, and agile, which as mentioned earlier may in particular relate to this aspect of dedicated teams.

3.1.2 Previous discussions on generally improving development projects

To complement the discussions pertaining specifically to reducing lead time are also those about generally improving development projects, where the speed is an important component.

As mentioned earlier, Cooper’ (2019) list were not only about speed and remaining points that were mentioned were: having a unique superior product (USP) to differentiate; integrating voice-of-customer (VoC) throughout; having global products or products with global platforms instead of unique for different markets; an adequate launch strategy and execution; having a strong innovation strategy; focusing on core competencies; top management leading the way; having a gating system for a disciplined process; and finally, an ideation process to generate breakthrough ideas. This means that Cooper (2019) also share emphasis on re-use of components, albeit with focus on global versus local, which both Thomke and Fujimoto (2000) and Crawford and Di Benedetto (2011) did, and top management support and adequate launch mentioned by the latter.

Another discussion is by Wheelwright and Clark (1992) who describe critical aspects that contrasts ineffective and effective projects. First, establishing clear objectives and a shared and agreed understanding of the aims of the projects, as well as solving conflicts at the lower levels early. Otherwise, the planning stage can become long and the project acts as a forum to achieve agreement. Second, focusing on future customers rather than current to reduce risk of moving targets and late surprises that prompts rework. Third, always keeping time-to-market and a system view of the project in mind rather than overemphasis on engineering and creating elegant solutions. Fourth, instead of relying on engineering change orders (ECOs) and finding problems during manufacturing ramp-up, test and validate solutions beforehand. Fifth, not have narrow specialists in functional silos as it can lead to what they call “engineering ping-pong”, miscommunication and inefficient use resources. Instead, Wheelwright and Clark (1992) recommend having broad expertise in important functions, promote team responsibility and having integrated problem-solving across functions. Finally, having strong leadership, accountability throughout the organization and clear direction to combat having an incoherent and not mutually agreed project concept, and buck passing, which refers to believing one’s own responsibility is that of another.

Wheelwright and Clark (1992) thus touch upon several of the previous topics mentioned. The first, and in some degree also the second, aspect relate to adequate pre-development work. Meanwhile, the fourth relate to the iterative development and also to designing for manufacturing mentioned by Crawford and Di Benedetto (2011). The fifth is directly connected to cross-functional coordination, but Wheelwright and Clark (1992) discuss it more broadly than simply the aspect of cross-functional teams. The final aspect was also mentioned before to some extent due to top management support, but also with additional nuances that on the other hand relate to the organizational climate. The critical aspect not connecting back is thus the third, keeping system view and time-to-market in mind.

Schilling and Hill (1998) on their end offer thirteen recommendations for improving the efficiency and effectiveness of the product development process that are grouped by four topics: technology strategy, organizational context, teams and tools. Technology strategy comprises of setting a strategic intent that stretches beyond the current capabilities and mapping the company's project portfolio to support in finding the right mix of projects and allocating resources between them. Regarding organizational context, Schilling and Hill (1998) highlight alliances and partners to gain access to complementary technologies and other types of resources, aligning portfolio management with the company's strategy, parallel development process to improve cross-functional collaboration and executive champions to sponsor projects. The third major topic by Schilling and Hill (1998) is labeled teams and include having teams consisting of people from various functions to improve cross-functional communication and broaden the knowledge base, involving customers and suppliers in the development process to ensure fit with customers' requirements and tap into the knowledge of suppliers, matching team structure with type of project, assigning project managers with the right attributes, and finally, developing a mission, project charter and contract book together with the team to improve commitment. The final major topic is about tools, where Schilling and Hill (1998) give examples, among others, of stage-gate process, design for manufacturing and CAD.

As can be seen, several of the topics mentioned by Schilling and Hill (1998) are in common with previous themes. Including, portfolio prioritization, supplier and customer involvement parallel processing, cross-functional teams, adequate pre-development work and finally, various tools related to both preparing for manufacturing, processes and more.

Table 3.1: Previous discussions on ways to reduce lead times in development projects

Reference	**Practices**
Cooper (2019)	Seven success factors focusing on development speed • Adequate front-end homework • Quality-of-execution • Effective cross-functional teams

	• Parallel processing • Spiral or iterative development • Prioritizing and limiting number of projects to ensure resources are not spread too thin • Using an agile approach Additional success factors for general success that are of relevance • Focusing on core competencies • Establishing an organizational culture that supports innovation activities • Top management leading the way • Gating system for a disciplined process
Crawford & Di Benedetto (2012)	29 techniques and additional considerations for development speed (selection below) • Small, dedicated and empowered cross-functional teams • Transferring knowledge across projects • Integrating and involving suppliers, users and other types of stakeholders • Concurrent engineering • Using digital tools, such as CAD, and designing with consideration for the manufacturing and testing process • Re-using components • Rollouts instead of test markets and having service capabilities ready • Quality in early stages to avoid rework • Extensive training • Effective communication • Flexibility in processes, structures and attitude • Quick decision-making • Prioritizing what to eliminate well • Top management commitment that involves not only words but also significant resource investments
Thomke & Fujimoto (2000)	Five main categories on ways to improve development speed • Parallelizing tasks • Cross-functional teams • Work done before the development starts • Re-use of platforms and components

	• The degree of human resources, i.e. the number of people assigned to a development project.
Wheelwright & Clark (1992)	Six critical aspects differentiating effective and ineffective development projects • Clear objectives and a shared and agreed understanding of the aims of the projects, as well as solving conflicts at the lower levels early • Focusing on future customers rather than current to reduce risk of moving targets and late surprises that prompts rework • Always keeping time-to-market and a system view of the project in mind rather than overemphasis on engineering and creating elegant solutions • Instead of relying on engineering change orders (ECOs) and finding problems during manufacturing ramp-up, test and validate solutions beforehand • Strong leadership, accountability throughout the organization and clear direction to combat having an incoherent and not mutually agreed project concept, and buck passing
Schilling and Hill (1998)	Thirteen recommendations for improving the efficiency and effectiveness of the product development process • Ambitious strategic intent • Mapping the project portfolio to support finding the right mix of projects and allocating resources between them • Alliances and partners to gain access to complementary technologies and other types of resources • Aligning portfolio management with the company's strategy • Parallel development process to improve cross-functional collaboration • Executive champions to sponsor projects • Cross-functional teams, for improving cross-functional communication and broaden the knowledge base • Involving customers and suppliers in the development process to ensure fit with customers' requirements and tap into the knowledge of suppliers • Matching team structure with type of project • Assigning project managers with the right attributes • Developing a mission, project charter and contract book together with the team to improve commitment. • Various tools, e.g. stage-gate process, design for manufacturing and CAD.

3.1.3 Synthesis of previous discussions on ways to reduce lead times

In summary there is a variety of recommended practices across literature with slightly different emphasis, but where some themes stand out. These can be grouped into nine topics, shown in Table 3.2. To begin with, cross-functional coordination, which refer back to cross-functional teams, parallel processing and Wheelwright and Clark's (1992) more general coverage of it. Second, adequate pre-development work that was mentioned by several but with special emphasis by Cooper (2019), Wheelwright and Clark (1992) and Thomke and Fujimoto (2000). Likewise, iterative development, using various assisting tools, was another topic mentioned by several. Prioritizing the portfolio and having dedicated teams both connect to a topic that can be labeled as focus. Different types of organizational behavior and aspects related to organizational climate were also recurring and can be grouped together as one due to the large variety. Re-use of components were also common across several and labeled as platforms and modularization due to them being important enablers of that, which will be explained further in later sections. Involving customers to ensure effectiveness, i.e. developing the right thing, and suppliers to gain access to resources also stood out by being mentioned by several. Finally, using various tools and methods, which similarly to organizational behavior and climate act as an umbrella topic, for supporting the above and additional topics that did not stand out enough across the literature.

Table 3.2: Synthesis of themes in literature for successful development projects

Topic	Description
Cross-functional coordination	Cross-functional teams, joint problem-solving and communication are highlighted. The aims include enabling parallelization of tasks, reducing re-work and avoiding miscommunications.
Pre-development	Emphasis on clarity and agreement to avoid moving targets and prolonged discussions.
Iterative development	Frequent design-test-build cycles to solve problems early and avoid late changes, as it is more expensive and time-consuming then
Focus	The organization not being overcommitted and enough resources provided for the project, which in the ideal scenario are dedicated. This

	supports several other aspects, including quality-of-execution that in turn avoids re-work.
Organizational behavior and climate (Soft factors)	In various aspects, such as effective communication, clear direction, top management support, accountability, change management and many more.
Platforms and modularization	Enable re-use of solutions across projects
Customer involvement	To ensure effectiveness, i.e. that the product matches the customers' needs.
Supplier involvement	Working with suppliers to gain access to technology and other types of resources
Various tools and methods	For supporting the above and other aspects, such as structured process with stage gate

As Armstrong (2001), while advocating for the use of integrated product development (IPD), point out there is a need for a holistic approach in relation to product development, where insights are drawn from multiple bodies of knowledge. This becomes clear when viewing the various themes listed above.

As a reminder, the following sections of the literature review consist of what have been deemed relevant to present in relation to the empirical findings and the subsequent discussion. Several of these sections are in-depth explorations of the topics listed above. To begin with is an overview of the different process models, which acts more as context than being central to the later discussion.

3.2 Process models

Several different process models exist for the organization and execution of product development. One of the most common for physical products is the stage-gate model (Cooper, 2022), with agile being highly adopted in software development (Sommer et al., 2015). Recently, attempts to merge the two approaches has been made to create a hybrid model leveraging the benefits of both (Cooper and Sommer, 2016). Additionally, the V-model originating from systems engineering, which commonly used in automotive development, is also described (Rizvi et al., 2022).

3.2.1 Stage-gate

The stage-gate model is an approach to product development utilizing so-called gates in-between the different phases of development (Cooper, 1990). This gives the development process structure and discipline while also improving the visibility and insight into the projects. Furthermore, the built-in evaluation processes also give the possibility to prioritize resources between different projects. In more detail, the gates act as points of quality control and evaluation where a project's future is decided (Cooper, 1990). The decision-making in the gates is done by a steering committee, which is usually comprised by higher-level management and similar stakeholders. The decisions are typically based on economic forecasts or technical maturity. The phases are where the development takes place and the deliverables for the gate-decisions are produced. Note, a phase is not a single development activity but is comprised of multiple ones, often conducted in parallel. Furthermore, some activities can be initiated in previous phases and stretch over multiple.

3.2.2 Agile

In software development there is an agile approach to development (Sommer et al., 2015). Comparatively, agile has a larger focus on iteration, flexible processes and are more lightweight than for example the stage-gate model. However, agile is not a model or method itself, rather a more abstract approach to development. Yet, several different methods exist that are based on agile, but one is stated by Sommer et al. (2015) and Cooper and Sommer (2016) to be suitable for industrial product development when integrated into a stage-gate model, which is Scrum. Another model is the Scaled Agile Framework, also known as SAFe. It leverages aspects of agile combined with aspects from lean product development (SAFe, n.d.). A particular part pertaining to this model is program increment planning (PI-planning), a tool for dividing work into smaller increments of 8-12 weeks and then creating plans to maximize value over said increment by setting specific objectives. The planning is an event that usually takes place over multiple days and is undertaken by all involved, engineers and managers alike.

3.2.3 Agile Stage-Gate Hybrid

As previously mentioned, the integration of agile into the stage-gate model has according to Cooper and Sommer (2016) shown great potential and promises several benefits over the normal stage-gate model, albeit with some implementation challenges (Cooper, 2019). An agile stage-gate hybrid model leverages the built-in structure and quality from the phases and gates of the stage-gate while the agile, specifically the Scrum framework, elements are present in the phases to guide and shape them (Cooper and Sommer, 2016). However, not all stages can or should necessarily utilize agile within them. Typically, development and testing can utilize agile, but supposedly earlier stages as well, yet with additional adaptation required.

As mentioned previously, an important benefit of the agile stage-gate hybrid is the dedicated and co-located teams. Cooper and Sommer (2016) describe that in software development teams are typically fully dedicated and co-located, but the opposite is often true in hardware development. This works for software development due to the more homogenous work and expertise required for the type of project but is considerably harder to execute efficiently in hardware development. One solution to this dilemma proposed by Cooper and Sommer (2016) is that only a select few projects run with dedicated teams. However, as is also stated, the lead time reductions greatly stem from fully dedicated teams and as such relaxing this requirement then could compromise any such pursued gains. Another important consideration of this model mentioned by Cooper (2019) is that while the aim of a sprint in software development is to have demonstratable and working product, physical products, as they are not divisible, does not have to be working but still demonstratable through some sort of representation.

3.2.4 V-model

The V-model is commonly used in automotive development (Rizvi et al., 2022) and originates from systems engineering. Systems engineering is an approach with various principles and methods to manage the development of systems (International Council on Systems Engineering [INCOSE], 2023). There are several versions of the V-model but the main idea is the same. The left side of the “V” represents system decomposition, moving from the overall system at the top, through sub-systems and then elements. The right side represents corresponding integration, verification and validation activities for each system level. The flow is both from left to right through the “V” but also iteratively at each system level.

3.3 Cross-functional coordination

Cross-functional coordination is a fundamental topic in product development and critical for successful development projects. Wheelwright and Clark (1992) give the example of how having narrow specialists siloed within their functions lead to what they call “engineering ping-pong”, miscommunication and inefficient use resources. Armstrong (2001) advocate for the approach of integrated product development (IPD) to overcome the sequential, “over-the-wall” behavior that is otherwise common in product development. Similarly, Lorsch and Lawrence (1965) highlights the dilemma of functions both needing specialization and integration. Specialization is important for the function to perform well and occur as the functions are inherently different, both in competence and responsibility. However, at the same time integration is needed to overcome said differences to improve communication and understanding, ultimately improving overall performance. Classic relations in need of integration are sales and R&D as well as R&D and production. The differences between functions are categorized by Lawrence and Lorsch (1965) based on how rigidly structured it they are, their time-orientation, their members’ approach for collaboration and their relation to the surrounding environment outside the organization. As an example, the sales and production departments often have focus on the short-term while R&D tend to have more long-term thinking.

3.3.1 Achieving cross-functional integration

To integrate and improve the cross-functional coordination of a firm Wheelwright and Clark (1992) propose a handful of areas to address. To begin with, an emphasis on that it needs to be in place at the day-to-day operational level through e.g. shared problem-solving. This is achieved through building close relationships across functions through communication, a sense of shared responsibility for the product and recognizing the value added by other functions. In particular, Wheelwright and Clark (1992) highlight the importance of the relationships between those whose output serve as input for another, i.e. between an upstream group and a downstream one. Wheelwright and Clark (1992) then go more in-depth on how to achieve this cross-functional integration at the operational level.

First, Wheelwright and Clark (1992) address the patterns of communication between upstream and downstream stakeholders in the development environment. Related to this, four dimensions are mentioned: richness, frequency, direction and timing. Richness refers to the quality of the media being used for communication, e.g. poor being sparse using documents with good being rich using face-to-face discussions. Frequency is then how often communication is done, e.g. low frequency with large batches of information or high frequency with information being fed piece-by-piece. Further, direction refers to if the communication is one-way with monologues or two-ways with dialogues. Finally, timing relates to the initiation of communication, either being late after completion of previous process, ending said process, or early preliminary communication that begins the process.

Wheelwright and Clark (1992) give four examples using different permutations of these dimensions. The first they call “Serial mode”, a classic scenario where upstream sends a one-shot batch of information to downstream when they are finished with which downstream then starts their work. This examples often results in less integrated results as the communication lacks nuance, background and does not convey potential strengths or opportunities between upstream or downstream. The second example is “Early start in the dark”, here the end of upstream and beginning of downstream activates happen in parallel, but without any communication before the end of upstream activates when a one-way information batch arrives. This results in downstream usually having to spend time adjusting and sorting out confusion when the batch of information arrives. These results could then cause longer lead times then if the downstream activities had started at the end of upstream. The third example is “Early involvement”, this scenario similarly to the prior involves parallel work, but with rich continuous two-way communication until the end of upstream activities. Here integration is higher. The last example is “Integrated problem-solving”, here downstream is communicated with throughout the whole upstream process in a rich and two-way manner. This will benefit both downstream and upstream and result in even higher integration. Conclusively, relating to patterns of communication, Wheelwright and Clark (1992) emphasize intense, rich and bilateral communication where downstream and upstream are intimately connected and communication established appropriately early.

Comparably, Sætre et al. (2024) describe how previous research has shown that different functions have their own “thought worlds”, stemming from factors such as different backgrounds, terminology and norms, that inhibits achieving a shared understanding. Together with lack of relationships, this affects communication negatively and in turn, the likelihood of project success. Other challenges affecting cross-functional communication are misaligned goals, routines and cultures between functions (Sætre et al., 2024). However, pertaining to overcoming the aspect of different “thought worlds”, Sætre et al. (2024) highlight that prior research has emphasized making efforts to take the perspective of others, communicating tacit knowledge to a greater extent and having a supportive climate with high psychological safety. Enablers of these include narratives, which means to communicate not only what is in the handoffs but also the story surrounding them such as how they came about, considering assumptions, and establishing personal relationships through face-to-face socialization. In their own research, Sætre et al. (2024) found four facilitators to handoffs in innovation projects. First, communicating intentionally and establishing shared goals across functions. The latter bridges the classic “not invented here”-syndrome. Second, communicating what other functions are capable of supports perspective taking and gives appreciation of the values of other functions. Third, transferring people across functions. Fourth, psychological ownership is described as a must as it makes people committed to put in the effort required to bridge this barrier stemming from different thought worlds. To achieve psychological ownership, Sætre et al. (2024) point out involvement in the project over time.

