Understanding the Process Management of Product Platform Development for Industrialised Construction Companies : An Ecosystem Orchestrator Perspective

Construction Management and Engineering (CME)
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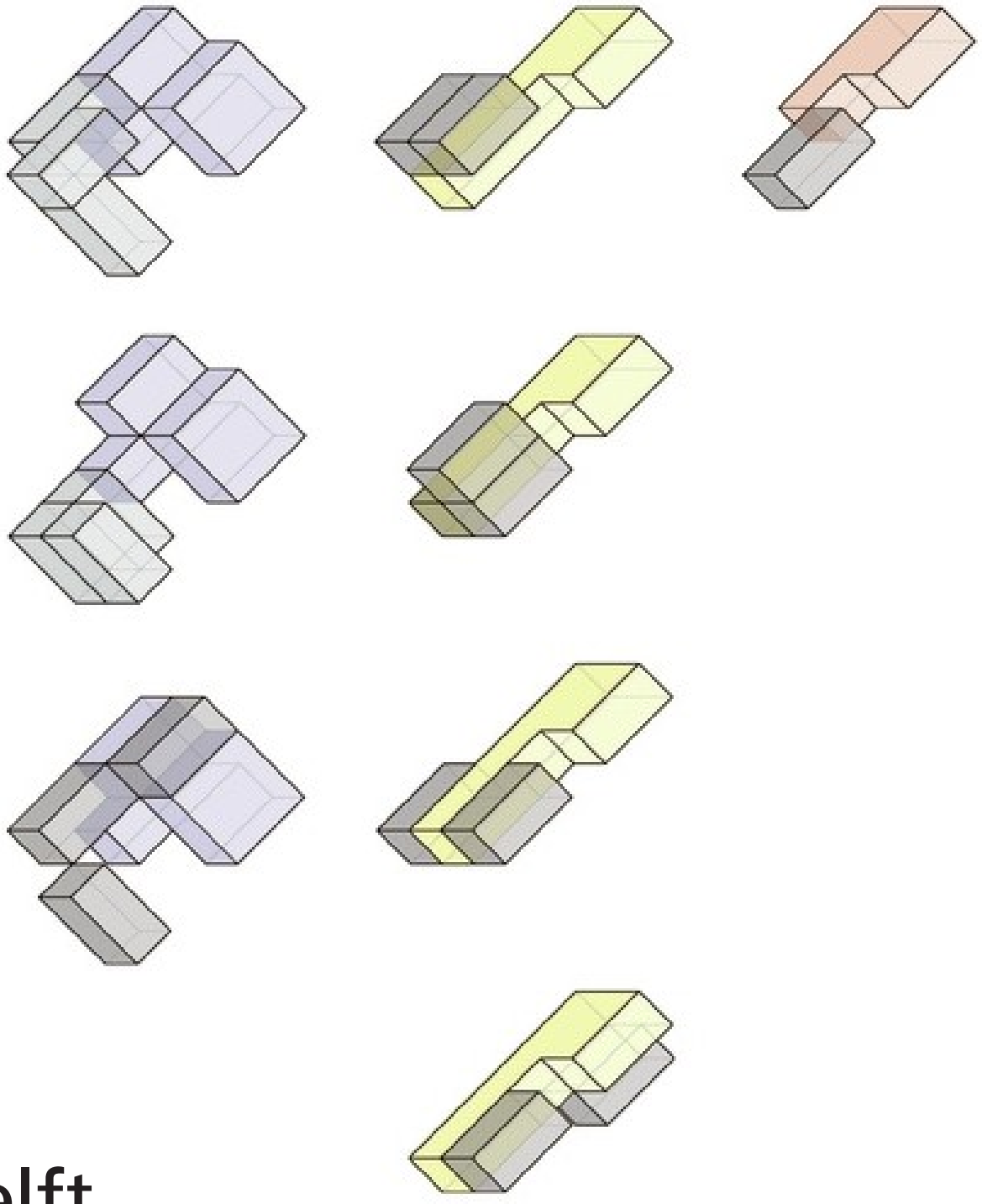

Delft University of Technology

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Understanding the Process Management of Product Platform Development for Industrialised Construction Companies : An Ecosystem Orchestrator Perspective

By

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Preface

This master's thesis represents the culmination of my studies in the Construction Management and Engineering master's program at TU Delft. My journey has been challenging yet rewarding, and one which has helped me to grow personally and professionally. I extend my deepest gratitude to all those who have been a part of this remarkable journey.

My interest in this research topic stemmed from a deep concern for the fragmented nature of the construction industry and its impact on productivity in a resource-constrained world. This led me to focus on exploring strategies for better collaboration within the industry, aiming to achieve sustainable business outcomes. Throughout this journey, I have been fortunate to engage with a variety of professionals, academics, and practitioners whose insights have greatly enriched my understanding of the subject.

I would like to express my deepest gratitude to my thesis committee, whose guidance, expertise, and encouragement have been invaluable in shaping this work. My sincere thanks to Dr. ir. Eleni Papadonikolaki for her steadfast support from the very beginning. A heartfelt thanks to Dr. Daniel Hall for his continuous supervision throughout the research, including connecting me with his colleagues for the case studies. I am also deeply grateful to Dr Johan Ninan for his valuable insights and feedback at every stage. I sincerely hope that none of you feel that your advice has been taken for granted. I have endeavoured to reflect my gratitude through my work, and I hope it shows.

I would like to thank all interview participants from all three companies for their cooperation and for providing me with significant insights on the topic. Thank you for having me and for the warm welcome and support.

This work is dedicated to my family, whose unwavering belief in the power of education and relentless hard work have been my guidance. Their belief in my abilities has kept me determined throughout this process. I am here today because of my family's expectations, and I dedicate this accomplishment to them with immense gratitude. Moreover, my most sincere thanks to my friends both in the Netherlands and Indonesia, who have been a constant source of support for my entire master's journey.

As I embark on the next phase of my journey, I carry forward the skills and knowledge gained during this master's program. I am eager to apply these learnings in contributing to a more sustainable construction industry. The journey does not end here; rather, it serves as a stepping stone to a future where the principles of sustainability and innovation continue to guide my path.

It is my hope that this thesis not only adds to the existing body of knowledge but also inspires further research and action in the field of industrialised construction, particularly in product platform development. I wish you a pleasant read!

- Tharina Nursalika Adhyati
Delft, Netherlands
September 2024

Executive Summary

Introduction and Problem Statement
The AEC industry's labor-productivity growth has been stagnant at 1% per year for the previous two decades, lagging considerably behind the growth rates of the global economy (2.8%) and the manufacturing sector (3.6%). One of the factors for stagnant growth is the fragmented project-based nature, which makes it difficult to apply lessons learned and optimise processes across projects. Several strategies have been suggested to address fragmentation, including re-application of industrialised ways of working.

In the industrialised construction environment, the adoption of a platform-based strategy offers considerable advances, particularly in improving process management. However, there is still a lack of understanding of the ability of product platforms to contribute to sustainable competitive advantages for a company. Furthermore, the firm-level research direction remains relatively immature, and platform aspects for platforming are considerably less understood. The objective of this research is to explore and understand how to develop and manage a product platform, with a focus on enhancing ecosystem collaboration to address industry fragmentation and enhance business efficiency. Furthermore, the research also looks at the influence of ecosystem conditions and internal capabilities on the decision-making process of product platform development. The main research question is :

"How do industrialised construction companies enhance ecosystem collaboration in product platform development?"

Methodology
Four sequential steps were conducted to answer this question. First, understanding the fundamental concepts of product platforms, ecosystem dynamics, and partner alignment mechanisms was achieved through a literature review. This provided the theoretical foundation needed to examine the role of industrialised construction companies in developing product platforms and orchestrating ecosystem alignment. Next, insights into how industrialised construction companies approach product platform development were gained through semi-structured interviews with 12 respondents from three European industrialised construction companies. Secondary data supplemented these interviews gathered through data triangulation from company websites, social media, webinars, and other publicly available sources, offering a broader understanding of the companies' strategies and ecosystem structures, such as how they manage boundaries within their ecosystems. The triangulation of data helped validate the findings from the interviews, offering a more comprehensive understanding of how companies align with ecosystem partners and manage internal and external boundaries during product platform development. Then, followed by an analysis that focused on the use of orchestration mechanisms such as standardisation, nurturing, negotiation, and ownership, revealing how different roles, such as keystones and niche players, influence their approach to platform development. Furthermore, a cross-case analysis was conducted to compare findings across the three companies. This analysis identified patterns and differences in how companies manage ecosystem boundaries, partner alignment, and platform development. Finally, an orchestration mechanism framework (see Figure 1) was developed to guide industrialised construction companies in aligning their partners to enhance their ecosystem collaboration.