The impact of capabilities and relationships are also explored by Wheelwright and Clark (1992). Regarding upstream capabilities, the downstream friendliness must be kept in mind which product development putting attention on manufacturability is an example of. Nevertheless, the customer may not be forgotten, and e.g. manufacturability must be balanced with the demands and wishes of the customer as to not compromise the market performance. Furthermore, related to downstream friendliness is having error-free deliverables where effective design reviews, testing and overall engineering discipline is stated as central. Moreover, conflicts are inevitable with complex product and demanding customers, and to mitigate and solve said conflicts fast testing and problem-solving cycles are vital. Concerning downstream capabilities, the challenge is stated as getting a “flying start” before having complete information. One capability related to this is forecasting from upstream. This entails working with a higher degree of uncertainty while continuously monitoring upstream to forecast and predict outcome, i.e. predictions of information to come. Understanding and insight into upstream activities are then crucial for this as well as historical knowledge of previous comparable situations. This necessitates close and frequent communication between upstream and downstream. However, operating on these forecasts brings inherent risk, which calls for the capability to manage risk. This concerns the matter of weighing benefits of an early start versus potential risk exposure and then managing tradeoffs related to risks and corresponding benefits. Furthermore, as forecasts and actual outcome will unavoidably differ to some extent, then coping with these unexpected changes becomes an essential capability. Hence, downstream needs to be flexible and fast in adapting to changes as to avoid lengthy delays and idleness. This capability hinges both on the problem-solving and diagnostic ability of the organization but also the ability to mobilize resources and prioritize. Nevertheless, even with these factors in place, it is stated that engineering competence is still vital, which there is no true substitute for.

Lastly, other less comprehensive yet important factors are also discussed by Wheelwright and Clark (1992). Regarding attitude towards the integration, upstream must be willing to share preliminary information to downstream while downstream must accept the preliminary status of said information knowing that there is inherent risk involved. Moreover, they must both have mutual trust and joint responsibility. The mutual trust depends on both committing to the success of the other and allowing each side to open up and expose their weaknesses, mistakes and limit of their abilities. Joint responsibility should come from the realization that the ultimate objective is the final product, in which all play a part, i.e. joint responsibility for joint output. Concerning the role of senior management, to enable integrated problem-solving their support and focus is required. They need to establish the patterns and frameworks that enable this cross-functional problem-solving all the while investing in education, training and experience to develop the aforementioned capabilities. Promotion and compensation are also relevant topics as these structures can create obstacles for successful integration. Creating fair chances for promotion and compensation between all functions are stated as important actions to enable integration as overrepresentation of certain functions in senior management or uneven distribution of compensation between functions distances them.

Lawrence and Lorsch’s (1965) suggestions for optimizing the, as they describe it, dilemma of specialization and integration, are the use of a coordinating unit and cross-functional committees or teams. An important characteristic of the coordinating unit is that it should be unbiased to either function and balance the different perspectives. For the committees or teams, Lawrence and Lorsch (1965) underline that it should be at such low level in the organization that the members have detailed knowledge about the technical or market aspects, and decision authority to resolve the differences themselves.

3.3.2 Enabling parallelization

A parallelized process is mentioned by many as an important practice to reduce lead time and cross-functional integration is key in achieving it. Schilling and Hill (1998) outline how the sequential approach especially increases the risk of mismatch between product design and the manufacturing process as there is insufficient communication between development engineers and manufacturing engineers. A parallel process would in this case imply that process design begins when the product design is still under development through close coordination between the two functions. This is similar to the third and fourth examples from Wheelwright and Clark (1992) relating to patterns of communication. Parallelization can also help with identifying and solving problems earlier, an important practice in the idea of front-loading (Thomke & Fujimoto, 2000).

3.3.2 Communication

Communication is not only important for cross-functional integration, but critical to organizations in general, and Buchanan and Huczynski (2023) argue that it is involved in all things that are significant in an organization. However, the effectiveness of communication depends on multiple factors (Buchanan & Huczynski, 2023). For example, social intelligence is highly important at the individual level, especially in culturally diverse settings, as it is about how well we understand others and adapt our communication to that.

Another factor that has been highlighted is how the proximity to others affects frequency of communication, summarized by the Allen curve, in which distance is strongly associated with less frequent communication. For example, that people at different building floors rarely communicate with each other. Buchanan and Huczynski (2023) note that this still holds in the modern day where technology-mediated communication is more common by referencing two recent studies. The first one (Waber et al., 2014) showed that engineers working in the same location also communicated more frequently digitally with each other than with engineers in other locations and that the higher volume of communication led to faster project completion. The second study (Friedman, 2021) describe how high-performing team members communicated more frequently and were more likely to make phone calls with each other, which was thought to have improved relationships, avoided misunderstandings and improved productivity.

Buchanan and Huczynski (2023) summarize that success factors for communication in organizations, albeit dependent on country or culture, are openness, mutual understanding and trust, focus on cooperation rather than competition, people organized in teams, and that decisions are made participatively. The main barriers are power differences affecting communication upwards and downwards in an organization, gender differences that can lead to misunderstandings, how the physical surroundings like office layout look, language barriers and cultural diversity where misunderstandings can take place due to not knowing the norms of other cultures. Buchanan and Huczynski (2023) emphasize the importance of face-to-face communication and empathy to alleviate these barriers. Face-to-face communication is recommended due to the increased media richness, i.e. one also receives non-verbal cues, instant feedback, personal feeling and more. However, for routine communications less rich medias, such as email, are recommended. Regarding communication climate Buchanan and Huczynski (2023) advocate for an open and supportive one, which involves being descriptive rather than judgmental, solution-oriented, open and honest without hidden messages, caring of others, valuing everyone the same, being forgiving of mistakes and giving frequent feedback.

3.4 Teams and organizational structure

Organizing for efficient and effective development is a major challenge in large organizations (Wheelwright & Clark, 1992). The imperative is to achieve appropriate integration to allow for the important cross-functional collaboration. However, in large organizations, the functions are often strong and different from each other, which adds complexity to the puzzle of organizing well. Cross-functional teams has been promoted as an important solution, such as Cooper (2019) describing that the success in development projects is strongly linked to how the project team was structured and how it functioned. Best performing firms have according to Cooper (2019) a project team with clearly assigned members that stays from beginning to end, have a clear leader, common information-sharing system and are accountable for the end result. Wheelwright and Clark (1992) describe that successfully set-up teams provide the benefits of improving communication, commitment and identification with project, and cross-functional problem solving. However, Wheelwright and Clark (1992) also emphasize that one can still go wrong with a cross-functional team if not implemented well.

3.4.1 Different types of team structures

Wheelwright and Clark (1992) introduce the typology of four different basic types of project organization structures, all with different advantages and disadvantages, and highlight the importance of matching it to the context, such as the type of project and the environment of the organization. The four basic types of project organization structure are labeled by the type of team, and they are: functional, lightweight, heavyweight and autonomous teams.

The functional team structure involves people being grouped first by functional area and second by subfunctions within each functional area. The project needs detailed specifications at the start to enable dividing tasks between functions and then subfunctions. The responsibility of the project shifts over time in a sequential manner through handoffs. The benefits of a functional team structure are that those overseeing the performance of tasks also are the ones controlling the resources, closely related that people are evaluated by those with authority to manage their career paths, and that expertise can be concentrated and used across projects and time. The main drawback is that cross-functional coordination and integration is limited. As individuals'' performances are not evaluated in relation to the project's success, responsibility for the project's outcome becomes limited. Pertaining to the third advantage, a potential disadvantage is that the experts do not consider the specific project's characteristics enough, i.e. local optimization perhaps over system optimization.

In the lightweight team structure people are also located in their functional areas, but now the project has a project coordinating committee consisting of a lightweight project manager and liaisons representing their respective function. The project manager is lightweight because they are not able to reallocate people or other types of resources and usually are not senior or with high status in the organization. The role of liaison is often an add-on to the usual duties of the person within their function, in which case it is not far from the functional team structure. The benefits and drawbacks are similar to the functional team structure except that coordination and communication is improved as it has a dedicated person for managing the project. However, as the project manager is lightweight these benefits are limited.

The heavyweight team structure is the one that most refer to when mentioning the use of cross-functional teams. The difference to the lightweight team is mainly that the project manager is now heavyweight, meaning that they are senior managers with the main influence over those working in the project, who the project manager supervises through key functional people. It is also common with co-location for the core group of people working in the project and that these are dedicated. However, it is still the subfunction managers and function managers that have authority over career development.

Wheelwright and Clark (1992) emphasize that the typology of team structures is not discrete, but rather a continuum defined by several dimensions. This means that a project manager can lie somewhere between lightweight and heavyweight dependent on for example the degree of responsibility and influence in various areas, and the level of contact with different types of stakeholders. The advantages of heavyweight teams relate to highly improved cross-functional coordination. This includes increased ownership and commitment from team members. It also improves the likelihood of an effective system design as members use generalist skills. However, there are also several potential disadvantages. To begin with, it often entails conflict the functional organization. There is also a risk that the team turns itself into a tiger team that goes on a different direction due to the high ownership and commitment. Another aspect is that others in the organization may perceive themselves as second class or that they become too underprioritized. The heavyweight team is likely to become demanding on the supporting activities, such as tests, motivating clear guidelines to achieve a balance across projects. Regarding the team having more generalist skills and likely being better at optimizing the system, there is a risk that sub-parts are less optimized than if specialists in functional groups did it. To manage the challenges associated with heavyweight teams Wheelwright and Clark (1992) promote the use of a project charter conveying a clear mission, a contract book for developing on an agreed plan and several considerations regarding the staffing, leadership, responsibilities and an executive sponsor.

The autonomous team structure, also known as tiger team, implies a team with fully dedicated and co-located people with a heavyweight project leader who has full control of resources and evaluates the performances of team members. The autonomous team have freedom to decide on their own regarding the aspects of the project, including the process, and are at the same held fully accountable. The main advantage of this team structure is focus, which often enables faster projects and improved cross-functional integration. The potential disadvantages are that the team may expand the scope too much due to their freedom, create unique solutions with limited re-use from other projects and that the project is difficult to steer back if it the team goes on the wrong trajectory.

3.4.2 Choosing team structure

Wheelwright and Clark (1992) explain that organizations tend to rely on one type of team structure across most, if not all, development projects. Large organizations tend to be focused on functional team structures, which Wheelwright and Clark (1992) argue can work well in mature and stable industries. However, if change in technology, competition and customer requirements is fast the functional structure is often not enough. In these situations, large organization tend to move to a lightweight or potentially a heavyweight team structure.

Underpinning the decision of dominant team structure is also the questions of what people and competence exist in the organizations and in which quantity, as well as the mix and types of projects. Wheelwright and Clark's (1992) typology for projects include: research or advanced development projects, where the aim is to invent new science and knowledge that can be used in more specific projects later; breakthrough or radical projects, in which the organization uses new core concepts and technologies to create an entirely new product; platform or next-generation projects, where the fundamental architecture with several years of design life is set for subsequent derivative projects; and finally, these derivative projects that have limited scope and resources to change a select few performance dimensions dependent on customer needs. Schilling and Hill (1998) follow the typology of Wheelwright and Clark (1998) and develop the idea of matching team structure with the type of project more in-depth. Schilling and Hill (1998) strongly advice against the use of functional teams regardless due to the weak coordination and communication. Lightweight teams may work for derivative projects if the required coordination is limited. Heavyweight teams are favored by Schilling and Hill (1998) for platform projects and seen as much better for coordination than the previous two. As for autonomous teams, Schilling and Hill (1998) assign them to breakthrough or some major platform project, but with caveats similar to those of Wheelwright and Clark (1992).

3.4.3 Multi-team membership

The vast majority of employees in global companies are working in multiple teams simultaneously in today's world, a stark contrast to before, and it is associated with both advantages and disadvantages (Buchanan & Huczynski, 2023). On the one hand, the often limited number of specialists can be utilized across multiple projects, learnings across teams can be fostered and incentivize employees if provides opportunities for learning and growth. On the other hand, if specialists are spread too thinly it can cause bottlenecks for the projects and hurt their own wellbeing, and for the team, frequently changing the composition can affect team cohesion negatively.

3.5 Pre-development

The pre-development work is highly important for the success of a project and Cooper (2019) mention that many firms underestimate it while successful firms spend nearly double the amount of time and money on it. The activities involved in this are preliminary market assessment, preliminary technical assessment, detailed market research, detailed technical assessment and business and financial analysis. Cooper (2019) describe that not only the number of resources going into these activities are important but also the balance between the technical and business activities, in which unsuccessful firms are more likely to rush through the more business-oriented tasks. Two of the main benefits with adequate pre-development work according to Cooper (2019) is achieving a superior project definition and lowering the risk of late design changes. The latter occurs through being better prepared at anticipating the risk of changes and trying to deal with them earlier when they are cheaper to deal with. The former is particularly emphasized by Cooper (2019) in relation to lead time, naming scope creep and unstable product specs as the main issues, both of which are likened to moving goalposts. One of the solutions is establishing a more clear and factual product definition early as it puts emphasis on doing the pre-development work right, acts as communication tool for everyone involved and gives clear objectives in the development stage.

Another perspective on setting the stage for project success early relate to the concept of front-loading (Thomke & Fujimoto, 2000). It is about identifying and solving problems earlier in the product development process, with the potential of reducing cost and development lead time as companies do not need make the changes later in the process when it is more expensive and time-consuming. Front-loading can be achieved by several means, but Thomke and Fujimoto (2000) highlight transferring knowledge between projects to reduce the number of problems to solve for subsequent projects and utilizing rapid problem-solving with advanced technology to identify and solve problems more efficiently as the two main practices. The latter will be returned to in the section on testing and prototyping.

Regarding knowledge transfer, Thomke and Fujimoto (2000) underscore that it is common among firms to have repeated problems across projects and that many struggle with transferring learnings, if not at all. One practice that could help with the transfer of knowledge us using what Thomke and Fujimoto (2000) describe as a post-mortem, which is a detailed documentation of a project including, but not exclusively, the various product and process problems that it encountered and their solutions. In addition, it is recommended to take time in reviewing and discussing these post-mortems before or in the early phase of new projects. However, the effectiveness of these post-mortems also depends on nature of knowledge, i.e. how well it can be encoded. For tacit knowledge, Thomke and Fujimoto (2000) mention the use of face-to-face communication and similar as more effective.

3.6 Testing and prototyping

The detailed engineering phase of a development project is characterized by the design-build-test cycles (Wheelwright & Clark, 1992) and is an area that many point towards opportunities to reduce lead time both in literature and practice, such as virtual testing over physical prototypes being one of the most promising practices brought forward by consulting firms in relation to the speed of Chinese OEMs (Borden et al., 2025).

While this iterative part in development projects is described by Wheelwright and Clark (1992) as design-build-test cycles, Thomke and Fujimoto (2000) view them as problem-solving cycles and Cooper (2019) as build-test-feedback-revise cycles. However, they are in essence the same. Problem solving is defined by Thomke and Fujimoto (2000) as iteratively conducting experiments using different types of test models, where the timing and fidelity, i.e. the level of completeness, are important choices. Thomke and Fujimoto (2000) also introduce that the problem can be of two types: related to fit or function. Fit is about parts geometrically not fitting with each other, i.e. interference, while function is about product performance. Meanwhile, Wheelwright and Clark (1992) describe the process as designing, building and ultimately testing prototypes. Camburn et al. (2017) define a prototype as a representation of a part, a concept or a final design. As such, what Thomke and Fujimoto (2000) describe as test model is just another word for prototype. The purpose of prototypes varies greatly. Camburn et al. (2017) mention that prototypes can be used for exploration of concepts, refinement of concept, or for communication in order to share information and increase understanding of a design or similar. It is not only about technical aspects either, as Cooper (2019) highlighted when promoting iterative or spiral development, very similar to design-build-test cycles, for eliciting customer feedback.

There are also several suggestions on how to go about prototyping and testing. To begin with, Wheelwright and Clark (1992) describe how the representation level of prototypes should vary over the project. Initially, system level prototypes of the concepts can be made but as the work becomes more engineering focused prototypes of sub-systems followed by components are done. As progress comes closer to the pilot production the prototypes should shift from sub-system back to complete system prototypes. Essentially, Wheelwright and Clark (1992) suggest starting with rough system prototypes during the concept phase and then making sure that everything works on a detailed component and sub-system level before testing the whole system again. This is very similar to the V-model of systems engineering.

Wheelwright and Clark (1992) then go onto emphasize four focus areas: low-cost prototypes using e.g. mock-ups or virtual simulation tools; quality in the process of building prototypes, meaning reducing mistakes while working fast and responsive; non-overlapping prototype cycles and thorough closure of cycles; continually capturing knowledge about the process of design-build-test and prototyping for the purpose of improving said process. Moreover, Camburn et al. (2017) states that there is an inverse correlation between the success of a prototype and the number of parts in said prototype, hence, they recommended to utilize minimum viable prototypes. Thomke and Fujimoto (2000) mention that for fit problems, computer-aided-design (CAD) and related software to test for interference is very effective. Meanwhile, for function problems computer-aided-engineering (CAE), such as different types of virtual simulations, can significantly support in identifying and solving problems faster and cheaper.

3.7 Platforms and modularization

To use platforms and re-use components was another topic that several highlighted as a means to reduce lead time. Relatedly, modularization is a separate concept more related with product architecture yet is typically associated with platforms due to their generally synergistic nature, such as using modules in platforms to easily and rapidly create variety (Magnusson & Pasche, 2014).

3.7.1 Platforms

Product platforms, henceforth referred to as simply platforms, are in essence a collection of shared assets (Robertson & Ulrich, 1998). The assets in question are components, production processes and more intangible assets in knowledge followed by people and relationships. By leveraging the shared assets, the manufacturing firm can achieve greater economies of scale and scope (Magnusson & Pasche, 2014), generally resulting in less cost, less product portfolio complexity and shorter lead times when developing new product variants based on a platform. However, the initial development of a platform is generally more expensive and time consuming than if an equivalent non-platform product is to be developed given the larger scope and additional complexity added by the variability necessary for it to be used for multiple products. Hence, to secure the benefits of a platform it has to be used for multiple products, and the more it is used the more cost effective it becomes.

For the best economies of scale and scope, then the extent of shared assets, i.e. commonality, should be maximized, however this dilutes the created products' uniqueness and adaptability to the needs of the customer which makes it less distinctive on the market. This trade-off between commonality and distinctiveness is crucial to consider when planning and creating a platform (Robertson and Ulrich, 1998). As implied, the commonality impacts cost and distinctiveness impact perceived value by the customer. Hence, to create a successful platform Robertson and Ulrich (1998) mention that the firm needs to identify components strongly linked with desirable distinguishable attributes as these are what makes the product feel unique and suitable to the customer. Similarly, yet contrary, the firm also needs to identify components which should be shared to reduce cost, complexity, etc. However, components can both be a large cost-driver, etc. and carry inherent distinguishable attributes.

3.7.2 Modularization

The product architecture of a given physical product can be described by its degree of modular architecture or integral architecture (Ulrich, 1995). A modular architecture can be described as having close similarity between the functional boundaries and physical boundaries of a component, i.e. different components are decoupled in their function and changes so one should theoretically not impact neighboring ones. Opposite of this is integral architecture, here the functional boundaries typically stretch over physical boundaries of multiple components.

An implementation of a modular architecture predictably results in the use of modules. A module is a functionally and spatially independent component with defined interfaces outlining the interactions and connections both functionally and physically (Persson & Åhlström, 2013). Moreover, due to the defined interfaces the development of modules can be done in parallel and with theoretically less managerial oversight and cross-component coordination than with normal components. However, as Persson and Åhlström (2013) describe the nature of the product plays an important role in determining the degree of necessary managerial involvement and cross-module coordination. Furthermore, Persson and Åhlström (2013) emphasize the difficulty of defining functional interfaces due to their more intangible nature in contrast to physical interfaces. As modules can easily be re-used due to their defined interfaces and contained functionality, they can both save time but also reduce complexity by e.g. reducing the necessary amount of part numbers (Magnusson and Pasche, 2014). Further, as previously mentioned, the parallel workflow enabled by modules also results in potential reduced lead time due to parallel development of modules (Persson and Åhlström, 2013).

Regarding the use of modularization in platforms, Magnusson and Pasche (2014) remarks the similarity between the two in their shared focus of enabling product customization while still increasing standardization and keeping the cost relatively low, thereby circumventing an often otherwise assumed tradeoff between customization and cost. Moreover, the use of modules facilitates customizability by allowing for substituting to other modules more suitable for a given customer or market need while not impacting other functions of the product. Hence, a customized assembly of modules can be constructed on the platform utilizing the standardization of modules to reduce cost and complexity. Magnusson and Pasche (2014) also mentions different scenarios where the combinations of platforms and modularization are more or less suitable. In the scenario where the market demands high customizability and the rate of change is high, e.g. technological development, market trends, etc., then the modular architecture is suitable. In another scenario where the market demands low cost and the rate of change is low, then platforms are suitable. Finally, in the scenario where the market demands high customization, but is less price sensitive, then modularization and/or platforms may be less suitable.

3.7.3 Successful implementation of platforms and modularization

To successfully implement and create platforms and modularization into one's development organization there are several factors to consider and obstacles to acknowledge. First, Magnusson and Parche (2014) highlight the importance of acknowledging the two approaches as separate and to put more attention on understanding the differences. Furthermore, they emphasize to not neglect the demand and business-related sides of the approaches, i.e. not only focusing on the potential cost reduction. If the customer is not considered, then the pursuit of standardization in the platform may for example result in over-standardization and subsequent loss of sales due to an inadequate product offering. In short, they highlight the importance of also including a demand and business perspective when considering platform and modularization approaches in conjunction with e.g. the development and production related perspectives. Additionally, Magnusson and Parche (2014) mentions the conflicting decision-making and coordination requirements between modularization and platforms. Modularization has a more decentralized approach where each module can operate and manage itself given defined interfaces while platform management require a more top-down approach to guarantee stable platforms. Ultimately, they argue that these conflicting approaches require careful consideration when allocating decision-making authority and autonomy. Secondly, Persson and Åhlström (2013) covers the intricacies of modularization and organizational coordination. They underline the importance and difficulty in defining the functional interfaces in comparison to the physical ones. Consequently, the functional dependencies between modules are those that cause coordination issues and it is stated that modules still require coordination, although comparatively less, between them.

3.8 Synthesis of the literature review

As mentioned earlier, these areas in literature have been selected due to their relevance in the subsequent discussion, i.e. they pertain to the main issues found at the case company. However, a moment can be taken to summarizing the literature and drawing connections between them.

To begin with, ten topics where singled out in the synthesis of previous literature. Out of these, cross-functional coordination was one of the core topics. While Wheelwright and Clark (1992) focused to a large degree on the downstream and upstream relationships and patterns of communication, Sætra et al. (2023) complemented with how to bridge the inherent differences between functions, such as their different “thought worlds”. Additionally, the importance of ownership for making the effort to bridge these differences. As Lawrence and Lorsch (1965) pointed out, these differences are also important and both specialization and integration need to co-exist.

Closely related to cross-functional integration is the second major topic how to organize for development projects, where both Wheelwright and Clark (1992) and Schilling and Hill (1998) described how the heavyweight team structure is preferable for cross-functional integration. However, also that all of the team structures come with different advantages and disadvantages, and that large organizations have a tendency for the functional or lightweight team structure due to the established nature of the different functions. One specific connection is that Sætra et al. (2024) mentioned involvement over time in the project as the main driver of ownership, which the setup in terms of teams and organizational structure is an important factor in. The importance of dedicated resources, i.e. focus on the list of topics, is also a central consideration of organizing where Cooper and Sommer (2016) discussed if it was perhaps the main benefit of the agile approach.

Pre-development was also in the list of topics and according to Cooper (2019) an often-overlooked aspect in relation to lead time, but where clear and agreed specifications, which Wheelwright and Clark (1992) also emphasized, is essential. Additionally, Cooper (2019) pointed towards the importance of anticipating late changes, which is more costly and time consuming, and it was also the core aspect that Thomke and Fujimoto (2000) focused on mitigating through identifying and solving problems early. The two main approaches for doing this were transferring knowledge between projects and using advanced technology, such as virtual testing. The latter bridges to the fourth major section of testing and prototyping. Iterative development with design-test-build (Wheelwright and Clark, 1992) or problem-solving (Thomke and Fujimoto, 2000) cycles are a key component to development projects, where cheap and fast iterations is the main takeaway. Additionally, the importance of testing on multiple system decomposition levels, which both Wheelwright and Clark (19929 mentioned and is central to the V-model, commonly used in the automotive industry.

Platforms and modularization, or re-use of components, were also highlighted in the literature on ways to reduce lead time, where platforms aid with economies of scale and scope (Magnusson & Pasche, 2014), and modularization with reducing complexity and enabling parallel workflows (Persson & Åhlström, 2013). Modularization thus connects to one of the fundamental challenges in product development of complexity (Wheelwright & Clark, 1992) and parallelization of tasks, which connects back to cross-functional integration as another important enabler to it.

As can be viewed, the topics related to reduced lead times have a high degree of interconnectedness and as Knudsen et al. (2023) mentioned, the best firms need to be strong in multiple areas and adopt several practices. Hence, a holistic approach is important.

4. Empirical findings

The following chapter covers the empirical findings. It begins with a description of the case company’s context and its structure and processes related to the management development projects. Following this is a presentation of the findings from the interviews related to issues affecting lead times of the development projects. Note that considerations to anonymity and confidentiality have influenced the descriptions.

4.1 General description of the case company

The case company is a large established European automotive OEM currently experiencing pressure from several factors, including the overall accelerated technological development pace, resulting in ambitions to reduce lead time while also simultaneously lowering prices and improving quality. The case company serves customers globally and as part of the automotive industry, there are various regulations to consider. Characteristic of the case company is a broad product portfolio with many variants, as several market segments and niches are served. Relatedly, the case company utilizes product platforms as bases for product development as a means to handle the complexity.

Another defining aspect of the case company is its place within a larger organization that involves sharing of technical solutions and certain resources across the larger organization. For the case company, a significant number of solutions are sourced from affiliated organizations within the larger organization, making projects generally more so a matter of adapting, refitting and integrating existing solutions to its unique product. Furthermore, one particular unit, serving as a shared resource, is highly important in several of the projects at the company. However, due to it residing within a larger sister company, the case company’s influence is somewhat weaker than it if would have been one of their own resources, essentially making it an internal supplier to the case company. Consequently, this unit will henceforth be referred to as the internal supplier. The case company also extensively collaborate with various external partners and suppliers, which are more or less integrated in the development process.

4.1.1 Organizational structure and responsibilities

At the highest abstraction level, the case company's organization consists of several divisions, such as technology, manufacturing, purchasing and sales that have different internal structures. Located within the divisions are different functional departments, with various types of units below each. Illustrated in Figure X, where the main units of interest are included.

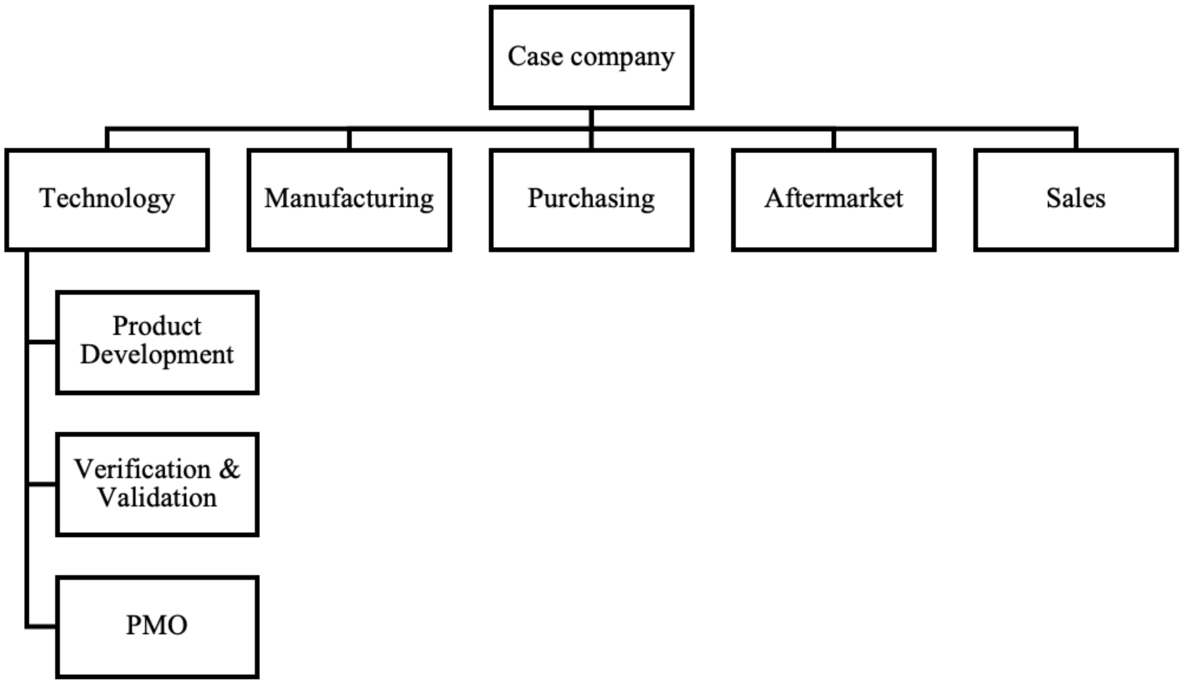


Figure 4.1: Representation of organizational chart with the units of interest included

The unit that this study aims to mainly assist is the project management office (PMO) located under the technology division at the case company. The PMO oversees the processes, governance structures and other practices for managing development projects while also housing the lead project managers and project coordinators. Lead project managers are tasked with managing the case company's largest development projects. In these projects they act as a leader of the project management group, which consists of other project managers representing the different functions involved. These functions include product development, manufacturing, purchasing, finance and aftermarket. Furthermore, the lead project manager is also responsible for representing the project before the steering committee that oversees all projects at the technology division and makes higher-level decisions. The projects led by lead project managers are typically platform projects or related derivative projects. The project coordinators assist project managers with various tasks, such as project planning and quality assurance.

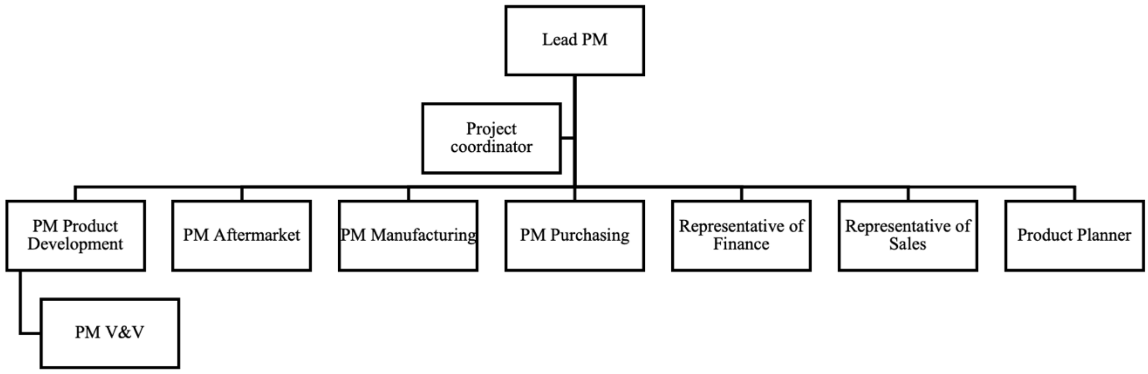


Figure 4.2: Representation of the project management group's composition.

The product development department, also residing under the technology division, concerns itself with the development and design of parts for the concepts, prototypes and final builds with the other functions serving as inputs for requirements, constraints and similar. The foundation of the product development organization are the engineers. They are structured in different groups divided by their area of expertise, such as electrical software, electrical hardware, structural hardware, etc. Engineering tasks, whether they originate from a project or not, are then assigned to a group rather than one specific engineer. Within the groups, engineers are often relatively specialized in terms of how tasks are divided even though they share the same area of expertise. In the major projects, the project manager representing product development manages and oversees the progress and completion of tasks. The product development project managers reside together in an own unit separate from the product development department, very closely related to the PMO. Aside from being part of the major projects at the company, this type of project manager also manages their own, smaller, projects. Underneath the product development project manager, in the major projects, is also a project manager representing the unit for testing to conduct verification and validation of the products. This unit is separate within the organizational structure from the product development department, but houses much of the testing infrastructure. However, note that this does not include all infrastructure, as a significant portion is also located among the different sub-functional groups at the product development department.

In the major projects the manufacturing department is involved by building the full prototypes, conducting manufacturing preparation and ensuring manufacturability of the product. The full prototypes act both as an opportunity for the product development department to test their solution but also an opportunity to reveal incompatibilities between the manufacturability and the designs. These are documented and sent to product development engineers for revision through engineering change orders (ECOs). In the project organization, the manufacturing project managers manage and oversee the tasks for building the full prototypes and preparing for manufacturing. This includes planning, resourcing and interactions with assembly workers and engineers tasked with preparation work.

In short, the aftermarket function is tasked with ensuring that the product is serviceable after it has been manufactured and purchased by the customer, but it also covers certain digital services. The responsibility includes developing spare parts, maintenance instructions, ensuring the necessary accessibility of parts during repair or maintenance, etc. Similarly to project work in the manufacturing department, the aftermarket project manager manages the project related interactions while the work is carried out by engineers from the aftermarket sub-functional groups. Recently, the responsibility of aftermarket has expanded from previously being solely focused on serviceability and maintenance related matters to include digital services and similar offerings.

Purchasing is concerned with the procurement of physical material for production and as such is included in the development projects as to ensure that suppliers and material are in place when production starts. Similarly, they are tasked with the procurement of material for prototypes as it gives them the opportunity to start their work of finding suitable suppliers. In short, this work consists of finding a set of potential suppliers for each part or material needed and then ultimately recommending one to be used. Furthermore, as they only procure physical material, they are not directly involved in the software development parts of the projects, yet in certain cases they provide specifications for the software. In the project they are represented by a purchasing project manager and the procurement is done by one of two teams of purchasers where each team both cover all categories of material.

Product planning has a broad responsibility ranging from high-level strategic planning, project prerequisites and follow-up of projects. The unit houses the product planners and portfolio managers. These work closely with product architects and representatives from the sales department. Regarding the strategic planning, it includes the amount and scope of projects undertaken at the company. Together with the product architects they have a focus on ensuring a wide range of product variants from the product platforms. As the product development at the company, as mentioned earlier, is to a significant degree a question of refitting and integrating already mostly developed technology, they also interact with other units in the firm who are suppliers of this technology. At the same time, the product planners also consider the demands from sales and the situation of competitors for together with others deciding on architecture and concepts. The representatives from the sales department are highly engaged in the development of pre-prerequisites. Concerning later project follow-up, the product planners monitor the progress and issues that arises in projects both in steering committees but also in the project management meetings and similar.