Findings
The findings from this research highlight key insights into the product platform development process within industrialised construction companies. Companies adopt iterative strategies, either focusing deeply on specific segments or expanding their portfolios gradually. The introduction of new roles, such as product managers and designers, and the influence of company size are significant factors in platform development. Larger companies like Company C face more complexity, while smaller firms

like Company B achieve higher levels of platform mobilisation through focused efforts. Additionally, product platforms serve as negotiation tools, leveraging ownership for favourable terms with partners. The research also shows that companies apply orchestration mechanisms—standardisation, nurturing, negotiation, and ownership—differently based on their roles within the ecosystem, with keystones like Company A and C emphasising standardisation and niche players like Company B focusing on negotiation. Ultimately, effective orchestration and strategic collaboration are essential for successful platform development and long-term ecosystem alignment.

Discussion

The discussion highlights several key insights into product platform development in the industrialised construction company. Companies develop product platforms iteratively, using evolving elements to address specific project needs. The introduction of new roles, such as product managers and designers, is essential for managing platform development, especially in larger companies like Company C. While company size influences platform strategies, it does not solely determine platform mobilisation. Smaller companies like Company B can achieve higher levels of platform development through focused efforts. Additionally, the product platform itself can serve as a negotiation tool, leveraging ownership to secure favourable terms with partners. The orchestration mechanisms—standardisation, nurturing, negotiation, and ownership—are applied differently depending on a company's role as a keystone or niche player. Company A and C focus on standardisation, while Company B excels in negotiation but lags in nurturing. Finally, ecosystem differences reflect each company's strategic focus, with keystone players orchestrating project delivery and niche players providing specialised services. Together, these insights emphasise the need for companies to balance their use of orchestration mechanisms to ensure ecosystem alignment and long-term success.

Recommendations

This study has limitations that must be acknowledged. First, the constrained research timeframe limited the number of interviews conducted, potentially restricting the depth of insights into orchestration management and leaving some key ecosystem stakeholders unrepresented. A more comprehensive study involving all stakeholders would provide a fuller understanding, particularly regarding intellectual property sharing. Additionally, the focus on three European industrialised construction companies with similar business models limits the generalisability of the findings.

Therefore, future research should explore the relevance of using product platforms as leverage in the intersection of ownership and negotiation mechanisms across different ecosystems. Studies should also investigate companies with varied business models, such as physical dominators as ecosystem orchestrators, to assess how business models influence the use of orchestration mechanisms. Quantifying the distribution of these mechanisms across different company types will provide further insight into their role-specific priorities. Additionally, conducting case studies with full participation from all ecosystem actors would offer a holistic view of ecosystem dynamics.

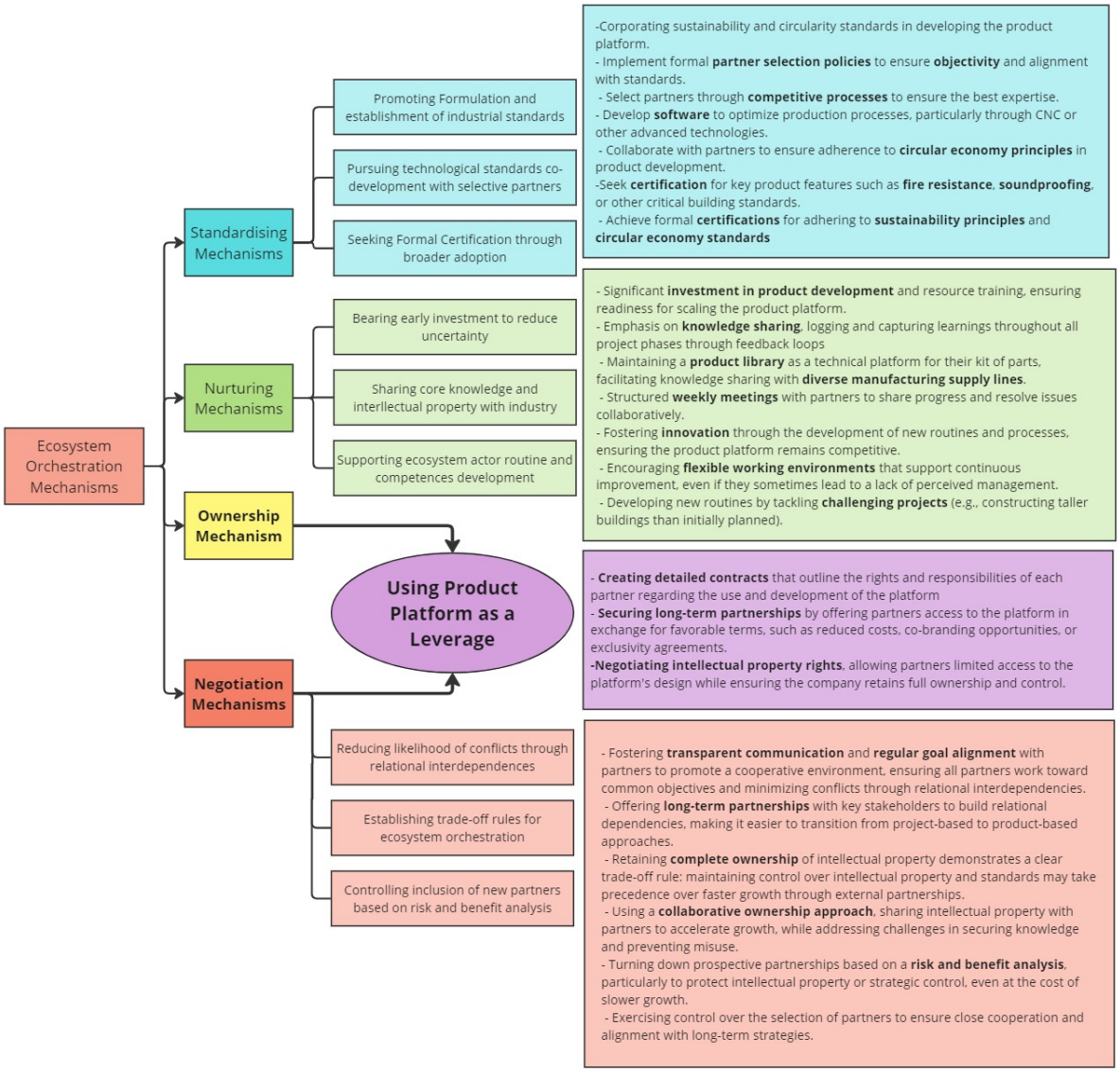

Figure 1: Orchestration Mechanism for Industrialised Construction Companies in Developing Product Platform

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Nomenclature

Abbreviations

Abbreviation	Definition
AEC	Architecture, Engineering, & Construction
ATO	Assemble-to-Order
BDS	Building Delivery System
CNC	Computer Numerical Control
CODP	Customer Order Decoupling Point
CTO	Concept-to-Order
ETO	Engineer-to-Order
IP	Intellectual Property
ISA	International Standard Atmosphere
LCA	Life Cycle Assessment
LVL	Laminated Veneer Lumber
MEP	Mechanical, Electrical, Plumbing
MTO	Make-to-Order
MTS	Make-to-Stock
R&D	Research and Development

1

Introduction

This chapter presents an overview of global issues and how the construction sector contributes to them. To deal with the issues, industrialisation construction is seen as one of the promising solutions. Product platform development as part of industrialisation construction is thus the primary focus, and the problems that need to be discussed are presented. The research questions are then formulated following the research gap and research objective. This chapter lays the foundation for understanding the significance of the research's background.