Finally, the sales department consist of several geographically divided offices all over the world. Other than selling the product they also probe the markets and competition to find demand. All demand is passed along to the head sales office where said aggregated demand is used as input for development projects. Representatives from the sales department are then present when major development projects are created together with the product planners and product architects. These representatives from sales are also present in the major projects as a representation of the customers and their demand for the purpose of feedback and monitoring rather than as in an active development role.

4.1.2 Processes

The case company has an established and well-documented process for project and product development management. The process model is fundamentally based on a stage-gate process, with set phases and checkpoints with corresponding activities for the different functions to execute, i.e. it sets flow of the development. Furthermore, the stage-gate process acts as governance as the gates aims to ensure that the project holds the desired quality as a set of criteria needs to be fulfilled and presented for the steering committee. According to documentation, the project should only be let through the gate if all deliverables are considered satisfactory. In practice, there can be a discrepancy between the formal written criteria and what is deemed satisfactory. Projects can also be let through conditionally, meaning that there is some sort of gap and that the lead project manager must return to present for the steering committee about the closing of such gap.

The process model also includes a version of the V-model as guidance for defining requirements, designing, integrating, verifying and validating products at all system hierarchies, i.e. total system, sub-system and components or units. While not only used for software development the V-model does act as important direction for it.

Closely related is the process for testing and prototyping, which promotes the use of more virtual tools such as digital mock-ups, simulation but also lower-cost solutions than full protypes such as rigs or mules, which are old prototypes or products that have been rebuilt. The emphasis is on frequent iteration for learning, but also for verification and validation. The process model also includes building two or three full prototypes during the project. These full prototypes refer to a complete assembly with all components and are related to the culmination of different maturity phases. The plan, which has already been implemented in some projects, is to only do two full prototypes, removing the early third-to-last prototype where maturity is comparably low. To successfully do this, the case company recognize that more of what their process model prescribes for testing and prototyping needs to be implemented in practice, for which there are ongoing efforts, as a way to substitute the verification and validation done through building the third-to-last full prototype. The process describes that the second-to-last should be stable, i.e. with few or preferably none ECOs afterwards, which is important for other processes dependent on it, e.g. the manufacturing department's processes. The last full prototype is meant to be fully mature and it is constructed before ramp-up of production with the aim of finalizing the preparations for production.

For planning, prioritizing and allocating tasks. the case company has adapted some elements from the Scaled Agile Framework (SAFe), mainly Program Increment planning (PI-planning) with related terminology such as epics and features. The sales, purchasing and manufacturing departments, and their project managers, are noteworthy not included in this system for planning. For the departments and units that are included, the process is that all tasks that need to be completed are added to the system. These tasks are then prioritized, based on a prioritization of projects, and those functions or sub-functions needed for a task commit to completing within the Program Increment. A Program Increment is around 10 weeks and preceded with a week of planning. The tasks that do not reach full commitment stay in the backlog for later Program Increments. This planning is thus how the work of the sub-functional groups of engineers in the product development department are assigned, planned and prioritized. The main aim of using PI-planning is to improve prioritization of what to do at the portfolio level. Note that the case company seemingly does not utilize other elements of SAFe nor from other types of agile frameworks, except from guiding principles for what mindset to have, such as focus on iterations.

On a more general note, the process model also accounts for cross-functional alignment and collaboration, which aims to permeate all stages, gates and processes. It also includes lean product development ideas by utilizing a knowledge and product value stream. The former represents the company's aggregated knowledge from which the latter emerges as a product development project, which in turn provides more knowledge to the value stream at the same time as it delivers the product. In practice, this manifests as writing down lessons learned during and at the end of projects. The process model also includes descriptions on risk management, sustainability and various other aspects, which are of less importance in relation to the findings and scope of the study but point towards the comprehensiveness of the documented process model.

Following the process model in the aspect of the flow of development is supposedly not a necessity but is intended to serve as a baseline process from which the project management group can, to some extent, deviate from and adapt to their projects as they see fit. However, others may also give input beforehand or be consulted, such as the project steering committee. To summarize, the company already leverages certain literature-based processes with a certain degree of flexibility, yet the concern of long lead times persists.

4.2 Issues related to lead time

During the interviews several lead time related issues arose with a select few persisting across functional boundaries and hierarchical levels. A selection of issues deemed most impactful on lead time will be presented followed by a brief overview of other less impactful but nonetheless noteworthy issues.

4.2.1 Coordination

The most prominent issue was related to coordination where the interviewees used different terms, most frequently as "dependencies" but also for example related to communication.

The interviewees expressed that the coordination within the project management group, consisting mainly of the lead project manager and the functional representatives, for each project worked relatively well. The lead project manager and functional representatives communicated frequently and, in many cases, had a relatively shared understanding of the project's content. However, some functional representatives were more involved than others during the project, which influenced the degree of coordination.

However, several mentioned an issue of poor understanding and insight into other functions, especially on an operative level, including between those in direct sequential order from each other. The consequences of the latter involved deliverables not being completely aligned with the implicit and explicit requirements of the next step. This was especially illustrated during the construction of full prototypes where it was common with, in the interviewees' terms, a large number of engineering change requests (ECRs) and subsequently ECOs, in turn leading to time-consuming administration and rework for the already limited resources. Especially the second-to-last full prototype that is meant to be mature and stable, i.e. not result in ECOs, according to the process resulted in friction in processes as it still required many ECOs. For example, manufacturing had begun to expect this and adapted by delaying some processes, such as writing instructions, to avoid the rework. However, this was not without tensions as the ambition was to follow the processes as written. Furthermore, it was expressed that the understanding and insight into manufacturing and what is manufacturable also was an important factor affecting the number of ECOs, where some wished for increased presence by other functions at the factory. Moreover, late changes to parts that was assumed among other functions to be completed also lead to rework, which in some cases involved inadequate communication from all sides.

The aspect of understanding other functions and the larger picture was also brought up in general. Several, across functions, expressed that the understanding of how deliverables fit into the project as a whole and in the sequential chain was lacking to some degree, resulting in mismatches and rework. Related to the aspect of understanding was that some interviewees expressed that "standard lead times", which some functions communicated with in relation to executing tasks, resulted in limited insight to the work. For example, there was a standard lead time for the sourcing of parts, where those outside purchasing experienced uncertainty surrounding what the actual lead time would be or subsequently was. When functions communicated with standard lead times it was also met with a perceived inflexibility, e.g. to quicken processes. In many cases this tension surrounding standard lead times appeared to stem from the lack of insight and understanding into the processes and policies of other functions. However, related to flexibility, functions appear to have different degrees of acceptable deviations from the established processes leading to frustrations when they are to collaborate if the gap is large. Furthermore, the functions do not have the same emphasis in their strategies with regards to reducing lead times in development projects, affecting for example this flexibility in processes. The use of standard lead times also appears to be related to resource constraints, which for example affect the ability to estimate lead time of tasks.

As shown with the process for ECOs, another related issue was the approach to deliveries and communication. Broadly, work was in most cases done with limited input from other functions until the hand-off, at which point the feedback given often resulted in the need for rework. It also led to administrative work for writing and reviewing the ECOs at both ends. This approach to deliveries and communication also related to the limited insight and understanding mentioned earlier. Furthermore, work was described as rather sequential by interviewees, which was linked to dependencies in their words.

There were several suggestions brought forward by the interviewees for improving the coordination. It mainly involved increasing the presence of other functions, such as product development, at the factory and have joint problem-solving sessions. An example of the latter was to explore the potential of building early mock-ups together to reach a common understanding of geometrical constraints, ergonomics and similar. Also to be present during the construction of full prototypes to be available to swiftly deal with issues that normally would result in ECOs, for which the process is time-consuming and communication is limited. Interviewees also expressed that this would likely improve the understanding of manufacturing and benefit future projects. However, suggestions for traditional education and training were also mentioned in relation to this understanding and not only for manufacturing, but in general for and across all functions. Co-location and increasing face-to-face communication were also brought forward by several interviewees. There were also suggestions that relate to another of the major issues, namely teams and organization structure, which will be returned to.

Another aspect, but relatively minor, related to coordination was that maintaining the date for start of production (SOP), as written in the time plan, was something that management at the technology division viewed as highly important. This resulted in that when the project had been delayed, the functional departments that were more involved in the later stages expressed that pressure was high, the time limited and that they had to scramble to try to meet SOP.

Another minor topic related to coordination involved the use of different planning tools, such as PI-planning, in the different functions. For example, PI-planning is not used by sales, purchasing or manufacturing. In some cases, this affected the efficiency of coordination within the projects. Related to PI-planning, it was described as having both benefits and drawbacks among the interviewees. To mention briefly, on the positive side, several mentioned an improved overview and structure for prioritizing work. Among the drawbacks, several described that it resulted in a sort of lock-in for the Program Increment period, where if for example an unplanned issue or similar would arise it would be dealt with first within an upcoming period.

4.2.2 Teams and organizational structure

The organizational structure, mainly of the product development department, and how people are allocated to projects is another topic that stands out as a major issue, and as mentioned with connection to the topic of coordination.

Several described that a large number of engineers are involved in projects, even several from each sub-functional group who then have high task specialization. Interviewees expressed that the problems of this were unclear and limited ownership among those involved in the project at the operating level, lack of clear speaking points and technical challenges related to limited system perspective. Several project managers described how they can get bounced between engineers, for example when several engineers have been involved in developing a component but no one with responsibility for the component. Another telling example given by several was that the size of technical meetings for the projects was of very large, which had consequences on communication and ownership.

Several interviews connected these issues to coordination, including the limited understanding of how deliverables fit in the larger project, insufficient communication and the high number of ECOs. One illustration of this was the high ratio between receivers of ECOs, engineers at the product development department, and senders, at the manufacturing department, in part resulting in a bottleneck.

There was a consensus among all interviewees who touched the topic of organizational structure to strive for having fewer and more focused people involved in projects. However, many of the interviewees also recognized potential barriers in overall limited resources, a limited number of key experts and engineers who had become relatively specialized in tasks. Many pointed towards that certain projects could have a smaller and nearly dedicated team, but that the major challenge is how to go about it across the project portfolio and that there is a risk of selecting the most experienced and competent people for the more prioritized projects, which would then result in other projects suffering. On the other hand, some interviewees mentioned that the current structure aimed to support the sub-functional groups in developing competence together and increase the commonality in the products when the members of the sub-functional groups are not split up between their own different projects. Several interviewees also brought up a desire for staff with more T-shaped competences to enable the vision of fewer and more focused people in projects. One suggestion, regardless of the number of people involved, was that there should be assigned owners of components or certain sub-areas, even if multiple engineers are involved. It was inspired by how a previous organizational unit at an internal supplier had representatives per sub-functional group, which simplified communication and clarified ownership.

4.2.3 Internal supplier

As previously mentioned, collaboration with others in the firm is very important for the case company and especially with one unit, which can be labeled the internal supplier. In this, the case company gives requirements, develops the solution for integrating and to some degree adapts the solution that the internal supplier provides, and maintains a collaboration with the respective project at the internal supplier. It was also one of the major issues that interviewees mentioned in relation to lead time, often using the term “dependencies”.

The primary problems affecting lead times in relation to this were waiting for delays by the internal suppliers, late changes leading to rework, and unclear responsibilities in some tasks. The latter related to that both parties are involved in the development, and the consequences are waiting time while discussing who should take on the task or late surprises. The reasons that interviewees gave for these issues related to the internal supplier can be summarized into a perceived limited prioritization of the case company at the internal supplier and relatively limited insight and understanding of the case company’s business, products and processes. The former is described to stem from the internal supplier serving multiple companies in the group and with relatively limited resources in relation to this. The latter is explained to affect the former, by not having enough time for it, but also being influenced by the differences between the companies in the firm with regard to the aspects above. This leads to some assumptions regarding requirements, process and similar being wrong. As one interviewee described this was not only one way, but also that those at the case company similarly lacked a deep insight and understanding of the internal supplier. For example, the two companies share a general process model but still have slight differences, such as requirements for gates and deliverables, which affect the effectiveness of coordination. Some interviewees also brought up that perhaps the case company is asking too much out of the internal supplier in terms of requirements and adapting the solution to the case company in relation to the limited resources that the internal supplier needs to prioritize, which increases the lead time.

Lastly, the communication with certain external suppliers or partners, in a large degree, goes through the internal supplier, which was presented as a challenge by interviewees. The issue of the internal supplier acting as a middleman allegedly stems from the earlier mentioned differences, which results in different perceptions of e.g. specifications and constraints, and that communication is affected negatively. One interviewee mentioned that the issue of this is more common with new external suppliers.

4.2.4 Scope and pre-development

Another topic that was brought up by several interviewees as a major issue related to lead time is the scope of projects and similar aspects before the development begins. At an overview, the interviewees expressed that the scope tends to be broad, not clear enough and changing. Several believed that the main driving force behind this was the high tendency of adapting to customers' preferences, which in turn leads to a large variety in the offering and, as several put it, that the sales division wants to have as many options available as possible. Additionally, requests for products with slightly different specifications can occur during projects, which lead to uncertainty and late changes.

A telling example of the variety given by some interviewees was that a large number of parts are released during a project but the majority of them are not being used in the final product due to not belonging to variants that are ultimately sold. As with this example, the broad and not clear enough scope led to spending resources on things that are unnecessary and having time-consuming discussions during the project. Regarding clarity, one interviewee gave the example of a recent project where the specifications for a component that had been changed since the last project was set as "Friday to Monday-functionality", meaning that it was to have the same features as the old component. However, the project manager mentioned that it was not clear what was meant by neither "Friday" nor "Monday", leading to uncertainty during the project. Additionally, the specifications of old products and components are updated throughout their lifecycle, resulting in some confusion about which "Friday" is referred, i.e. the specifications during the launch, at the start of the new project or some other point of time.

A smaller, more focused scope, with clear expectations and direction is wanted by several interviewees. Some mentioned that this is highly important to reach the shorter lead times that the top management is pushing for. One interviewee suggested that the company perhaps should take an approach similar to a minimum-viable product (MVP), in the sense of developing new products with much more limited scope. To mitigate the consequences of variety, one interviewee suggested that the company should aim to be the one giving clear and limited options to the customers rather than customers being able to request as they wish. Another suggestion was to prepare for parts, but not release them until used, as the act of releasing a part triggers several processes.

Another related issue is low maturity in the early phase. Several mentioned that it would be beneficial to be more knowledgeable earlier in the project. An example that some mentioned is that the maturity of components or solutions has been underestimated or accepted despite being low for some projects. Interviewees expressed that this significantly increased the lead time of the projects, as the project takes on the task of increasing the maturity. One component provided by a supplier was communicated as being off-the-shelf, i.e. to be highly mature, but still turned out to be in development at the supplier, which led to delays and late changes to solutions that were dependent on the component. However, this continued development according to some, as mentioned earlier, seems to not only be at the fault of the supplier but also by the case company having extensive requirements, which prompts adaptations to components to meet these requirements.

It was suggested by several to include lead project managers more in the pre-study with the aim of bringing experience in planning and executing projects. Relatedly, one interviewee implied that leveraging more communication and collaboration between all functions during project planning is necessary if the scopes are to be improved. Another aspect is that some interviewees expressed that the pre-development work is time-consuming and with challenges in reaching and agreeing on concepts. Some also expressed that time and effort is spent on making clear requirements but that perhaps more focus should be spent on establishing it together with those that eventually execute projects, including to improve the sense of involvement and ownership of the project.

4.2.5 Testing and prototyping

One aspect of the development process that most interviewees mentioned in some respect is testing. In summary, there is a high volume of testing in relation to a limited testing infrastructure, both for software and hardware, which results in bottlenecks for projects.

Concerning the testing capacity, the tests are usually done on large test objects that are complete or nearly complete versions of the product, which are expensive and time consuming to attain, leading to them being relatively few and shared across many projects. Whiles several of the major projects have a designated large test object, which also leads to smaller projects suffering from waiting for testing capacity to be available, it still acted as a major bottleneck in the project as several functions and suppliers need it for testing. Testing in the large test object was also a stated must by the previously mentioned internal supplier. It acting as a bottleneck led to much work being spent on prioritizing tests. Regarding the testing volume, several stated that there is high tendency for testing, while some mention that other organizations in the larger organization that the case company belongs to have more testing. Another aspect is that even when virtual tests are done, they tend to be complemented with physical ones.

However, several interviewees mentioned that there should be more small-scale tests of individual components or sub-systems using rigs, mock-ups, virtual testing or similar, which could substitute the demands on these full scale, large testing objects. It is also argued that the small-scale tests could take place earlier and be used to make better and verifiable decisions earlier, potentially avoiding costly late changes.

As mentioned earlier, several full prototypes linked to different maturity phases are aimed to be built during the development project according to the established process. However, this step is stated as very time consuming to such an extent that the output from the tests do not make it into the next prototyping cycle. An initiative to explore alternate and small-scale testing, as mentioned above, are a direct response to this issue and the ambition is also to only construct two full-scale prototypes rather than three during a major project.

Additionally, there is a reported tendency for design iterations to continue before testing cycles are complete leading to new designs not based on insights from the tests ordered on its predecessor. Occasionally, more tests are then ordered on the new design, i.e. starting a new test cycle before the previous one are complete. This is also an issue the aforementioned initiative aims to indirectly solve with improved testing tools.

4.2.6 Software

Several interviewees also mentioned the software development as major issue affecting lead times. However, the same people also typically mentioned having limited insight into the causes of the problems affecting this. Individuals closer to software development showed a more nuanced picture, one pointing out an additional set of problems than those mentioned earlier. Categorizing the main issues pertaining to software development at the case company, based on the emphasis by the interviewees, results in two areas. First, bottlenecks in testing and second, work done in the front-end.

Concerning the testing related issues, as mentioned earlier, the general testing capacity is limited at the case company. One suggestion mentioned was to introduce a dedicated large testing object for software testing. The increase in small-scale testing was also at focus for software. Also increasing the automation of software testing was proposed.

Regarding the front-end related issues, the first concerns the high level of integration in the products, i.e. high product complexity. The high product complexity allegedly puts high strain on software development as more parts are involved in a single functionality. A proposed solution is to leverage a more modular product architecture and create clearer interface between modules to compartmentalize functionality and lessen complexity. The second issue relates to specifications, as from a software perspective current specifications typically require translation and further clarification to be usable for developing software.

There were also some discussions regarding the processes for software development. One described how it many years ago was less structured but working well due to flexibility and focus. Then as the share of software in the products' increased, the processes became more structured and gaps in competence needed to be closed. This transformation is stated as still ongoing according to interviewees, also considering that the importance of software in the products is increasing continuously. The structure of the process is telling, where some mentioned that more parts of the V-model should be adopted, namely, to include the sub-system level more, while others emphasized that resources are limited and that aspects like these needs to be evaluated from a cost- or time-benefits perspective.

4.2.7 Other issues

The following issues are those deemed less impactful but still noteworthy issues that interviewees have brought up. However, they will have minor or no involvement in the upcoming discussion either due to the time and resource limitations of the study or due to lying outside the scope of the study. The issues below are presented in an arbitrary order.

A fundamental issue gathered from the interviewees, relating both to their own work and that of other functions, were the resource constraints. They described resources, especially staff but also physical resources such as testing objects as being spread thinly across many projects, resulting in various types of bottlenecks. Likewise, issues relating to prioritization, such as how to go about planning and allocating resources, was a stated consequence of said bottlenecks creating another layer of complex problems on top of the aforementioned.

Issues relating to external partners also arose during the interviews, which nearly mirrored the issues related to the internal supplier in terms of delays, late changes and sometimes unclear responsibilities. However, generally with a lower level of transparency given by the partners' status of external, less communication and even less insight into the case company's situation.

Another expressed concern related to what some described as a lack of urgency and tendency to fall back on processes instead of being flexible and prioritizing urgency, i.e. striving for working faster and reducing lead times. In certain cases, the alleged lack of urgency seemingly stemmed from prioritization relating to the aforementioned bottlenecks and resource constraints, which was acknowledge by some. As mentioned under coordination it also related to differences in emphasis on reducing lead time in the strategies of different functions.

Yet another issue is related to knowledge management, specifically how past knowledge and experience is handled in the organization. Even though processes exist for this matter, lessons learned from prior accomplishments or mistakes are seldom shared to others, even though registered as per the processes. Hence, knowledge is reportedly often locked in people and mistakes have been repeated, which some mentioned is exacerbated by a relatively high employee turnover.

Lastly, some noteworthy issues are related to decision-making. Interviewees expressed concerns of certain decisions being unnecessarily pushed upwards in the hierarchy or forwards in time. A few interviewees mentioned that people need to dare more for taking decisions and connected in part to psychological safety. Additionally, one interviewee argued that the steering committee's high engagement and willingness to partake in decision-making, could have made people at lower hierarchical levels slightly less inclined in making them themselves. However, at the other end, several have expressed great appreciation for this engagement in other aspects, such as the high level of support.

4.3 Overview of main issues affecting lead times (RQ1)

RQ1: *What are the main issues affecting the lead times in development projects that the case company is facing when managing the execution in development projects?*

The seemingly most prominent issue affecting lead time is coordination, particularly between functions on the operational level. Coordination was not explicitly stated by many interviewees, but rather in terms of e.g. dependencies, the issue is rather an aggregated and also built on primarily two subordinate issues. First, the limited understanding and insight and second, the approach to deliveries and communication being rather sequential. Additionally, linked to this issue is another one of the main issues, teams and organizational structure, given that it affects how coordination takes place and is imposed. For example, the many engineers in projects that according to several interviewees that limit the sense of ownership and understanding and affects communication. Likewise, the internal supplier was frequently mentioned in the interviews, before any directly related questions were inquired, and the sub-issues pertaining to them were similar to those between the functions on the operational level, e.g. the parallel issue of mutual limited understanding and insight, albeit with some nuances such as the effects on not belonging to the case company.

Another noticeable area affecting lead time according to the interviewees was the pre-development work. Predominantly, the interviewees mentioned broad, uncertain and changing scopes which in turn resulted in issues such as high part variety, late changes etc. Also associated with the pre-development work was the low maturity in early phases and of solutions serving as input where reportedly too much uncertainty is carried over into the projects feeding into the scope issue while also creating other issues.

Semi-related to the low maturity is the other main issue of testing and prototyping, where there were sub-issues pertaining to capacity and the reliance on system-level tests with large test-objects. The connection between testing and problem-solving and low maturity in the early phases then lies in the company's limited small-scale testing and similar, for which there was ongoing efforts.

Connected to both pre-development work and testing and prototyping, were the sub-issues associated with the final main issue of software. First, the software development is affected by challenges related to adapting and defining specifications for software development. Second, software testing demands where high on the limited testing capacity that was highly reliant on large test objects. Furthermore, there were challenges with integrated architecture where multiple parts were involved in a single functionality, where it was stated that a more modular approach could be beneficial. Note however, that data saturation for software is comparatively limited as fewer interviewees had deeper insight compared to the other main issues, which was affected by time constraints of the study.

Conclusively, the main issues in order of perceived lead time influence based on the interviews are the following: coordination; pre-development work; testing and problem-solving; software. These issues, their sub-issues and the consequences of them can be found summarized in Table 4.1

Table 4.1: Identified main issues, their underlying sub-issues and subsequent consequences

Issue	Sub-issues	Consequences
Coordination	• Limited understanding and insight across functions • Approach to deliverables and communication being rather sequential • Misalignment between functions with regard to e.g. flexibility in processes • Internal supplier	• Many changes, especially during the building of the full prototypes • Rework and administration • Tensions in processes
Teams and organizational structure	• Many engineers involved in projects with high task specialization	• Limited ownership and accountability • Lack of clear speaking points • Technical challenges related to limited system perspective

		• Affecting the sub-issues of coordination
Pre-development	• Not clear enough specifications • Not sufficient agreement • Broad scope and high variety • Low maturity of components used as input • Potentially high requirements by the case company on such components, affecting maturity • Low maturity in early phases	• Prolonged discussions • Uncertainty • Moving goalposts • Work spent on things that would later not be used • Project becomes longer when needing to increase maturity • Late changes
Testing & prototyping	• Reliance on large test objects, with limited capacity • Limited sub-system level testing • Limited component level testing • Non-closed testing cycles	• Bottlenecks • Low maturity in early phases
Software	• Testing bottlenecks • Defining specifications • Integrated architecture	• Delays • Waiting • Re-work
Other issues	• *Resource constraints and prioritization* • *External partners* • *Sense of urgency and flexibility* • *Knowledge transfer* • *Decision-making*	*Various*

With these main issues identified, RQ1 is answered. The following section will build up to answering RQ2 and RQ3, by comparing and combining these issues with the relevant literature.

5. Discussion

Aligned with the abductive logic and systematic combining approach (Dubois & Gadde, 2002) of the study, the discussion intends to match and compare the issues identified during data collection with relevant literature to generate a synthesized analysis for answering the research questions. First those issues speculated to have a higher impact on lead time will be covered followed by those with considered less impactful yet actionable and still somewhat notable. However, to begin with is a brief overview of the case company's general situation in relation to lead times and the previous discussions in literature on the ways to reduce lead times.

Many of the issues found at the case company match those mentioned in previous literature and summarized in Table 3.2, i.e. the synthesis of themes. The main issue of coordination ties in with the fundamental aspect of cross-functional coordination, while teams and organizational structure links to both that and focus. Focus also links to one of the other issues, namely the resource constraints and challenges of prioritization that comes with it. Both of the main issues regarding scope and pre-development and testing and prototyping, mirror themes in the recommendations on reducing lead times, with the latter referring to iterative development. The importance of organizational behavior and climate, in various aspects, were also reflected in the case company's situation, such as in relation to communication and some of the other issues, such as sense of urgency and decision-making. With regard to platforms and modularization, the latter was mentioned in relation to software and is an area that will be explored in a subsequent section. Customer involvement was not touched upon significantly during the interviews and with the study's focus on the main issues, will not be investigated further. Supplier involvement was important for the case company, where it did well in using it to access to technology and resources, but where there were also challenges as described. Finally, the aspect of various tools and methods naturally ties in with the other topics. See Table 5.1 for the connections between issues in empirical findings and the topics highlighted in the literature for reducing lead times of development projects.

Table 5.1: Comparing the themes recommended in literature with the issues found, issues that were not main issues are cursive.

Topic	Issues
Cross-functional coordination	• Coordination • Teams and organizational structure • Internal supplier
Pre-development	• Scope and pre-development • Software • *Knowledge transfer*
Iterative development	• Testing and prototyping • Software
Focus	• Teams and organizational structure • *Resource constraints and prioritization*
Organizational behavior and climate (Soft factors)	• Coordination • *Sense of urgency and flexibility* • *Decision-making*
Platforms and modularization	• Software • To be continued in a subsequent section
Customer involvement	Not touched upon significantly
Supplier involvement	• Internal supplier • *External partners*
Various tools and methods	Included in several, such as Testing and prototyping

It is also important to recognize that the case company does not only have issues in relation to the topics in Table 3.1. The case company has a structured way of working that in several respects consider the above or an awareness about many of these best practices. Rather, it seems to be a matter of gaps and in several cases, as mentioned in the literature, challenges that companies' battles continuously with (Knudsen et al., 2023).

The following sections of the discussion will focus on cross-functional coordination, teams and organizational structure, pre-development and testing and prototyping. Software is considered both in pre-development and testing and prototyping due to the nature of its main sub-issues reflecting these. In each section a comparison will first take place between the situation at the case company, a diagnosis of sorts, followed by a discussion with the aim of identifying potential actions.

5.1 Cross-functional coordination

As stated, the coordination across functions seemingly works generally well on a managerial level. However, the issues described by interviewees related to collaboration are analogous to symptoms of weak cross-functional coordination and collaboration on an operational level. Hence, said subject is of significance. Likewise, the relation to the internal supplier can be categorized similarly since even though they have been stated as almost perceived as a supplier by some interviewees they are still an internal resource and rationally only a very distant function with similar issues as seen between the traditional functions. Furthermore, regarding the subject of cross-functional coordination and communication, the literature provides potential lead time reductions from its potential to parallelize, reduce errors and rework, and generally improve collaboration and development pace.

5.1.1 Comparing empirical findings and theory

On the operational level the issues raised were in short: an "over-the-wall" approach to communication and deliverables between functions; limited understanding and insight between different functions and the larger picture. These issues, including the aggregated issue itself, are mentioned by the literature, through Lawrence and Lorch (1965) and Wheelwright and Clark (1992), as signs of weak cross-functional coordination and communication. The solution, they explain, lies in cross-functional integration, especially of those functions in direct sequential order.

Contextualizing the former “over-the-wall”-issue, it is a large obstacle which can be illustrated by the patterns of communication mentioned by Wheelwright and Clark (1992). Applying the four dimensions of patterns of communication, it is evident that the company currently has more of a batch approach to frequency. Timing wise, they communicate most often during hand-over of deliverables. Regarding richness they seemingly generally rely on documents, but face-to-face meetings or talks are not uncommon. Lastly, findings relating to direction are unsatisfying, but their tendency to use documents as the preferred media suggests a more one-directional predisposition. Overall, the company’s pattern of communication within their development projects on an operational level evidently is that of the Wheelwrights and Clarks (1992) first example, “Serial mode”. Another aspect to communication to mention briefly due to its importance for the frequency of communication, which was brought up by Buchanan and Huczynski (2023), is the physical proximity where, in this case, some of the functions are not in the same location as most.

The latter limited understanding and insight issue is an obvious obstacle in the development flow as attested to by the interviewees. In particular, the consideration of how one’s deliverables fit into the larger picture and as input for the next, which together with related issues, led to deliverables not being aligned between the downstream and upstream, and in turn, errors and rework. Furthermore, as Sætre et al. (2024) explained, functions tend to create and operate in different “thought worlds”, pertaining to their different experience, education, norms, etc., inhibiting the understanding between functions and impacting the communication. This aspect of different thought worlds appeared at the case company too, albeit more implicitly rather than explicitly addressed by interviewees. This included the flexibility to processes and sense of urgency, where the “standard lead times” acted as the discussion object for some interviewees. It was especially seen in the goals of the functions, where for example some were more focused on cost while others on lead time. This also touches upon the other aspects to cross-functional communication that Sætre et al. (2024) also mentioned, i.e. misaligned goals, routines and cultures. Likewise, Lorsch and Lawrence (1965) highlights that functions are inherently different and that specialization occurs through the functions having different competence and responsibility. This was apparent at the case company too, where for example the sales department had many short-term matter to deal with and focus on. As Lawrence and Lorsch (1965) describe specialization is important for an effective function, hence why it is a dilemma, solving or mitigating this issue then is not a question of drastically lessening specialization as it would risk weakening the functional competence. Rather, other measures are needed to combat the consequences stemming from different "thought worlds" and the inherent differences between functions. One such measure that Lawrence and Lorsch (1965) suggested is a coordinating unit, which the PMO and closely related units such as product planning acts as at the case company. Lawrence and Lorsch (1965) pointed out the importance of a balanced view of functions, which seems to be relatively true at the case company. However, a few interviewees argued that sales and product development have relatively large influence compared to other functions.

In summary, the issues point towards the need for cross-functional integration of the operational level. Nevertheless, a cross-functional integration process is a large undertaking requiring change from effectively all involved in the projects. Hence, it will also affect the managerial level of the projects and those adjacent or hierarchically close above.

5.1.2 Identifying potential actions

Central to cross-functional integration is communication and collaboration. Both Wheelwright and Clark (1992) and Sætre et al. (2024) propose improvements to communication which promotes cross-functional integration where Wheelwright and Clark (1992) also delve more into the adjacent subject of collaboration.

Wheelwright and Clark (1992), in relation to their dimensions of patterns of communication states that optimal communication in a product development project should be: timing wise, initiated suitably early; regarding direction, downstream and upstream intimately connected and communicating bilaterally; regarding frequency, continuous interaction throughout the whole activity; concerning richness, a rich media is optimal, i.e. face-to-face. Hence, the optimal scenario is akin to their fourth example, "Integrated problem-solving". However, this example also entails parallelization of upstream and downstream activities. Comparing with the case companies' situation, they are as discussed closer to the "Serial mode". Regarding the dimensional differences, richness and direction lean somewhat towards the wrong ends of their respective spectrums with their tendency to use less rich media such as documents a very one-way directed form of communication. Instead, the company should promote short face-to-face communication which allows for better understanding through e.g. facial expression, body language and dialogue. With that said, documents, mail and similar should not be discarded, they do serve their different purposes in certain situations, e.g. for routine communication mail is sufficient as mentioned by Buchanan and Huczynski (2023).

Moreover, the largest dimensional discrepancies are in frequency and timing. Here the case company seemingly does the opposite of what the literature considers optimal, though perhaps as a natural consequence of their apparently very sequential workflow. They should instead consider promoting continuous interaction and communication between upstream and downstream throughout these activities. However, this also necessitates a switch in workflow with upstream and downstream activates now working in parallel, i.e. optimal communication and parallelization are related, as per Wheelwright and Clark (1992). Yet, looking beyond the immediate need for cross-functional integration, as Schilling and Hill (1998) imply, cross-functional integration is also an enabler of parallelization, an approach accompanied by shorter lead times. Hence, cross-functional integration is not only a possible solution to current issue with its own potential for lead time reduction, but also a prospect for further reduced lead times through parallelization. Parallelization will be further discussed in regard to modularization.

Regarding communication and also collaboration are the capabilities and relationships described by Wheelwright and Clark (1992) as fundamental for cross-functional integration. Pertaining to upstream capabilities, evidently the company needs to develop their downstream friendliness and reduce errors in deliverables, as per the mentions of rework and errors common in the example of the product development and production dynamic, yet while not forgetting the ultimate goal of the product being the satisfaction of the customer. Regarding reducing errors, here design reviews, testing and general engineering discipline is fundamental. Likewise, fast problem-solving cycles, including testing, are necessary to solve conflicts. This the company reportedly struggles with, but this subject will be revisited later. As the literature explains, the downstream must develop capabilities to enable a "flying start" without complete information, i.e. be comfortable working in parallel when the previous activity is still under development as in the "Integrated problem-solving" example. This entails the following capabilities: forecasting from upstream, risk management, and coping with unexpected change. The first capability is something unfamiliar to the case company given their sequential habits likely not necessitating this capability or something similar previously. However, the company already has experience with the second capability of risk management. It is a practice done regularly at the company and reportedly to a successful extent, meaning that the foundation is likely solid and only the new types of risks from forecasting needs to be accounted for. Lastly, the third capability of coping with unexpected change hinges on the problem-solving and diagnostic ability of the organization and their ability to mobilize resources and prioritize. Once again, the problem-solving, i.e. testing, ability of the organization may prove problematic. Moreover, the reported “lock-in” from PI-planning could hinder mobilization and prioritization given that the current implementation of PI-planning at the company is seemingly inadequate in handling unexpected or non-planned matters, which is foundational in this capability. Hence, considerations regarding their PI-planning implementation may be needed if the company are to develop this capability and in extension improve cross-functional integration.