1.1. Background

Industry Challenges and Environmental Impacts

Based on the (McKinsey & Company, 2017) report, two significant developments highlight the need for reform in the Architecture, Engineering, and Construction (AEC) sector. First and foremost, buildings account for 30% of global greenhouse gas emissions, demanding a sustainable construction approach. Second, the AEC industry's labor-productivity growth has been stagnant at 1% per year for the previous two decades, lagging considerably behind the growth rates of the global economy (2.8%) and the manufacturing sector (3.6%). One of the factors for stagnant growth is the project-based nature, which makes it difficult to apply lessons learned and optimise processes across projects. The project-based delivery model in construction has led to fragmentation in three dimensions: horizontal, vertical, and longitudinal (Jones et al., 2022). Tan et al. (2012) highlighted that the construction industry often experiences knowledge loss, mainly because learning and work processes are not integrated, a problem worsened by longitudinal fragmentation.

Industrialised Construction

Several strategies have been suggested for addressing those challenges, including increasing the use of digital technologies and the re-application of industrialised ways of working (Thuesen and Hvam, 2011). Platform thinking is a widely recognised strategy in product-oriented industries, where it is used to achieve economies of scale through product standardisation. In the context of construction, industrialised building applies technology and principles from advanced manufacturing and digital delivery to enhance sustainability in the building process (Zhou, 2024). Therefore, firms need to assess a strategy to derive products achieving economies of scale and scope by developing and deploying a product platform (Zhou, 2024). Harland et al. (2018) mentioned several benefits of product platforms, such as accelerating product development, decreasing development costs, and expanding product variety.

Product Platform

The product platform is applied in the design phase, which makes engineering a crucial activity unconfining the platform and preventing project-based development of new variants (Jansson et al., 2014). Robertson and K. T. Ulrich (1998) defined a product platform as the collection of assets (i.e. components, processes, knowledge, people, and relationships) that are shared by a set of products (for an example, see Figure 1.1). They constituted modular product architectures (kit of parts), interfaces, and standard design rules for a building project, indicating potential benefits on cost and productivity. Chan

(2020) stated that platforms that connect users on the demand side and providers on the supply side can help address failures in the market, while the rise of the sharing economy can help democratise the production process. The product platform covered the importance of maintaining a balance between platform knowledge, relationships, and technical aspects (Jansson et al., 2014). Cao et al. (2021) and Gan (2022) explained that modules, or components, can be pre-engineered and specified prior to design and manufacturing through digital delivery, with predefined interfaces that allow for varying levels of prefabrication and different combinations of structural, mechanical, plumbing, and other modules. Zhou (2024) suggested that product platforms can incorporate design rules into the development process for industrialised buildings by efficiently reusing existing knowledge and processes. Therefore, product platforms offer the potential to address fragmentations in construction, especially longitudinal fragmentation that occurs from project to project.

Figure 1.1: Example of Product Platform from the Automotive Industry (Source : engineering.com)

Challenges

Product platform implementation faces several challenges across various industries. The traditional rigid design modes struggle to meet diverse user needs, necessitating a shift towards resilient design approaches that can adapt to continuous improvement. One of the challenges is balancing the focus on the project's uniqueness with the economies of scale created by standardisation (Jansson et al., 2014). Furthermore, Gibb (2001) stated that standardisation is effective by ensuring component accuracy and interchangeability, making the interfaces between components crucial for standardisation efforts. Additionally, when working as an engineer, the task is not to optimise the engineering work only but also to balance the solutions for the success of the entire platform (Jansson et al., 2014). This challenge of handling standardisation and flexibility is central to platform strategies. Another challenge is the potential need for extensive organisational restructuring to support the change to a platform strategy, particularly in industries with diverse customer requirements (Weidmann et al., 2016).

The same challenges also occur in the construction industry. Even though platforms have begun to emerge in the AEC sector (Chan, 2020), the fragmented nature of the construction industry complicates collaboration between stakeholders (Kennedy et al., 2023). The fragmentation of the construction industry is based on several factors, one of them being the conservatism of employees of the building site (Bougrain et al., 2010). Platforms are not very easily implemented in the construction industry since there is a strong instituted principle in the construction industry to avoid standardised solutions and off-the-shelf design of buildings (Styhre and Gluch, 2010). Changing from a project-based approach to a product-based approach also introduces challenges across various functional areas, such as managing the differing interests of stakeholders like platform owners, complementors, and end-users, which can result in conflicting institutional priorities (Altman and Tushman, 2017).Given these complexities and uncertainties, industrialised construction firms may struggle to align platform elements while addressing unpredictable customer demands during platform development and deployment (Zhou, 2024). To ensure platform success, industrialised construction companies must adopt a comprehensive strategic approach and ensure company-wide coordination to maximise the benefits of their investments in product platforms (Harland et al., 2018).

1.2. Problem Definition

In the industrialised construction environment, the adoption of a platform-based strategy offers considerable advances, particularly in improving process management. However, the fragmented nature of the construction industry leads to inefficiencies, knowledge loss, and difficulties in standardising processes across projects. The dynamic nature of the project adds complexity to the successful implementation of platform strategies. Thus, a closer evaluation of the transformation strategies is necessary to understand how the alignment of various stakeholders impacts the platform's success. Many studies have analysed ways of organising partner alignment from an ecosystem perspective, but not in the construction industry. According to Vosman et al. (2023), an ecosystem perspective offers the potential to investigate the construction ecosystem dynamics and an ability to understand the complexities of stakeholders' interrelationships further. Understanding this dynamic is important for implementing and scaling a platform-based approach in the construction industry.

Moreover, Harland et al. (2018) argue that there is still a lack of understanding on the ability of product platforms to contribute to sustainable competitive advantages for a company. Being able to negotiate both inside and outside of its boundaries continually is one approach a business may use to sustain a competitive advantage and is a key strategic driver (Caputo et al., 2018). The boundaries define the extent to which a firm can manage and control its resources and capabilities. Chan (2020) stresses the importance of understanding platform development as a process rather than an end goal.

Given these issues, there is a need to explore how industrialised construction companies can develop and manage product platforms to address industry fragmentation and enhance business efficiency. This includes analysing how to handle the complexities arising from the dynamic nature of projects. Additionally, understanding how firms can manage their ecosystem boundaries is part of maintaining competitive advantages and implementing platform strategies. The influenced factors of decision-making within firms and how these decisions impact platform development also need to be identified. As Zhou (2024) mentioned, more in-depth future research can explore aspects that might influence the decision process. The decision-making process will give insight into the actors's perspectives and the decision's impact on the product platform development.

1.3. Research Objective and Scope

Platforming strategies for construction products, including platform development and deployment, have been explored. However, the firm-level research direction remains relatively immature, and platform aspects for platforming are considerably less understood, i.e. the development and deployment in various market segment conditions (Zhou, 2024). The objective of this research is to explore and understand how to develop and manage a product platform, with a focus on enhancing ecosystem collaboration to address industry fragmentation and enhance business efficiency. This involves identifying the key components and principles to develop a product platform within the construction industry. Furthermore, the research also looks at the influence of ecosystem conditions and internal capabilities on the decision-making process of product platform development. By analysing these factors, the research will give insights and guidelines for industrialised construction companies to change from traditional project-based approaches to an integrated product-based model. Additionally, understanding alignment strategies among actors in the ecosystem might help industrialised construction companies manage the complexities of platform implementation. There are several key points analysed in the research, which are :

- Key components and principles to have a good product platform development for industrialised construction companies.
- Ecosystem conditions and internal capabilities that influence the company's decision-making process and routine procedures in developing the product platform.
- Process management in managing the product platform development and alignments with other actors in the ecosystem.

Based on the research objective, there is a need to investigate strategies to develop a product platform by industrialised construction companies. The research was designed to answer the main research question as follows.

"How do industrialised construction companies enhance ecosystem collaboration in product platform development?"

To answer the main question, the following sub- questions are formulated.

a. **What is the process flow in product platform development?**
This sub-question aims to gain an understanding of the process involved in creating or developing a product platform, which is essential for setting the foundation for a successful product platform and effective collaboration. This involves the understanding of product platform concepts and principles, such as its components and capabilities, to address the construction industry's fragmentation.

b. **How do industrialised construction companies manage boundaries in the ecosystem to develop their product platform?**
This sub-question focuses on identifying existing boundaries in the industrialised construction company's ecosystem. Furthermore, this question explores how industrialised construction companies develop their product platform by managing the boundaries by setting their business model strategy, including considering internal and external factors that influence decision-making.

c. **How do industrialised construction companies ensure ecosystem alignment to enhance ecosystem collaboration?**
This sub-question aims to explore how companies align their partners with the company's goals of product platform development. By implementing the proposed orchestration mechanism, industrialised construction companies can enhance collaboration within the ecosystem, ensuring that partners are aligned and working towards shared objectives in product platform development.