The different “thought worlds” described by Sætre et al. (2024) and the other challenges, in misaligned goals, routines and cultures between functions, were all matters reportedly present at the company to varying degrees. The solutions for overcoming the “thought worlds” that Sætre et al. (2024) propose lies in the following enablers: communicating narratives, considering assumptions and establishing personal relationships. Pertaining to communicating narratives, it is connected to the media richness dimension mentioned by Wheelwright and Clark (1992) through narratives being an example of the more detailed and rich communication which a richer media, such as face-to-face, allows. Arguably, the recommendation of narratives highlights the importance of richer media. Similarly, considering assumptions is arguably part of the capability of downstream friendliness as considering assumptions and correcting one’s communication for them results in better and more correctly received communication from downstream. Yet, assumptions should also be considered the other way around too, but the argument persists. Conclusively, the company should consider these enablers in their integration work.

Table 5.2: Potential actions and their respective reasoning in relation to cross-functional coordination

Potential actions	**Reasoning**
Parallelize upstream and downstream activates and promote earlier, continuous and face-to-face communication between them and all other functions	Earlier and more frequent communication in combination with a rich and directionally two-way medium improves understanding and problem-solving with less errors, less rework, etc.

Focus on downstream friendliness and error-free deliverables	Reducing rework and errors downstream relies on upstream integrating downstream needs in their solutions while also delivering error-free deliverables
Develop downstream capability to forecast from upstream	Parallelizing downstream and upstream activities requires new ways of working as deliverables are not complete. One such is capability to predict outcome and act accordingly, i.e. forecast
Learn to handle new type of risk from upstream forecasting	They already conduct risk management, thus only the new type of risk pertaining to the forecasts needs to be learnt to handle
Develop downstream capability to cope with unexpected change from upstream	Parallelizing downstream and upstream activities requires new ways of working since deliverables are not complete. One such capability is to cope with unexpected changes.
Improve testing and problem-solving capabilities	Objective insights from this can help in conflicts and also help with the potential action of coping with unexpected change
Promote communicating narratives, considering assumptions and establishing personal relationships across functions	This concerns overcoming the different "thought worlds" of the different functions without compromising specialization, i.e. functional competence.

5.1.3 Internal supplier

Concerning the relationship between the project functions and internal supplier, they are arguably only a very distant function, a statement which is further reinforced by considering the corresponding issues from the findings. The issues are very similar to those described and linked with cross-functional coordination and communication above. Namely, limited insight and understanding seemingly stemming from differing processes, policies, inadequate communication, and the nature of the sister company. Consequently, applying the same solutions, i.e. cross-functional integration, should improve the communication and collaboration between the company and internal supplier.

However, there are still parts of the internal supplier related issues which fall outside of this frame. Particularly those pertaining to the fundamentally different business of the company and the sister company.

5.2 Teams and organizational structure

The structure and functioning of the project team was mentioned as critical for successful development projects, including Cooper (2019), and with strong ties to cross-functional coordination, where some team structures were more promising than others for cross-functional integration. Similarly, in the empirical findings the issues of coordination were associated by several interviewees to the teams and organizational structure.

5.2.1 Comparing empirical findings and theory

As Wheelwright and Clark (1992) describe the configurations of team structure are not discrete but rather lie on a continuum. This becomes apparent when analyzing the team structure at the case company. The staff that executes operational tasks are structured by functional area and in turn into subfunctions. The project also has a project coordinating committee consisting of a lead project manager and functional project managers. However, the lead project manager has minor influence over those working in the project at the operational level. The project coordinating committee points means that is in not a functional team structure, especially as the liaisons, i.e. the functional project managers at the case company, does not have it as an add-on to usual tasks. It is not an autonomous team structure either as that would require a fully dedicated team with a project manager with complete control over the recourses in the project. Rather, empirical findings point towards the team structure lying somewhere between lightweight and heavyweight but with tendency towards lightweight. The key differentiator is the role of the project manager. On the one hand, Wheelwright and Clark (1992) describe that a lightweight project manager is junior with limited status in the organization, which is not the case here where the lead project manager is highly experienced, but on the other hand a heavyweight project manager has the main influence over those working in the project, which as stated above instead is minor. The conclusion is that the case company seems to have a lightweight team structure with heavyweight tendencies in terms of the seniority of the lead project manager and the focus given to the liaisons as they are also project managers. It also important to consider that the lead project manager and functional projects rarely have a single project at a time but rather two or three most commonly, lessening the degree of heavyweightedness.

The advantages and disadvantages with the different team structures of Wheelwright and Clark (1992) are also found at the case company. As Wheelwright and Clark (1992) mention, the lightweight team structure has the same benefits and drawbacks as the functional team structure apart from an improved communication and coordination due to a dedicated person for the project. Following this line of thought with the seniority of the lead project manager and the liaisons being project managers this would likely be furthered improved. This seems to be the case based on the findings pointing towards coordination and communication at the project committee level working relatively well. However, circling back to the characteristics of the functional team structure, the main issues with the team structure in relation to cross-functional coordination that the interviewees mentioned are found. As earlier described, there were many engineers allocated to a single project where their assigned tasks were highly specialized. Given their high task specialization and comparatively small extent of involvement in any given project due to also being spread over many different projects also result in a weakened ownership in individual projects. While Wheelwright and Clark (1992) mentioned the limited responsibility for the project's success to the individual's performances being evaluated by the subfunction manager, this seems to be exacerbated in the case company by the high task specialization within the functional teams. Furthermore, the case company has needed to considerately reflect on how to go about planning, resulting in the current PI-planning, with some interviewees mentioning significant effort going into adapting this new approach. This is similar to the functional team structure prompting the need for detailed specifications in order to divide tasks across the functions and subfunctions. Another characteristic of the functional team structure that Wheelwright and Clark (1992) mentioned is the sequential shift in responsibility between function through handoffs. In this case, the responsibility of the project seems to be more centrally at the PMO rather than that of a function, although the process seems to be quite focused on handoffs and limited parallelization. Another aspect, which was also mentioned by Buchanan and Huczynski (2023), that was pointed by a few of the interviewees is that experts can be used across projects. Additionally, these interviewees also argued for improvements to the use of platforms and commonality. Wheelwright and Clark (1992) mentioned the drawback that the experts may not enough consider the project's specific characteristics and system. There were some interviewees pointing towards something similar, i.e. an insufficient consideration of the entire system by engineers, and that it was one of the drivers for the high number of ECOs. However, this aspect of system thinking may also be related to the engineers spread in multiple teams or due to the other factors related to cross-functional coordination.

As Wheelwright and Clark (1992) described, organizing in large, established organizations is challenging due to the complexity and that they often lean towards the use of the functional team structure. Wheelwright and Clark (1992) argue that this works well in stable industries and that when change is faster these large organizations tend to adopt lightweight team structures or more rarely heavyweight team structures. However, when it comes to achieving cross-functional integration, the heavyweight team structure is described by both Wheelwright and Clark (1992) and Schilling and Hill (1998) as the preferred set-up. As a reminder, Schilling and Hill (1998) specifically recommended the heavyweight team structure for platform projects and strongly advised against the functional team structure regardless. What the case company should do will be returned upon in a short while in another section.

5.2.2 Identifying potential actions

The benefits of a heavyweight team seem to be able to counteract several of the issues interviewees mentioned, such as improving commitment, ownership and system thinking in the project. However, the interviewees also brought up some of the downsides with heavyweight teams, which Wheelwright and Clark (1992) outlined as barriers, such as other projects becoming too underprioritized and that more generalist competences are needed. Implicitly, it is also about potential conflicts with the functional organization. A heavyweight team would need to go around the PI-planning system and the subfunction groups are used to division of tasks within their group. Furthermore, Wheelwright and Clark (1992) mention that fundamental to the decision of team structure is the competence and people available in the organization and the mix and types of projects. In relation to this, interviewees mentioned that the number of specialists were limited and that people and resources are spread across many projects, some implying that the number of projects is potentially too high.

Related to this is the question of the team being dedicated or not, which is common for heavyweight teams but not a necessity. As several authors stated dedicated teams are highly beneficial for speed, including Cooper and Sommer (2016) discussing whether it is the main benefit of agile. However, as mentioned in relation to barriers for heavyweight teams, the interviewees point towards challenges in implementing this. Perhaps, as Cooper and Sommer (2016) suggested, a select few projects of higher importance and priority could have dedicated teams. However, it is a balancing act as the larger projects are often dependent on some smaller projects, and if they are too underprioritized in terms of resources may act as bottlenecks.

Another aspect similar to the team being dedicated or not is co-location. As mentioned by Buchanan and Huczynski (2023) closer proximity and being face-to-face improves communication. With regard to aspects of communication mentioned above, the ambition should be to increase the degree of closeness, but a full co-location is probably not feasible with the resources at hand nor optimal when taking into the account the importance of knowledge exchanges in the subfunction groups.

Viewing the situation, the issues and literature point towards striving for higher dedication level and fewer people involved, closer communication and more of a heavyweight team structure for major projects. To enable this, the case company should based on the literature foster more generalist skills among engineers long-term, gradually increasing the breadth of responsibility and reducing task specialization. In the transition period, there could be at least assigned owners of systems, sub-systems or components to avoid project managers being bounced around between engineers in subfunction groups. These owners could also be involved in others way, such as workshops or other activities, with the aim of promoting a sense of ownership in the project. In turn, this could also support the communication aspects that are discussed above, such as other functions knowing who to contact at the operational level. Regarding the relation to the functional organization, the enabler may be to let people be formally assigned to projects and have that project's task prioritized. Meanwhile, other tasks remain in the PI-planning system for down periods for these people or for members in the subfunction group that are not assigned to projects. Perhaps, there could be split within subfunction groups where some focus more on the smaller projects, however with major considerations to how it affects the competence development and re-use of solutions across projects. The limited number of specialists also needs to be considered, which is a similar balancing act between re-using solutions and knowledge between projects on one end, and focus and not becoming a bottleneck on the other. These were also some of the characteristics associated with being a member of multiple teams at once (Buchanan & Huczynski, 2023) A potential suggestion is to have the same specialist where it is difficult to hire or train someone to off-load but perhaps the timing of projects can be considered to balance the workload so the focus on one project at a time can be higher. Perhaps, there should be a core group of people at the operational level from different functions that are involved in the project over time, as the latter leading to improved ownership and in turn, bridges the issue of understanding between functions (Sætre et al., 2024). Relatedly, it is important with promoting personal relationships through socializing face to face. Finally, the number of projects, which is out of scope for the study, should also be explored furthered as a factor related to achieving the suggestions.

Table 5.3: Potential actions and their respective reasoning in relation to teams and organizational structure

Potential actions	**Reasoning**
Move towards heavyweight teams for platform projects, i.e. give project authority over resources	Improve cross-functional integration, ownership, commitment and systems thinking
More dedicated team, at operational level, for select few projects	Same as for move towards heavyweight teams
Co-location of team, operational level included	Improved communication, coordination and personal relationships
Foster more generalist skills, gradually increase breath of responsibility & reduce task specialization	Support the move towards fewer and more dedicated people involved in projects
Assign owners of sub-systems or components at the operational level	Improve communication and ownership
Separate tasks related to a project the individual is assigned to versus other tasks in the PI-planning system	Enable the move towards heavyweight and more dedicated teams
Consider timing of projects for specialists	Improve focus and workload for specialists

5.3 Pre-development

The work done before development begins is critical for the overall project's success, including the ultimate time of it, and was brought forward as one of the main themes both in literature and among the interviewees. The following sections will begin with a comparison of the issues found at the case company and those in literature, which is followed by a discussion about potential actions the case company can take to improve the situation.

5.3.1 Comparing empirical findings and theory

The case company undertakes the steps that Cooper (2019) mention should be included in the pre-development phase, such as preliminary market and technical assessments etc., and that a significant time is spent in this phase. The latter is in contrast with the behavior of many firms, who underestimate the importance of these activities and spend less time than needed (Cooper, 2019). However, some interviewees argued that the phase is too long and influenced by challenges in agreeing on concepts. Additionally, interviewees pointed out the need for more clarity, exemplified with "Friday to Monday-functionality", and that more effort could be needed in establishing the project with those that will subsequently execute it and include them more in this phase. The combination of these elements seems to tie in with one of the critical aspects differentiating an effective and ineffective project that Wheelwright and Clark (1992) mentioned, namely that when objectives are not clear, shared and agreed beforehand the project itself can become a forum for achieving agreement.

Furthermore, Cooper (2019) highlighted that two of the main aims with adequate work before development starts is to avoid late changes and moving goalposts in the form of scope creep or unstable specifications. These symptoms were present at the case company too. To begin with, the specifications using the label "Friday to Monday-functionality" were described as unstable as it was not established which "Friday" and "Monday" was referred to, both of which change during the project. Hence, they could act as moving goalposts. However, perhaps even more pressing on these matters was the broad and changing scope influenced by the variety in options and many potential product variants. Parts were prepared for all options and sales were, in some interviewee's words, requesting for as many options as possible. It led to resources being spent on what would later not be used and discussions about what to focus on. Additionally, new specifications could be requested during a project leading to late changes. This aspect of large variety introduces complexity, one of the fundamental challenges in product development (Wheelwright & Clark, 1992), which influences the difficulty level for an effective project. This was pointed out by interviewees who argued that limiting the scope and being more focused would benefit the length of the development projects.

Related to late changes and increasing the development time in itself was the low maturity in early phases and of components or solutions that were taken on in the project. As mentioned in the description of the case company, the use of solutions provided by affiliated units in the larger organization, which they all belong to, is prominent. It could also relate to solutions provided by external suppliers. In any case, a lower maturity of the input for the project led to longer time in understanding, defining requirements for and developing the solution further to fit into the case company's products. It also influenced the frequency of late changes, presumably due to a reduced ability of anticipating it compared to solutions or components more known for the case company. As was argued by some interviewees, the extensive requirements by the case company on the solutions also introduced longer lead times and, in a sense, reduced the maturity of them when they needed more development to meet the requirements.

Thomke and Fujimoto (2000) introduce the concept of front-loading to handle the low maturity in early phases and solve problems early, bringing forward knowledge transfer between projects and rapid problem-solving through e.g. testing with advanced technology. The former was one of the issues outside of the main issues, where a post-mortem similar to what Thomke and Fujimoto (2000) advocated for were kept for each project, but where interviewees pointed towards limited transfer. The latter ties into the subsequent section of testing and prototyping where the case company is looking to increase small-scale testing in the early phases.

An important factor in of the other main issues, software, also connected to work done before development begins. It related both to product complexity, a decision made during the pre-development phase, and for defining the specifications for the software. The latter may in part be influenced be the above-mentioned issues related to specifications in general for the projects, but it was also that software-specific challenges related to defining specifications. A discussion about the product architecture will follow in another section.

5.3.2 Identifying potential actions

To increase clarity of objectives, defining “Friday” and “Monday” as suggested by some interviewees may help, but with an increased burden on the people involved during the pre-development. This ties in with Cooper (2019) advocating for early, fact-based product definitions and as also the arguments for the values of an adequate pre-development work for the subsequent project. At the same time, to avoid the project being a forum for discussion surrounding the objectives, establishing them early on with the project management group of the project, as suggested by some interviewees, seem to be of value. However, there is an important emphasis on reaching clear objectives, rather than a continued discussion. The involvement of the lead project manager earlier on was also mentioned by several interviewees to e.g. contribute with project planning also appears promising, as it can both aid in resolving ambiguity and other matters, such as the question of maturity.

Carefully evaluating the maturity of said solutions developed in other organizations appears highly important in relation to the length of the development projects based on the what the interviewees expressed and the importance of avoiding late design changes. Furthermore, Cooper (2019) mentioned focusing on core competences as one of the general success factors, as unfamiliar projects are riskier due to gaps in knowledge and resources. At the same time, Cooper (2019) described that it is a balancing act as companies occasionally must do such projects. With the fast technological pace in the case company’s industry and other similar factors, this seems to be the case. However, although it comes with challenges, such as having limited knowledge, the degree of maturity and the accuracy of that estimation can be considered to a greater extent it appears. Another aspect that some interviewees pointed out was how what they perceived as extensive requirements by the case company influenced the maturity of the solutions when they needed be developed further. Perhaps, an improved consideration of and dialogue with the providers of the solutions regarding the implications of requirements on development lead time may influence the assessment of the maturity and the decision on what is acceptable. However, uncertainty, the other one of the two fundamental challenges (Wheelwright & Clark, 1992), affects this process.

With regard to the aspect of variety some potential actions lie outside of the scope, such as more business strategy level decisions on the product offering. However, within the scope of the project lies how to handle that with the aim of reducing complexity. This includes the platform strategy mentioned earlier but also for example the suggestion on not releasing parts until used to avoid undertaking the processes it triggers for each part. Furthermore, the suggestions on limiting the scope should be considered due to its potential for reducing complexity. Circling back to clear objectives, perhaps there needs to be increased clarity for handling the perception among several interviewees that the sales department wants as much as possible, i.e. setting a bar of sorts instead of having moving goalposts.

Referring back to knowledge management, there seems to lie potential in increasing the transferring of knowledge across project at the case company per Thomke and Fujimoto (2000) advocating for it and interviewees expressing it as limited. For example, it may contribute with assessment of maturity as those who have undertaken a similar project may be more knowledgeable. Hence, perhaps more time could be spent in the pre-development on communicating the post-mortems of a similar or preceding project. However, for tacit knowledge it seems important with having the same people continue in a similar project.

Improving the testing and problem-solving capability are also likely to help in the early stages to increase the maturity in early phases, which follows the line of though used by Thomke and Fujimoto (2000) on identifying and solving problems earlier. This topic will be returned to in the section on testing and prototyping.