1.4. Research Outline

Chapter 1 : Introduction
This chapter serves as an introduction to the problem statement, the research questions, the scope of the thesis, and expected research contributions.

Chapter 2 : Literature Review
This chapter provides insights into the specific concepts of product platform development, its process management, the company's role and responsibilities in the platform ecosystem, and digital system integrator as a business model.

Chapter 3 : Methodology
This chapter outlines the approach of the research, which is multiple case studies. Followed by the elaboration of data collection, data processing, and data analysis in the subsequent sections.

Chapter 4 : Case Studies
This chapter presents the findings of the research. The findings are organised to provide an overview of the industrialised construction company's product platform, followed by its process to develop the product platform.

Chapter 5 : Analysis
This chapter presents a cross-case analysis of the cases that look into research objectives.

Chapter 6 : Discussion
This chapter addresses the discussion, including the limitations, novelty, and implications of the research derived from the cross-case analysis conducted in the previous chapter.

Chapter 7 : Conclusion
This chapter concludes the thesis by elaborating the research findings in accordance with the research question and ends with recommendations for future research.

2

Literature Review

This chapter discusses product platform development strategies by construction companies in detail. It will also look at the company's position in the ecosystem. Furthermore, change management will be explained, particularly on how companies orchestrate alignments with partners in their ecosystem.

2.1. Product Platform Development

The following section explains the development of product platforms in the construction industry. It starts by knowing the historical context of industrialisation construction, highlighting the shift towards mass customisation. Then, identify the key components important for implementing product platforms, which are client, project, and product domains. It outlines the strategic development process, emphasising the importance of platform strategy. Furthermore, this section presents a framework for product platform development.

2.1.1. History

The construction sector has a low productivity rate that is caused by several possible factors, one of them being fragmented decision-making. Industrialisation is a promising solution where its principles have developed over time and led to different gains and performance (Brusa Cattaneo et al., 2024; Hall et al., 2020). Industrialised construction focuses on standardising building methods and components, using highly predefined product modules and constant processes throughout the production and supply chain. This approach is enhanced by efficient information flow and a commitment to ongoing improvement (Mansoori et al., 2024).

The industrialisation principle was developed by adding new elements or capabilities which aligned with market demands and technological advancements (see Figure 2.1). Today's principle is mass customisation, which is a combination of mass production and the ability to create bespoke products through automation. According to Popovic et al. (2022), the main enabler of mass customisation is a product platform. Furthermore, Popovic et al. mentioned that developing and utilising product platforms has proven to be an effective means of achieving mass customisation. A product platform is a flexible asset that allows companies to combine components, systems, and elements with various levels of predefinition to create offerings that align with market demands (Popovic et al., 2022).

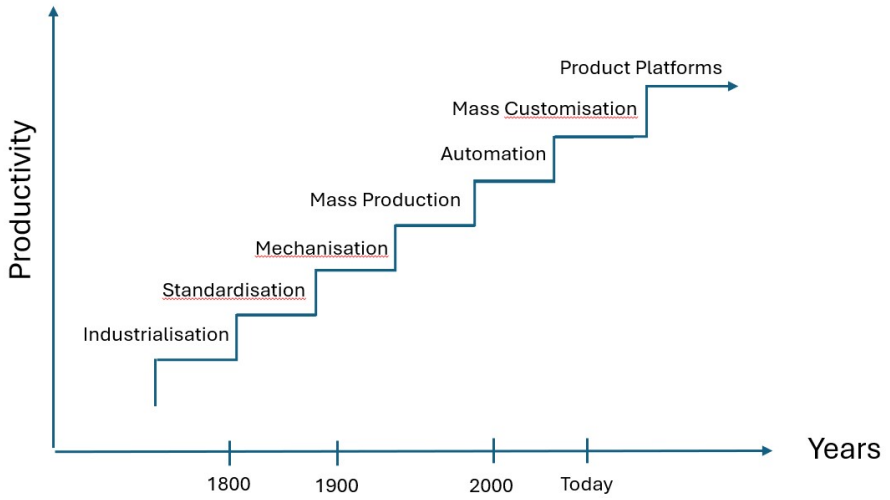

Figure 2.1: Industrialisation Principles Development (adapted from (Hall et al., 2020; Brusa Cattaneo et al., 2024)

2.1.2. Components

To identify the key enablers for the adoption of product platforms in the construction industry, it is important to understand the context in which they will be deployed. Based on The Product Platfom Rulebook (2023), the construction sector has three major domains: client, project, and product domains.

The client domain represents those responsible for the delivery, operation and management of the built environment. Representations vary from governments, developers, and individual parties. In this domain, there is often a disconnect between design, construction, and operational performance, which limits opportunities for continuous enhancement.

The project domain encompasses organisations that are involved in the design, delivery and management of construction works. The temporary and variable nature of projects (in terms of size, times, site, and client requirements) makes a fragmented and specialised delivery process, which is challenging to make more efficient through continuous improvement. These organisations interact with the product domain to choose appropriate products and services for specific projects and their unique requirements.

Meanwhile, the product domain includes those responsible for sourcing, processing, and manufacturing construction materials and products. There is minimal communication between the client and product domains, with the project domain serving as an intermediary to translate client needs into technical solutions. It is a challenge for continuous improvement due to the bespoke way that products are brought together in the project environment, the level of customisation, and the lack of feedback from client domains.

Jansson et al. (2014) and Bonev et al. (2015) place product platforms within the product domain, while the use of product platforms occurs within the project domain. This implies that organisations in the project domain can also act as providers of product platforms. Furthermore, Malmgren et al. (2010) demonstrated how a building system for single-family houses can be adapted to meet customer preferences for customisation without relying on temporary solutions.

2.1.3. Development Process Strategy

Product platforms offer benefits, such as reduced time and costs, increased flexibility and adaptability, and improved opportunities for learning across different products (Mosca et al., 2020). These platforms manifest in three primary forms: scalable, modular, and generational. While scalable and modular platforms aim to furnish product variety instantly, generational platforms leverage platform stability over time. Building on these advantages, the process of developing a product platform requires a deep understanding of the product platform components.

Development Process

Numerous companies, including construction companies, are adopting a platform-based approach to develop and manufacture product families, aiming to increase product variety, enhance customer satisfaction, shorten lead times, and reduce costs (Chai et al., 2012)). A product platform, as mentioned by Sawhney (1998), consists of a set of subsystems and interfaces that create a common foundation from which a range of derivative products can be efficiently developed and manufactured. These derivative products together form the product families. The success of a product or service relies on the provider's ability to build strong, shared platforms that can be used across multiple products, ensuring features, quick development, and cost efficiency (Veenstra et al., 2006). The development process of product platforms is split into three stages: product platform strategy, planning, and design.

A product platform strategy involves defining strategic goals for the platform, including determining the target market and approach to deliver variety at lower costs by leveraging common technology. Product platform planning focuses on identifying the problem to be solved and outlining the approach for the proposed platform before beginning the design process. Product platform design entails creating the platform, setting up production, and establishing ongoing management and deployment methods. The platform strategy is one of the crucial phases to succeed in developing and deploying product platforms. According to The The Product Platfom Rulebook (2023), defining the platform's strategic intent is the first step, with technical specifications being finalised later in the process.

Product Platform Development Framework

Based on The Product Platfom Rulebook (2023), the product platform development framework consists of three domains, and in each domain, there are steps to follow (see Figure 2.2). First, observation in the client domain, which is identifying pipeline(s) of demand and aggregating the demand. This is an analysis of market and technological trends to understand the overall demand for certain products, which is helpful in grouping market opportunities. The observation's result will be an input to strategise the intended product platform. Other considerations to include are product type and commonality strategy. The product is defined as the final configuration of repeatable core and complementary components which are deployed into a project. Each instance of deploying the product platform to a project results in a distinct product variant, and collectively, these variants form a product family. Balancing commonality and variability is the key to increasing the flexibility and responsiveness of offerings. A strong commonality strategy needs to address four key areas: technically feasible, financially beneficial, acceptable to the market, and organisationally possible.

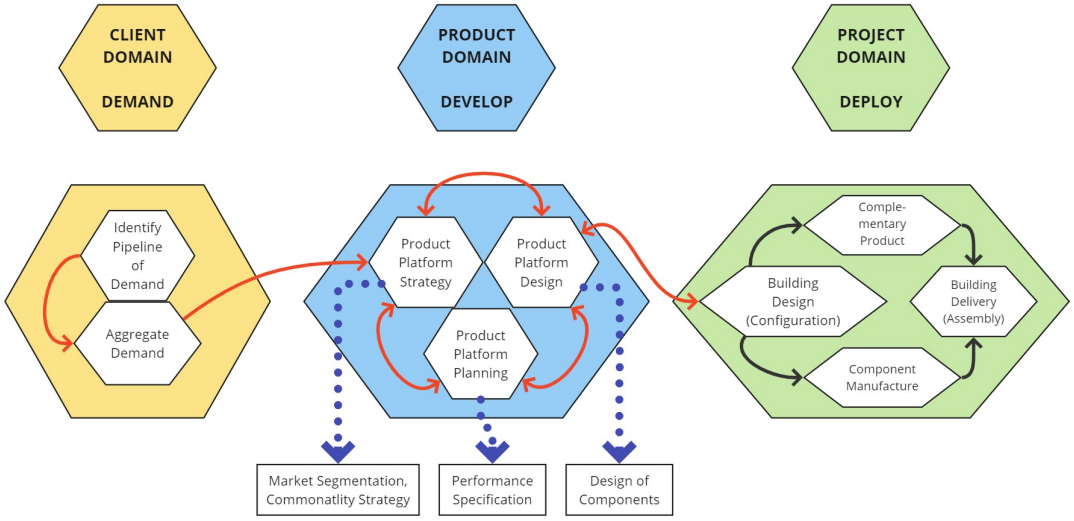

Figure 2.2: Product Platform Development Framework (The Product Platfom Rulebook, 2023)

Product Development Degree

The building system concept in industrialised construction involves integrating the knowledge and experience necessary for efficient project execution (Olofsson et al., 2010). This involves standardisation not only in technical solutions but also in work processes. According to Lessing (2006), industrialised

house-building includes creating and configuring a building system that combines both technical and process platforms. However, the drive for standardisation to improve production efficiency must be balanced with the need for customisation.

Customisation in house building can often fall under full customisation; that is, there are a number of attributes that cannot be altered (e.g., columns, beams, external walls, etc.) instead of a number of attributes for which options are available (measures). Standardisation, which involves using identical components or subsystems across multiple products or within a single product, significantly impacts other processes, particularly modularisation. According to Feist et al. (2022), modularisation involves dividing a building design into standardised units for offsite fabrication while preserving the integrity of the original design.

To explore the potential for platforms, product manufacturing processes are categorised based on the customer order decoupling point (CODP) (see Figure 2.3). This classification identifies how much customer input is involved in manufacturing, whether based on forecasts or specific orders (Bonev et al., 2015). Their study covers common strategies outlined by Wikner and Rudberg (2005), such as Engineer-to-Order (ETO), Make-to-Order (MTO), Assemble-to-Order (ATO), and Make-to-Stock (MTS). In the context of construction, Concept-to-Order (CTO) additionally describes a scenario where customers play a significant role in the early design phase of a building project (Winch, 2003).

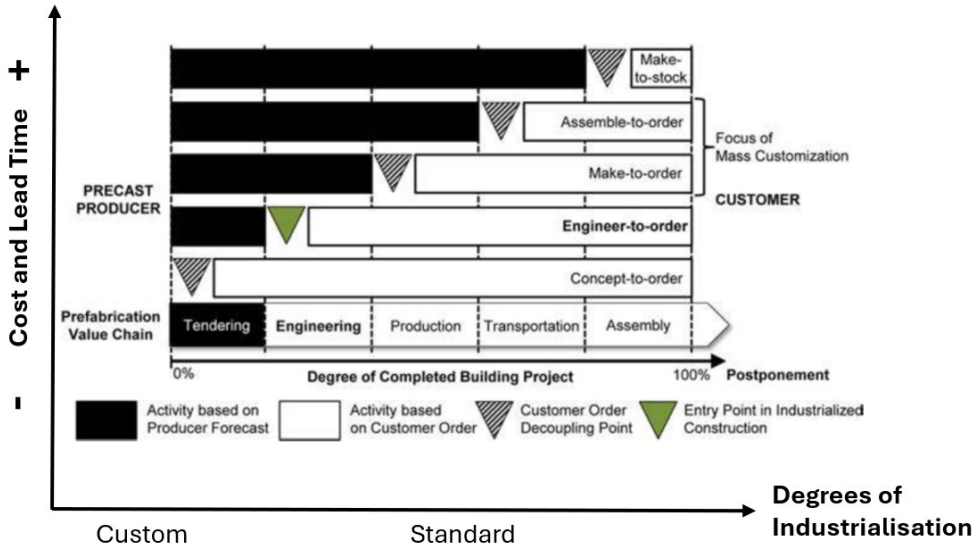

Figure 2.3: Product Specification Process for Different Variants of Building System adapted from Bonev et al. (2015) and Brusa Cattaneo et al. (2024)

Bonev et al. (2015) explain that in the context of construction, CTO and ETO are descriptions of traditional or project-based approaches to delivering a construction project. ETO indicates how the clients enter the engineering phase of the value chain after completing the tendering process for a project. On the other hand, the MTS strategy shows the client's involvement in a project at the very last phase of its value creation. This strategy leverages market forecasts to transform raw materials and components into final standard products that meet client demands. Between the extremes of this approach, MTO and ATO strategies offer varying levels of customisation depending on the degree of standardization within their products. The difference between MTO and ATO lies in the customer involvement and customisation degree. MTO strategy describes that production starts only after receiving a customer order, while ATO describes that assembly occurs after receiving a customer order.

For companies aiming to achieve mass customisation, those starting with an MTS strategy need to shift towards ATO production, while ETO companies must increase the level of standardisation in their products or processes. To avoid this trade-off and push the balance towards greater flexibility and productivity, companies are adopting platform concepts. These platforms help maintain the required level of standardisation while ensuring the desired flexibility across the value chain.

Platform Mobilisation Degree
An increasingly popular new product development strategy is the use of a platform-based approach to create a new product family (Chai et al., 2012) (see Figure 2.4). Platforming involves creating and utilising a digitally-enabled product platform, consisting of predefined subsystems and interfaces that companies can leverage to efficiently develop a series of derivative products through digital delivery (Zhou, 2024). The platform includes a modular kit of parts, interfaces which connect the subsystems, and the design rules to which the modules conform. To automate the platform designs, typically, a digital configurator is used to digitally enable the platform components (Cao et al., 2021).

A *digitally-enabled kit of parts* refers to a collection of discrete building modules that are pre-engineered and designed for manufacturing and assembly in various configurations to create a finished building. These modules can be combined in different ways to cover structural, mechanical, electrical, plumbing, and other services. D*igitally-enabled interface* is defined as a set of digital and physical specifications or protocols to define interactions and relationships between modules, which can be digitally defined and codified using building information modelling (BIM) objects containing interface requirements. Additionally, *a digitally enabled design rule* is a set of digitally codified protocols, standards, and specifications for product reconfiguration and the development of future products.

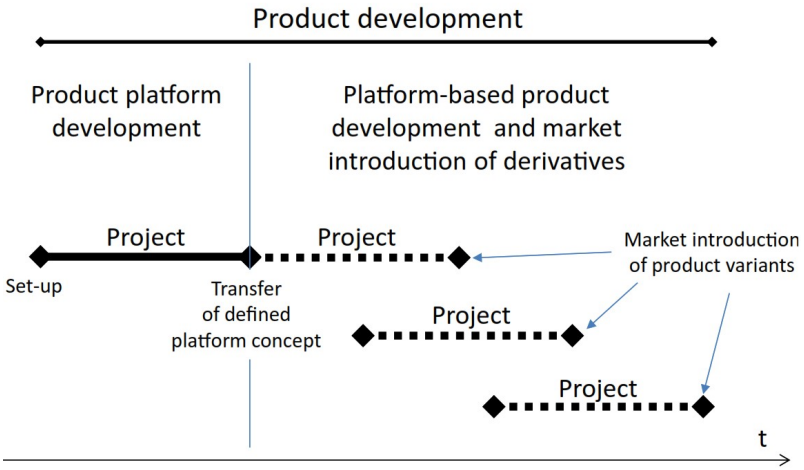

Figure 2.4: Development of Product Platform and Platform-Based Products (Harland et al., 2018)

Challenges
Transforming from a construction to a manufacturing mindset, product platforms enable organisations to cultivate product families based on a stable central technical architecture and a range of peripheral components. Adopting product family strategies empowers organisations to target multiple market segments by enhancing or customising a core model over time.