Concerning software, one suggestion to mitigate the complexity issue was for the products to pivot towards a more modular architecture with functionality contained within modules. This will be explored further in a separate section.

Table 5.4: Potential actions and their respective reasoning in relation to pre-development

Potential actions	**Reasoning**
More clear specifications, e.g. defining “Friday” and “Monday”	Avoid moving goalposts or discussions about what the objectives are
Involving and discussing with project management group earlier	Reach shared and agreed objectives, and support in e.g. project planning
Consider to a greater extent the degree of maturity of solutions that are used as input to the project and how that degree is estimated	Support decision-making on adequate maturity level
Limit scope or less extensive requirements	Lower complexity

Discuss port-mortems more and re-use people across similar projects	Improve knowledge transfer between projects, in turn increasing maturity in early phases
Improve capabilities for early problem-solving with small-scale tests and rapid problem-solving	Increase maturity in early phases
Adopt Modularization strategy	TBC in the following section

5.3.3 Modularization strategy

As stated, the company already employs a platform strategy to handle their product variety, yet the product variety still stands as a reported issue. However, the underlying cause of the product variety is as told the customers many and differing desires and wishes, i.e. large number of distinguishable attributes. Combining this with the current apparently more integrated product architecture which typically requires custom solutions, it is then as stated that to accommodate the customer then a lot of part and subsequent part numbers are created with only minor deviations between them. Additionally, this puts further strain on development, such as for software as was previously mentioned with the expressed opinion of an overly integrated architecture leading to complex dependencies and in turn resulting in lengthy testing, debugging and overall development.

As was directly suggested, adopting a modularization strategy and in extension a more modular architecture into their existing platform strategy could alleviate the part and part number issue as well and development related issues. By modularizing their architecture and constraining functions within geometrically defined modules they drastically reduce dependencies resulting in easier testing and debugging for software development where now theoretically only the module itself, i.e. sub-system, needs to be tested reducing the compulsion for system tests. The modular architecture and decreased dependencies between parts and functions should also decrease the number of parts and part numbers necessary to be developed in a project, as is stated by Magnusson and Pasche (2014). This is as with less dependencies given by the standardized interfaces of modules then theoretically the required adaptations for each part due to its neighboring ones, geometrically or functionally, should also be less.

Additionally, modularizing their product also enables other means of reducing lead time than directly solving or mitigating the issues above, as outlined by the following most notable examples. First, modules from past projects can be re-used given that newer interfaces do not deviate excessively, which was highlighted by Thomke and Fujimoto (2000) and Crawford and Di Benedetto (2011) as re-usage of components was important for reducing lead times of development projects. Although, this requires time and effort to search old projects for suitable modules the overall time gains by skipping a development phase should outweigh the extra pre-development work. Secondly, as the number of dependencies is inherently lower in a modular architecture and those dependencies are sufficiently defined in the interfaces between modules, then this means that development of modules can be done relatively independently. Due to this independence, parallel development of modules is enabled, as stated by Persson and Åhlström (2013). However, this opportunity relies on the interfaces being sufficiently well-defined to minimize required coordination and communication between module development. This approach does require additional time and effort in the pre-development stage to define said interfaces, but even with this added time the overall lead time should be lower given the reductions from parallelizing module development. Note, this type of parallelization arguably differs from the type concerning cross-functional communication and the "Integrated Problem-solving" example from Wheelwright and Clark (1992). In "Integrated Problem-solving" upstream and downstream activates are parallelized, essentially compressing the existing workflow. However, with parallel development of modules then activates are instead decoupled allowing them to be done in parallel and creating parallel workflows. The upstream and downstream activates in these parallel workflows could then potentially also be parallelized, as in "Integrated Problem-solving", further reducing lead time. Furthermore, as described by Magnusson and Pasche (2014), modularization in combination with platforms can circumvent the otherwise often assumed trade-off between customizability and cost. Thus, modularization can complement the company's existing platform strategy and bring additional advantages other than those relating to lead time reduction.

In summary, adopting a modularization strategy is not only a good complement to the company's existing platform strategy by circumventing the often-assumed tradeoff between customization and cost, but can also mitigate some of the pre-development related issues. Namely, product variety and product complexity. Additionally, it can further reduce lead time by allowing for parallelization. This parallelization then also synergizes with upstream and downstream activity parallelization pertaining to the proposed actions of cross-functional integration, potentially further reducing lead time.

5.4 Testing and prototyping

The phase of development projects with design-build-test- or problem-solving cycles using testing and prototyping were brought forward in literature and in practice as an important area of improvement. Likewise, it was one of the main issues expressed by interviewees.

5.4.1 Comparing empirical findings and theory

The case company has a large focus on testing in complete full-scale test objects, which acts as a bottleneck for the projects due to the limited capacity in relation to the demands. Furthermore, there is limited sub-system level testing according to interviewees, which contrasts to both Wheelwright and Clark (1992) and the V-model (INCOSE, 2023) about how the system decomposition level of tests should vary over the project. Other issues pertaining to large test objects when comparing to the literature are the high cost and high number of parts associated with these large test objects, in which low-cost (Wheelwright & Clark, 1992) and prototypes with less parts are generally preferable (Camburn et al., 2017). There were also issues with a tendency to continue development before test results could be integrated into the design and even ordering new tests on those new designs. In other words, there were over-lapping cycles, which is contrary to Wheelwright and Clark's (1992) recommendation on thorough closure of cycles.

One of the two major sub-issues of the other main issue of software was the testing, where the problems brought up reflected those mentioned above. In other words, the bottleneck of accessing the large test objects for testing, limited system decomposition for testing and overlapping testing cycles. Thus, improvements to testing overall, which can free up capacity or increase testing cycle speed, would consequently improve the software development pace.

At the other end, the case company themselves have recognized the need for increased small-scale testing and the use of technology in supporting that to alleviate the demand on the large test objects and support in more rapid problem-solving, i.e. in line with the recommendations in theory on iterative development, such as by Thomke and Fujimoto (2000). However, with regard to the use of technology, it was mentioned that currently virtual tests often needed to be complemented with physical ones.

5.4.2 Identifying potential actions

Viewing the issues mentioned by interviewees and the gaps to literature, decreasing the use of testing on large test objects through increasing the use of testing on sub-system and component level is promising. First, it would alleviate the capacity of the full-scale test objects and second, based on the literature, aid in improving the efficiency and effectiveness of the problem-solving cycles. With regard to the former, attaining the large test objects is mentioned as expensive and time-consuming, and multiple parties wanting access to the same, point towards simply increasing the number of them as not enough. Furthermore, the argument is strengthened by the latter, which has the potential to enable the use of cheaper and faster testing cycles when advanced technology is used, such as virtual testing, and have fewer parts involved (Camburn et al., 2017), using e.g. rigs. An increased speed would then mitigate the issue of non-closed cycles as results are given swiftly rather than after having waited for access to the large test object. Additionally, the literature strongly suggested the use of testing covering all of the system decomposition levels, which some interviewees also mentioned as an area of improvement. Connecting back to the modularization strategy and software, if a modular architecture is adopted, then sub-system tests become natural as functionality contained within modules are essentially sub-systems which can be tested independently.

Furthermore, part of successful cross-functional integration is having fast problem-solving cycles. This is to be able to avoid lengthy conflict between functions of what solutions is better for the product, customer, etc. by simply testing which is better. Additionally, as suggested by some interviewees, for example early mock-ups can act as joint problem-solving Improving the testing at the company is then also to some extent part of successful cross-functional integration.

Conclusively, solving the testing and problem-solving issues are then not only beneficial for the sake of testing and problem-solving itself, but coordination and software development as well. Circling back to the section on pre-development, an improvement could also aid in increasing the maturity in early phases.

Table 5.5: Potential actions and their respective reasoning in relation to teams and organizational structure

Potential actions	**Reasoning**
Increase sub-system level testing	Alleviate capacity issues with the large test objects & improve problem-solving efficiency and effectiveness
Increase component level testing	Alleviate capacity issues with the large test objects & improve problem-solving efficiency and effectiveness
Increase use of advanced technology for testing, e.g. different types of virtual testing	Support the above
Increase use of simpler prototypes, e.g. rigs, mock-ups or mules	Support the above
Adopt modularization strategy	Support the increase of sub-system level testing

5.5 Overview of potential actions (RQ2)

RQ2: *Based on the identified issues, combined with insights from relevant literature and industry best practices, what potential actions exist for the case company to reduce future development projects' lead times?*

The main issues have been explored in-depth by themselves resulting in the following Table 5.6 that gives an overview of all the potential actions to reduce future development projects' lead times, i.e. answering RQ2. Note that several potential actions connect to multiple main issues, such as capabilities for small-scale tests, showing the interdependency of issues and the complexity of development projects.

Table 5.6: Overview of all potential actions

Issue	Potential actions
Cross-functional coordination	• Parallelize upstream and downstream activates and promote earlier, continuous and face-to-face communication between them and all other functions • Focus on downstream friendliness and error-free deliverables • Develop downstream capability to forecast from upstream • Learn to handle new type of risk from upstream forecasting • Develop downstream capability to cope with unexpected change from upstream • Improve testing and problem-solving capabilities • Promote communicating narratives, considering assumptions and establishing personal relationships across functions
Teams and organizational structure	• Move towards heavyweight teams for platform projects, i.e. give project authority over resources • More dedicated team, at operational level, for select few projects • Co-location of team, operational level included • Foster more generalist skills, gradually increase breath of responsibility & reduce task specialization • Assign owners of sub-systems or components at the operational level • Separate tasks related to a project the individual is assigned to versus other tasks in the PI-planning system • Consider timing of projects for specialists
Pre-development	• More clear specifications, e.g. defining "Friday" and "Monday" • Involving and discussing with project management group earlier • Consider to a greater extent the degree of maturity of solutions that are used as input to the project and how that degree is estimated • Limit scope or less extensive requirements • Discuss port-mortems more and re-use people across similar projects • Improve capabilities for early problem-solving with small-scale tests and rapid problem-solving • Adopt modularization strategy
Testing & prototyping	• Increase sub-system level testing • Increase component level testing • Increase use of advanced technology for testing, e.g. different types of virtual testing

- Increase use of simpler prototypes, e.g. rigs, mock-ups or mules
- Adopt modularization strategy

Conclusively, by combining the main issues from the empirical findings with relevant literature, the above presented proposed actions were formulated, each with the ultimate purpose of reducing lead time in future projects. Additionally, as stated above, there is a high degree of interconnectedness between the proposed actions which in combination with the large sets of actions and resource constraints then can potentially create a complex pursuit for the company. However, which actions to prioritize will be discussed in the next section that covers the answer to RQ3.

5.6 Recommendations (RQ3)

RQ3: *Which of these actions should the case company pursue based on feasibility and potential to reduce the lead times of future development projects?*

The potential actions included in the above Table 5.6 are the result of an analysis where both feasibility but more so potential to reduce lead times have already been considered. In other words, the list has already been curated in the sense that all of the actions show some promise. However, as was mentioned under the other issues, are the resource constraints that underpins many areas. Hence, a prioritization is needed regarding which actions to focus on, both in the short-term and long-term.

Based on the emphasis both by interviewees and in literature, cross-functional coordination stands out as perhaps the main focus area, but it is also closely connected to the aspect of teams and organizational structure. In short, fewer and more dedicated people in the project would benefit focus and ownership, with the latter improving the motivation to bridge the understanding between functions. However, due to the established PI-planning system, the line organization's way of working and engineer's high task specialization there are likely to be hurdles in achieving this. Still, its potential large benefits points towards that it is worth attempting in the short term by having a select few projects with this setup and in the long term by fostering more generalist skills within the organization and evaluating the projects with the aim of gaining acceptance of this way of working. Meanwhile, several of the actions related to cross-functional integration, such as the communications aspects with e.g. increased face-to-face interactions and using narratives, appear more feasible in the sense that they do not involve a re-structuring but rather changes in processes and attitudes, i.e. more soft factors. In other words, while the current set-up of the project's organization is still there, people at the different sub-function could still for example increase presence at the factory in joint problem-solving sessions. However, there are of course challenges associated with this, such as the motivation in doing so, and the implementation should not be underestimated. Still, there also mitigations for such perceived challenges. For example, parallelizing upstream and downstream activates may be perceived as a challenge, but focusing on the outlined capabilities somewhat concretizes and structures the undertaking. Related to the feasibility of parallelization of upstream and downstream, to succeed the company should foster a positive attitude towards the integration were everyone needs to be comfortable in sharing and using preliminary information (Wheelwright and Clark, 1992). Likewise, they need to foster mutual trust and joint responsibility among the functions. These are two examples of the synergistic nature between teams and organizational structure and cross-functional coordination, in that the former would benefit in these aspects. Regarding the internal supplier there are likely to be more hurdles in aspects such as these given the inherent differences of belonging to a different organization within the larger organization. Additionally, the support and engagement of senior management is essential in implementing any potential action and related is also the distribution of representation of the different functions in senior management, i.e. promoting in such a way so as to not overrepresent one function in senior management.

The potential impact on the lead times stemming from the pre-development work is also significant, where the actions have varying degrees of feasibility. Attempting to define requirements more clearly, have discussions with the people executing the project earlier and increasing the sharing of learnings from previous projects all seem to come at relatively low expenses. However, that does not mean it comes without challenges, such as if the discussions still become prolonged without reaching shared and agreed objectives. But on the other hand, limiting scope and requirements touches upon more business strategy level decisions, both of which are out of scope and perhaps more long-term considerations for the case company. The degree of maturity is a similar matter but where an increased recognition and degree of accuracy surrounding the topic would likely benefit decision-making about the project, including the expected length of it.

With regard to testing and prototyping, the ongoing efforts point towards awareness and motivation for addressing several of the actions mentioned. Still, additional considerations for the case company are how the improvement of these capabilities can support other areas, such as the cross-functional coordination, and limited system decomposition relating to the sub-system level. Improving the capabilities for testing and problem-solving is a longer-term initiative, but where some early activities seem possible that involve cheap and rapid prototyping, e.g. mockups.

Concerning adopting a modularization strategy, there are certain factors affecting the feasibility for the case company. One such is the creation of modules and subsequent definitions of interfaces is an area, which Persson and Åhlström (2013) cover. They specifically highlight the importance and difficulty in defining the functional interfaces of modules as otherwise coordination issues might arise. Therefore, the company must put great attention to this step. Especially given the products current complexity which can potentially impair the process of transitioning architecture and resulting degree of complexity. In short, current complexity may prove to technically difficult to translate into modules and subsequently diminish coordination benefits from a modularization strategy. However, evaluating the extent of this feasibility factor relies on hard technical analysis outside the scope of this study, yet it is noteworthy. Moreover, adopting a modularization strategy is a large undertaking requiring large changes and additions to planning, development, product architecture, etc. Nevertheless, it still brings several benefits solving identified issues and synergizing with other proposed actions. Ultimately, it is a prospect in theory worth at least investigating for the sake of reducing lead time.

In summary, the case company should consider all of the proposed actions, particularly given their interconnectedness, where some can be attempted in the short-term while others are more long-term projects and with some needing further investigation, per the above analysis.

5.7 Limitations

Before presenting the conclusion of the study, some important limitations should be considered in relation to the findings and their implications.

To begin with, regarding the sample, multiple people across functions were interviewed reaching a saturation in multiple of the issues but more perspectives could have aided in nuancing some of the findings even further. Particularly, more managers in the line organization could have given additional opinions on for example the aspect of teams and organizational structure. However, several of the interviewees had previous experience from being managers in the line organization, likely aiding in the nuancing to some degree. Additionally, all functions were represented through the functional project managers. Furthermore, there were a lack of interviews with people at internal or external suppliers, which again could have nuanced the picture. However, these where not dealt with extensively in the analysis.

Regarding the studies scope, analyzing the number and mix of projects were out of scope, which several interviewees pointed towards may be an important driver. Furthermore, due to time constraints, software could not be investigated until saturation, not in the literature review nor in the data collection. However, the sub-issues associated with software were linked to other issues for which there were more coverage. Another aspect that was not investigated in detail but that could have been of value for the study, were the strengths of the case company in relation lead times in development projects. The research questions and the subsequent data collection were more focused on the issues. However, strengths were in many interviewees mentioned implicitly or directly in terms of expressing a lack of issues in certain areas in the interview guide's diagram.

Discussing the interview guide, there was careful consideration to not act as leading by beginning with questions similar to RQ1 and RQ2 where the interviewer did not give input beforehand or during on specific topics. Issues mentioned during these uninfluenced questions were given more weight than those prompted by the diagram.

With regard to the presentation of empirical findings, it was a balance between providing a thick description, as advocated by Bell et al. (2022), and maintain anonymity of interviewees at the case company and confidentiality, in line with the ethical principles. The thick description is important for others to assess the transferability (Bell et al., 2022). Discussing transferability, the fact that many of the issues in literature also were found independently in this context both supports the validity of the established theory and that the case company's context is relatively similar to that of other companies undertaking development projects. However, most similarities are to other large and established organizations, as especially seen in the topics of cross-functional coordination and organizational structure.

Finally, it can be mentioned that due to time constraints and the breadth of investigation, i.e. multiple issues and theoretical areas, the depth of each were affected, mainly in relation to the practical aspects of implementation and the assessment of feasibility. It should also be noted that due to the study being qualitative, the data was mainly based on the perception of interviewees, e.g. regarding the size of issues. However, triangulation through observation and documents, e.g. on old time plans of projects, also took place. Additionally, circling back, people from multiple different functions were interviewed, where several of the main issues were mentioned across functions despite the different "thought worlds" Sætra et al. (2024) mentioned.

6. Conclusions

The aim of the study was to identify how the PMO at the case company can change their practices to improve future development projects' lead time, without compromising quality or cost, in order to ultimately increase competitiveness. The study subsequently identified several lead time related issues at the case company. The largest and most extensive main issue concerns the coordination between functions where there were a seemingly limited understanding and insight between them and an unfavorable "over-the-wall" approach to deliverables. This issue is then intimately connected to another large main issue, namely the one regarding teams and organizational structure, which naturally shapes how said coordination is executed. Likewise, the main issue involving the internal supplier was also later connected to this group of issues given its similarities. Moreover, issues pertaining to pre-development were also found, specifically regarding scope and early phase work, making it a main issue. Furthermore, the testing and prototyping was also identified as main issue, including large test objects acting as bottlenecks for the projects. Lastly, many interviews pointed to the software development as a problematic area, with its sub-issues connecting to both of the main issues of testing and prototyping and pre-development.

Combining these issues with best practice found in literature resulted in many possible actions for reducing lead times being identified. Notable areas were cross-functional integration between functions and the internal supplier, a pivot towards heavyweight team structures and greater responsibility, clearer scopes and more thorough early-stage work, and more small-scale test at the sub-system and component levels. The latter two could also both benefit from adopting a modularization strategy. Additionally, mitigating the software issues closely connects to the actions proposed in relation to pre-development and testing and prototyping.

Conclusively, based on the interconnectedness and weighed feasibility of the proposed actions, which was primarily done in the creation of the actions themselves, they should all be considered in the company's pursuit of reducing lead time of their development projects. However, with varying degrees of promise and feasibility, where some can take place in the short-term while others are more long-term endeavors, some of which require further investigation.

Taking a step back, the issues found at the case company were highly similar to those found in literature, strengthening much of existing theory. Additionally, the study emphasized the interconnectedness and importance of taking a holistic approach. As Knudsen et al. (2023) mentioned, companies will continuously need to improve to get new products out faster.

7. References

Armstrong, S. C. (2001). *Engineering and Product Development Management.* Cambridge University Press.

Baker, B. (2007). Definition impossible. *PM Network, 21*(6), 25. https://www.pmi.org/learning/library/functions-project-management-offices-3083

Bell, E., Bryman, A., Harley, B. (2022). *Business Research Methods.* (6th ed.). Oxford University Press.

Borden, K., Küchler, S., Santos, A., Dost, C. (2025, August 19). Automotive product development: Accelerating to new horizons. McKinsey & Company. https://www.mckinsey.com/capabilities/operations/our-insights/automotive-product-development-accelerating-to-new-horizons#/

Buchanan, D. A., & Huczynski, A. A. (2023). *Organizational Behaviour*. (11th ed.). Pearson.

Bstieler, L., & Noble, C. H. (Eds.). (2023). *The PDMA Handbook of Innovation and New Product Development.* (4th ed.). Wiley.

Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., Otto, K., & Wood, K. (2017). Design prototyping methods: state of the art in strategies, techniques, and guidelines. *Design Science, 3*. https://doi.org/10.1017/dsj.2017.10

Cooper, R. G. (1990). Stage-gate systems: A new tool for managing new products. *Business Horizons, 33*(3), 44–54. https://doi.org/10.1016/0007-6813(90)90040-i

Cooper, R. G. (1993). *Winning at New Products: Accelerating the Process from Idea to Launch.* (2nd ed.). Addison-Wesley.

Cooper, R. G. (2019). The drivers of success in new-product development. *Industrial Marketing Management, 76*, 36–47. https://doi.org/10.1016/j.indmarman.2018.07.005

Cooper, R. G. (2022). The 5-th Generation Stage-Gate Idea-to-Launch process. *IEEE Engineering Management Review, 50*(4), 43–55. https://doi.org/10.1109/emr.2022.3222937

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*(5), 513–526. https://doi.org/10.1111/jpim.12314

Crawford, M., & Di Benedetto, A. (2011). *New Products Management*. (10th ed.). McGraw-Hill.

Dubois, A., & Gadde, L.-E. (2002). Systematic combining: an abductive approach to case research. *Journal of Business Research, 55*(7), 553-560. https://doi.org/10.1016/S0148-2963(00)00195-8

Friedman, R. (2021). Five things high-performing teams do differently. *Harvard Business Review Online.* https://hbr.org/2021/10/5-things-high-performing-teams-do-differently

International Council on Systems Engineering [INCOSE]. (2023). *Systems engineering handbook: A guide for system life cycle processes and activities* (5th ed.). Wiley.

Knudsen, M. P., Von Zedtwitz, M., Griffin, A., & Barczak, G. (2023). Best practices in new product development and innovation: Results from PDMA's 2021 global survey. *Journal of Product Innovation Management*. 40(3), 257–275. https://doi.org/10.1111/jpim.12663

Lorsch, J. W., & Lawrence, P. R. (1965). Organizing for Product Innovation. *Harvard Business Review*, *43*(1), 109–122.

Magnusson, M., & Pasche, M. (2013). A Contingency-Based approach to the use of product platforms and modules in new product development. *Journal of Product Innovation Management, 31*(3), 434–450. https://doi.org/10.1111/jpim.12106

Persson, M. & Åhlström, P. (2013) Product modularisation and organisational coordination. *International Journal Automotive Technology and Management, 13*(1), 55–74. https://doi.org/10.1504/IJATM.2013.052779

Rizvi, A., Hepp, D., Jana, P., Büchner, F, Geßler, F., & Feike, J. (2025). Winning the automotive software development race. McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/winning-the-automotive-software-development-race#/

Robertson, D, & Ulrich, K. (1998). Planning for product platfroms. *MIT Sloan Management Review, 39*(4), 19-31.

Roland Berger. (2025, June 18). Unlocking speed & cost: Lessons from China's competitive edge. https://www.rolandberger.com/en/Media/Unlocking-speed-cost-Lessons-from-China-s-competitive-edge.html

Scaled Agile Framework [SAFe]. (n.d.). Welcome to the Scaled Agile Framework: Big Picutre. Retrieved May 4, 2026 from https://framework.scaledagile.com/#big-picture

Schilling, M., Hill, C. (1998). Managing the new product development process: Strategic imperatives. *The Academy of Management Executive. 12*(3). 67–81. https://doi.org/10.5465/ame.1998.1109051

Schreiber, D., Brundin, N., Keller, V. Schmitz, K., Kolk, M., Parkin, R., Gui, J., Trancart, D. (2026, February). China Speed. Arthur D Little. https://www.adlittle.com/en/insights/viewpoints/china-speed

Schwarz, G., & Stensaker, I. (2014), Time to Take Off the Theoretical Straightjacket and (Re-)Introduce Phenomenon-Driven Research. *The Journal of Applied Behavioral Science 50*(4), 478-501. https://doi.org/10.1177/0021886314549919

Sommer, A. F., Hedegaard, C., Dukovska-Popovska, I., & Steger-Jensen, K. (2015). Improved Product Development Performance through Agile/Stage-Gate Hybrids: The Next-Generation Stage-Gate Process? *Research-Technology Management, 58*(1), 34–45. https://doi.org/10.5437/08956308x5801236

Steiber, A., & Teece, D. (2025, May 29). Shifting gears: How China is outpacing the global automotive competition [Blog post]. California Management Review https://cmr.berkeley.edu/2025/05/shifting-gears-how-china-is-accelerating-past-the-global-automotive-competition/

Sætre, A. S., Edmondson, A. C., Dregelid, O., & Zimmer, S. R. (2024). Psychological ownership for overcoming departmental barriers to innovation: A Study of innovation handoffs. *Journal of Engineering and Technology Management, 73*, 101831. https://doi.org/10.1016/j.jengtecman.2024.101831

Thomke, S., & Fujimoto, T. (2000). The effect of "front-loading" problem-solving on product development performance. *Journal of Product Innovation Management, 17*(2), 128–142. https://doi.org/10.1016/s0737-6782(99)00031-4

Ulrich, K. (1995). The role of product architecture in the manufacturing firm. *Research Policy 24*(3), 419-441.

Waber, B., Magnolfi, J., & Lindsay, G. (2014). Workspaces that move people. *Harvard Business Review, 92*(10), 69-77

Wheelwright, S. & Clark, K. (1992). *Revolutionizing Product development: Quantum leaps in Speed, Efficiency and Quality.* The Free Press.

Appendix

Appendix A - Interview guide (English)

Introduction

”Thank you for partaking in this interview for our master thesis!”

- Present us and the work:
    - *“The purpose of our study is to investigate the potential to reduce lead times in development projects”*
- Anonymity: Title, alternatively adjusted title
- Can we record?
- Background questions:
    - In short, what is your role, for how long have you had it and what does it involve?
    - Can you give a short summary of your background, for example previous jobs or education? This is only for the purpose of gathering context.

Potential interviewee-specific questions

- …

Factors affecting lead time

”Now we approach the core part of the interview - lead times of development projects. To get an answer that is not influenced by the questions we are to ask later we will begin by asking…”

- What do you perceive as the largest problems causing the projects to prolong in time?
- What do you think can be done differently to accelerate the projects?

Potential interviewee-specific questions

- …

Diagram

"We have created a diagram with the different areas relevant for managing development projects as an aid in the discussion regarding problems and potential improvements…"

- In which area or areas do you see problems or potential improvements related to lead time?
- If you were to rank, in which do you see the largest problem or potential improvement?
- Are there additional areas we should add?

Potential interviewee-specific questions

- …

Closure

"Before we end..."

- Is there anything we have forgotten to ask?
- Is there anyone else we should talk to?

"Once again, thank you!"

Appendix B - Interview guide (Swedish)

Inledning

"Stort tack för att du vill ställa upp på intervju för vårt masterarbete!"

- Presentera oss och arbetet:
  - *"Vårt arbete har kortfattat syftet att undersöka hur ledtiderna på utvecklingsprojekten kan kortas ned"*
- Anonymitet: Titel, alternativt justerad titel
- Får vi spela in?
- Inledande bakgrundsfrågor:
  - Kortfattat, vad är din roll, hur länge har du haft den och vad innebär den?

- Kan du ge en kort sammanfattning av din bakgrund, exempelvis tidigare jobb eller utbildning? Det är bara för att vi ska få lite kontext.

Potentiella specifika frågor för intervjuperson

- …

Faktorer som påverkar ledtid

”Nu går vi då in på kärnan – ledtider på utvecklingsprojekt. För att få ett svar ofärgat av frågorna vi kommer ställa senare så frågar vi nu först lite kort...”

- Vad ser du är de största problemen som leder till att projekten tar lång tid?
- Vad tror du man hade kunnat göra annorlunda för att snabba på projekten?

Potentiella specifika frågor för intervjuperson

- …

Diagram

“Vi har satt ihop ett diagram här på olika områden när man leder utvecklingsprojekt som stöd för att diskutera kring var det finns problem eller förbättringspotential ...”

- I vilken eller vilka ser du att det finns problem eller förbättringspotential relaterat till ledtid?
- Om du skulle ranka på ett ungefär, i vilka ser du störst problem eller förbättringspotential?
- Är det andra områden som vi borde lägga till?

Potentiella specifika frågor för intervjuperson

- …

Avslutning

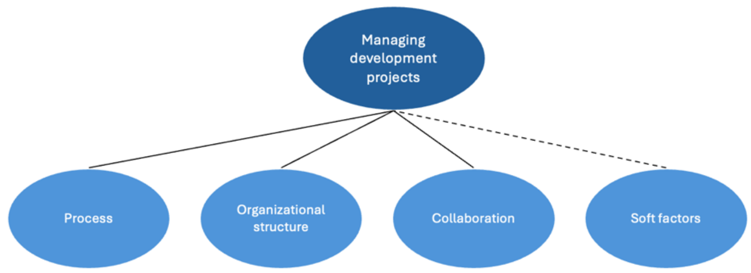
”Innan vi avslutar...”

- Är det något vi missat att fråga?
- Är det någon annan du tror vi borde prata med?

"Återigen ett stort tack!"

Appendix C - Diagram for interview guide

Slide 1



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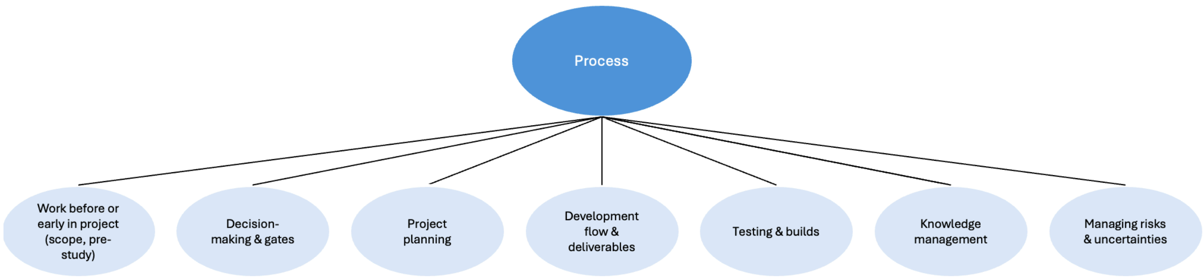

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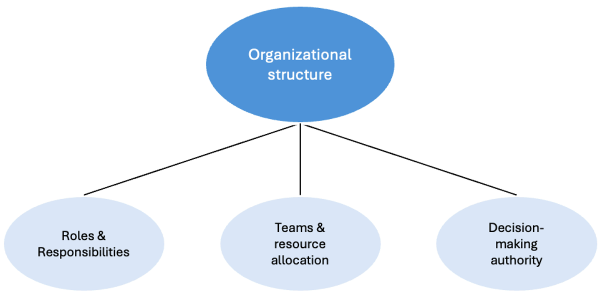

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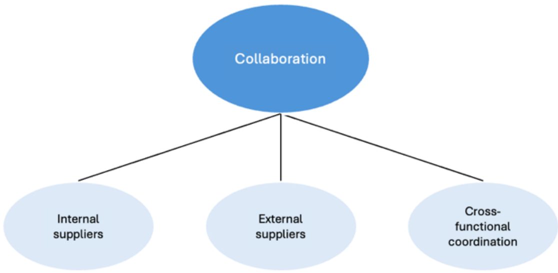

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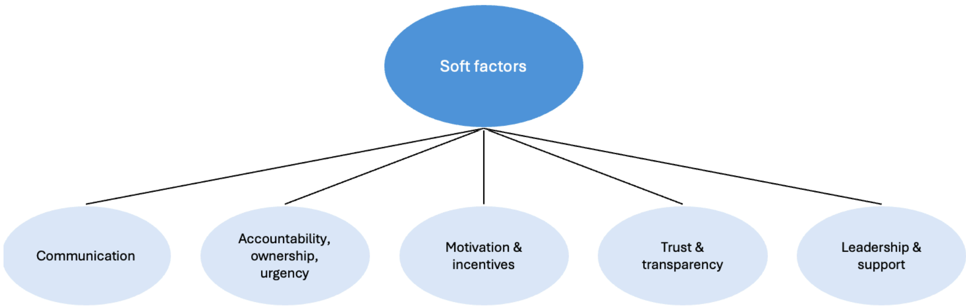

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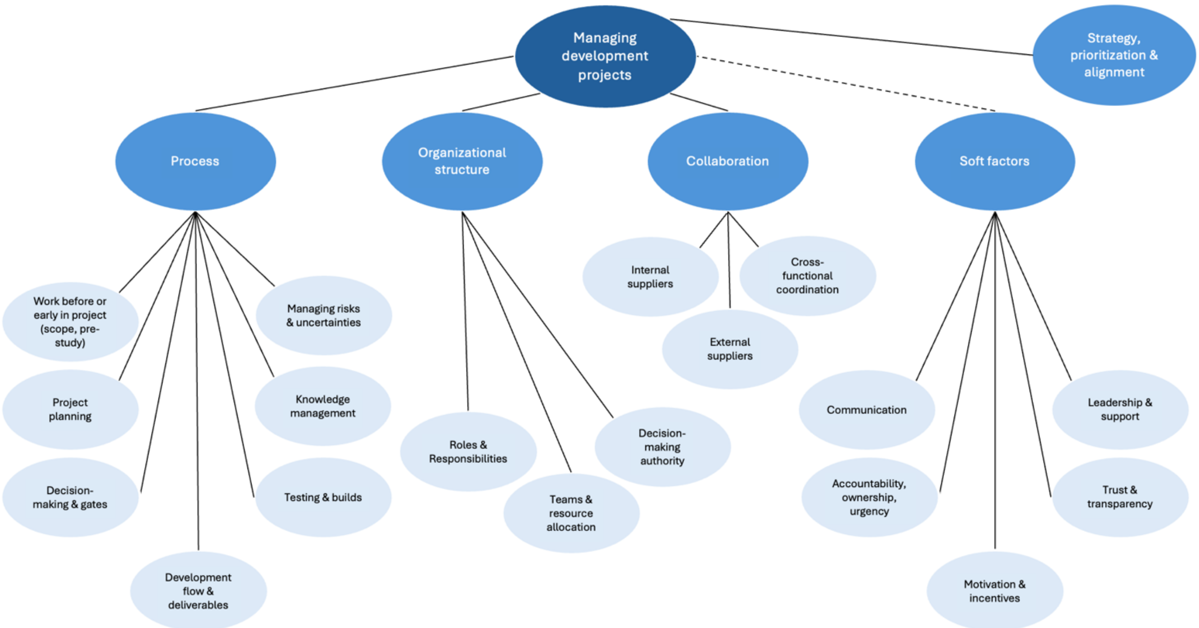

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