Cusumano and Gawer (2002) argue that the success of platform leaders hinges on managing the scope of innovation, the degree of modularity and product interfaces, relationships with external partners, and the organisation's structure and culture. In platform-based product development, maintaining continuity within the platform-based product development team is essential for long-term success.

Furthermore,Eastman and Sacks (2008) observe that product-based construction companies face higher capital requirements when starting manufacturing operations. These firms are more likely to bear the initial investment costs necessary to align the ecosystem partners with new manufacturing processes, bearing the associated risks within their own company. Consequently, the financial burden is greater for companies pursuing product-based offsite manufacturing.

2.2. Product Platform Ecosystem

This section explores the concept of the ecosystem that will help to manage the alignment of different actors in developing a product platform. The discussion includes the ecosystem strategy that emphasises the importance of aligning partner roles. Additionally, this section also addresses ecosystem boundaries to understand more about the ecosystem characteristics.

2.2.1. Ecosystem

An ecosystem in management research refers to an entity consisting of complementary actors taking varying roles linked through interdependencies. Ecosystems differ from other collaborative concepts in two key ways: the simultaneous presence of complementarities and interdependencies and the absence of full hierarchical control over the system. (Cobben et al., 2022). Scholars have conceptualised several different types of ecosystems, such as business ecosystems, innovation ecosystems, and knowledge ecosystems.

The business ecosystem was introduced in 1993 by James Moore with a focus on a focal firm and its environment and describes how this firm can collaborate across industry boundaries. Its research is centred on several aspects, such as relationships, partner selection, and governance (Jacobides et al., 2018). According to Adner (2006), *the innovation ecosystem* focuses on the development of innovation or collaboration of value propositions with centralised research on its emergence and evolution, value propositions, and business model. *The knowledge ecosystem* emphasizes the mechanism for knowledge exchange between actors to develop new knowledge (Järvi et al., 2018).

This study focuses on innovation in the form of developing a product platform which will foster company growth. Thus, in the innovation management context, there are two general approaches to the ecosystem: business ecosystem and innovation ecosystem (Han et al., 2022). Even though both approaches focus on yielding novel value, the business ecosystem focuses on value-co-capture, while the innovation ecosystem emphasises value co-creation. Implementing either of these approaches might create a low-performing ecosystem. Thus, there is a need to balance between co-creation and co-capture for a sustainable ecosystem.

2.2.2. Ecosystem Strategy

In the construction sector, projects are complex products that require specialised expertise to execute effectively (Papadopoulos et al., 2016). Firms can enhance their ability to address complex challenges by leveraging networks of specialised partners, such as contractors (Williamson and De Meyer, 2012).

The success of a business ecosystem hinges on the roles and positions of companies within it. Adner (2017) underscores the importance of consistency in ecosystem strategy for achieving partner alignment. Research highlights the importance of aligning companies within the ecosystem by combining strategies and resources (Havinga et al., 2023). Iansiti and Levien (2004) classify firms within the ecosystems as keystones, dominators, or niche players based on their level of influence (Figure 2.5a). Furthermore, Valkokari et al. (2017) differentiate between hub firms and spokes on both local and global scales, which is a way to answer how and where to collaborate (Figure 2.5b).

Based on the Company's Role

Iansiti and Levien (2004) introduce a company's choice of ecosystem strategy that is governed by the type of company it is or aims to be. However, the option also can be influenced by the business context in which it operates. *Niche Strategy* can be used for companies with narrowed focus and defined business segments by leveraging the assets of other firms. A company can develop its own specialised expertise. Niche companies drive value creation and innovation but must navigate their dependence on keystones and dominators.

Keystone strategy is an option for companies in unstable environments where the company is at the centre of a complex network of asset-sharing relationships. There is an opportunity to capitalise on the entire ecosystem's ability by managing the distributed assets – in part by sharing with its partners. Keystone company has the responsibility to enhance overall ecosystem health as a growth strategy by providing stable and predictable assets. These companies increase ecosystem productivity by simplifying networks among partners while enhancing ecosystem robustness by incorporating technological innovations and offering reliable reference points. Effective keystone strategies include creating and sharing value within the ecosystem.

However, if the business is in a mature industry where innovation is not a priority, the *physical dominator strategy* helps to get more control of needed assets by acquiring the company's partners or taking over their functions. In comparison with keystones, dominators use control more directly, while keystones influence the ecosystem indirectly. Physical dominators integrate vertically or horizontally to control most value creation and capture within a network.

Overall, a given actor may play different roles in the different ecosystems to which they belong. An ecosystem strategy is irrelevant when the business is in a mature industry, and the company operate relatively independently.

Based on the Company's Position
Valkokari et al. (2017) explore the ecosystem strategy based on the network position of the company. The keystone and dominators function as a *hub*, while niche firms typically occupy the role of *spokes*. The hub often serves as the primary point of contact for customers and acts as the orchestrator of the ecosystem, whereas the spokes consist of complementary entities that provide services, technological solutions, and other resources across various contexts. Consequently, a company's position and role within the network are influenced by the strategies and actions of other companies and are, therefore, subject to continual change. As the ecosystem continuously evolves, a niche player company may eventually rise to become a keystone in a newly emerging ecosystem.

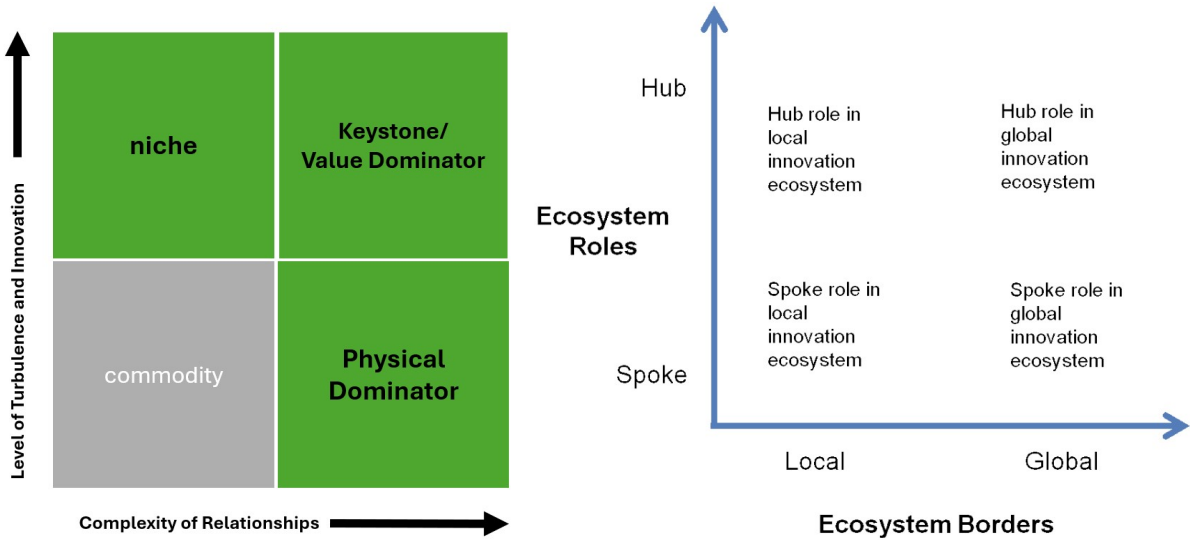

Figure 2.5: Ecosystem Strategies (a) Iansiti and Levien, 2004 (b) Valkokari et al., 2017

Changes in roles and responsibilities might occur not only when companies enter a new ecosystem but also when they create one. During product platform development, companies often find themselves collaborating with diverse actors within the ecosystem, leading to shifts in their roles. As they take on new tasks and responsibilities, they may need to develop or acquire new expertise and hybrid skills to fulfil evolving demands (Harala et al., 2023). This transformation can blur the lines between roles and responsibilities, requiring companies to be more flexible in their competencies (Hall et al., 2020)). Additionally, as companies expand into new ecosystems or create their own, they may need to adapt their capabilities to take on broader or more complex roles, further impacting their resource allocation and strategic focus (Harala et al., 2023).

2.2.3. Ecosystem Boundaries

One of the reason to develop a product platform as a business line is to solve low productivity caused by fragmentations in construction industry. Fellows and Liu (2012) stated that fragmentation within ecosystems occurs along horizontal and vertical dimensions. Horizontal fragmentation involves multiple actors performing functions at the same stage, while vertical fragmentation entails dividing the total process into components executed by separate actors. To integrate vertical elements (e.g., commissioning clients, designers, constructors) with horizontal elements (e.g., subcontractors), different business processes are needed to manage firm boundaries while developing a product platform.

Boundaries are defined transitional zones between internal and external environments, delineating the resources and capabilities over which firms exert governance and control (Caputo et al., 2018). Furthermore, in the ecosystem context, boundaries serve as ecosystem-specific attributes that differentiate one ecosystem from another conceptually (Cobben et al., 2022). Managing these boundaries

enhances project processes by fostering integration while preserving independence. Developing an ecosystem strategy requires an understanding of the boundaries of dependence and independence (Adner, 2017).

The boundaries of an ecosystem define the scope of its strategic framework. Criteria for identifying these boundaries can be derived from the system of governance, while "instrument roles" that clarify the strength and extent of these actions can be linked to factors such as communication and organisational elements (Caputo et al., 2018). Furthermore, Caputo et al. mentioned that the capacity of the firm to negotiate both within and beyond its boundaries is a crucial strategic factor in achieving and maintaining a competitive advantage.

Business boundaries in this study will be defined from the characteristics of the ecosystem. Based on Cobben et al. (2022), there are several ecosystem characteristics, such as competitive advantage, geographical scope, orchestration, and its actors and their roles. The competitive advantage of an ecosystem refers to its ability to surpass other ecosystems and/or individual companies in performance (Cobben et al., 2022) by concentrating on the internal organisation of firms rather than emphasising industry structures and the firm's position within a specific industry (Caputo et al., 2018). The geographical scope is important for product platform development in the construction industry. Each country has its own building code, regulations, and design preferences that can differ from each other. The geographical scope becomes important for this local resource access to be complemented with global market knowledge and expertise. Then, orchestration focuses on how the orchestrator's governance mechanism, such as aligning with partners, preventing opportunistic behaviour, and realising the joint value proposition. It is also important to look at actors as internal stakeholders in the ecosystem that have different interests. Each actor in an ecosystem has expectations for each other to ensure their goals are fulfilled.

Role boundaries are defined by Adner (2017) as gaps that can arise from a partner's activity-based challenges and from a partner's expectations, such as co-innovation risk and adoption chain. Furthermore, he explained that *co-innovation risk* pertains to the challenge partners face in developing the capabilities for their planned contributions, while adoption chain risk involves the partner's willingness to engage in the required activities, raising concerns about priorities and incentives for participation.

2.3. Change Management

The construction industry is organised in particular to its inter-organisational collaboration patterns. Rising complexity in multi-partner project organisations, along with interdependencies among actors, a lack of long-term relationships and inadequate knowledge, has led to calls for alternative approaches (Havinga et al., 2023). Alternative approaches, such as adding multiple new products and services to a company's portfolio, implementing new technologies, and creating new business alliances or partnerships, require transformation to a company's business model (Galpin, 2023). For example, in traditional project-based construction networks, where services are typically delivered through arm-length contracts, there is no guarantee that firms will act beyond the contract's terms. In contrast, the product-based approach (using a product platform) has a form cited to incentivise efficient inter-firm relationships and stronger partner alignment around mutual objectives. During this strategy execution process, a firm's leadership experiences challenges from the discipline of "change management", which is viewed as a set of activities that realigns organisations to effectively address the economic, technological and other forces that are transforming their marketplaces (Galpin, 2023). Such a challenge in adopting a product-based approach as an organisational approach is how to achieve alignment among firms, which can be viewed as a method of ecosystem orchestration (Havinga et al., 2023).

2.3.1. Orchestration

Effective orchestration is essential for aligning partners within an ecosystem. Orchestration is defined as "a set of deliberate, purposeful actions" by one actor that catalysed the emergence and subsequent development of the ecosystem (Havinga et al., 2023; Parida et al., 2019). It involves establishing and enforcing rules, managing risks related to moral hazard, and imposing sanctions or even excluding stakeholders who fail to adhere to these rules (Williamson and De Meyer, 2012). By coordinating and directing the actions of various ecosystem partners, companies can integrate both strategy and resources to align other partners within the same ecosystem. This proactive management helps

avoid problems caused by miscoordination and ensures that all partners work towards common goals, thereby reducing risks and enhancing overall ecosystem performance. Understanding the importance of orchestration in ecosystem strategy highlights how firms can effectively manage partner alignment, setting the stage for exploring the specific activities and mechanisms that can be employed to develop product platforms.

To do product platform development, a multidisciplinary approach is required, and usually, it involves several actors. Orchestration is conducted by a single actor, known as the orchestrator, who uses a top-down approach to ensure the partner's alignment within the ecosystem. In this approach, the orchestrator's goals guide and direct the actions of its partners. It is part of a company strategy to exploit opportunities through participation in ecosystems or networks, such as enabling access to resources and capabilities (Addo, 2022). A key role of ecosystem orchestrators has to do not only to improve the technological core while coordinating and managing diverse interests and ensuring alignment among ecosystem partners.

Research on types of orchestrators and their impact on ecosystem success highlights that their role and effectiveness are determined by their resource base and relational position (Hurmelinna-Laukkanen and Nätti, 2018). There are four classifications of orchestrator types, according to Hurmelinna-Laukkanen and Nätti, 2018. First, orchestrators can be categorised into players or non-players, with players posing a competitive threat to partners. Non-player orchestrators, on the other hand, may act as facilitators, leveraging their strong relational position to mediate partnership. Facilitator orchestrators focus solely on common interests and network viability to promote the dissemination of innovative ideas. Sponsor orchestrators can overlap, necessitating role-switching capabilities. For instance, player orchestrators may serve as judges or gatekeepers; facilitators may lead agenda-setting and network stabilisation; and sponsor orchestrators might act as coordinators or developers.

2.3.2. Ecosystem Transformation

Orchestration is an evolving process that demands a variety of skills from an orchestrator to facilitate the creation and extraction of value within the network (Addo, 2022). To help industrialised construction companies develop product platform strategy by organising their ecosystem, a transformation framework from Parida et al. (2019) proposes a two-stage model for ecosystem transformation. The first stage involves an ecosystem readiness assessment, identifying gaps in implementing the lead firm's strategy and vision. Subsequently, ecosystem transformation entails implementing standardisation, nurturing, and negotiation mechanisms to orchestrate the ecosystem. This framework is aligned with the product platform development framework from Figure 3.

a. **Ecosystem Readiness Assessment**
   Ecosystem readiness assessment provides an understanding of the orchestration and transformation process (see Figure 2.6). This assessment will help ecosystem companies to identify and gain a deeper understanding of gaps related to developing the product platform. The assessment consists of three aspects. First, *external trend assessment* is analysing trends and policies that may directly or indirectly influence the business potential of the ecosystem. The next one is *business model assessment*, which involves taking stock of the current business model and stance on the actions that need to be taken to move toward the new business model. This assessment will also help to understand the implications of the business model shift for ecosystem partners. Last, *ecosystem partner assessment* emphasised the importance of having a deep knowledge of their ecosystem partners' roles and responsibilities. This could be done by mapping the trade-offs between companies in the ecosystem. Furthermore, knowing each company's contribution to the ecosystem will help to analyse the need and potential for new ecosystem partners.

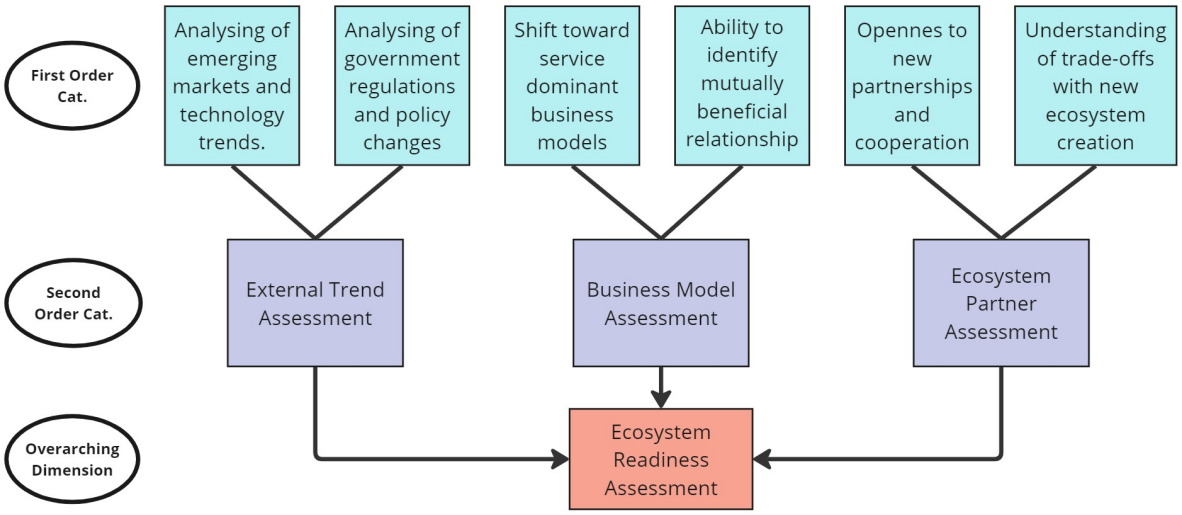

Figure 2.6: Transformational Model (Adapted from Parida et al., 2019)

b. **Orchestration Mechanism**
The ecosystem orchestration mechanisms framework from Parida et al. (2019) has been adjusted by Havinga et al. (2023) for the construction industry, particularly for the product-based (PDB) approach ecosystems (see Figure 2.7). The *Standardisation Mechanism* involves formulating and establishing industrial requirements. Besides that, ecosystem leaders use informal standards to influence and direct the development of the ecosystem alongside their closest partners by engaging in the co-development of technological standards with selected collaborators. In this study, a product-based approach in the form of a product platform is the technological standard. In addition, another dimension of standardisation is product architecture: it pertains to the ease with which connections and interactions with other actors can be established in predefined manners and how it can serve as a tool for alignment.

Nurturing mechanism helps to ensure the speed of innovation that, in turn, contributes to a successful ecosystem. One way to do it is to include openness toward sharing core knowledge and intellectual property (IP) materials. Sharing IP is important for establishing new partnerships within the ecosystem and is essential for transforming the ecosystem to deliver a business solution. Furthermore, developing a product platform is integral to creating processes that foster aligned incentives and adaptability. Therefore, ecosystem orchestrators need to invest in and guide partner companies within the ecosystem.

The negotiation mechanism helps manage the intricate web of mutual interdependencies among ecosystem partners. It is acknowledged that relationships within ecosystems are susceptible to conflict. Minimising conflicts through relational interdependence among selected partners is an effective strategy for conflict prevention.

Last but not least mechanism that is important is *the ownership mechanism*. Design ownership is one of the key factors in managing the construction process and can influence the lead firm's capacity to establish standards.

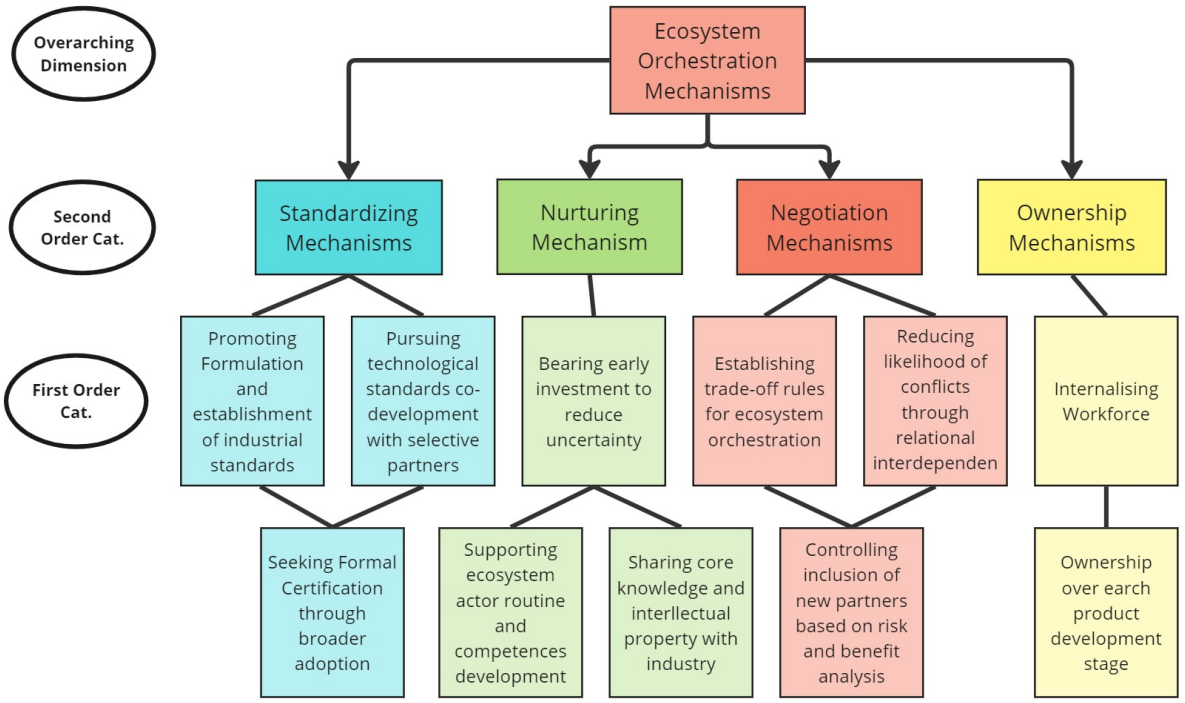

Figure 2.7: Ecosystem Orchestration Mechanism in the Product-Based Ecosystem (adapted from Parida et al., 2019 and Havinga et al., 2023)

2.4. Digital System Integrator – Business Model

A business model outlines the underlying logic of a company, detailing its operations, and how it generates value for its stakeholders (Baden-Fuller and Morgan, 2010). Zott and Amit (2010) describe a business model as "a system of interdependent activities that extends beyond the focal firm and spans its boundaries". They emphasise interdependencies beyond firm boundaries. In addition, (Teece, 2010) defines a business model as the method through which a firm delivers value to customers and transforms payment into profits, and relates business model innovation to technical innovation. Industrialised construction through a product platform approach may disrupt the ways in which firms do business because of the development of new business models. Identified business models for the product platforms approach are shown in Figure 2.8.

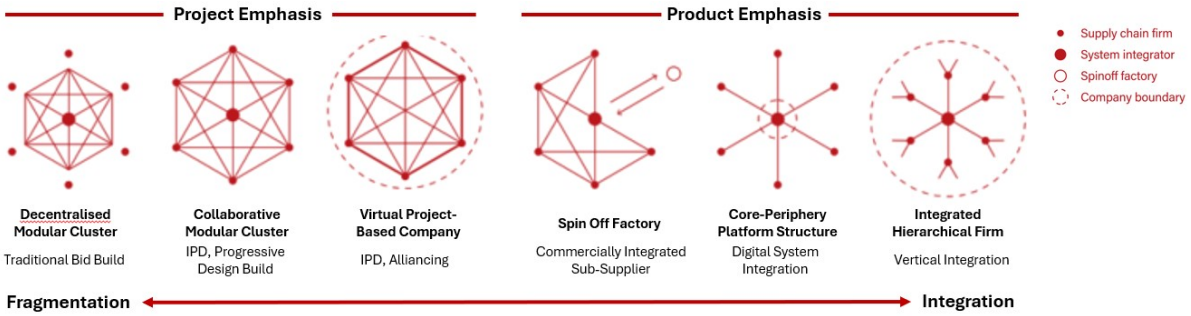

Figure 2.8: Business Model of Construction Companies (adapted from Hall. et al., 2022; Brusa Cattaneo et al., 2024)

A project delivery model defines how the stakeholders of a project are organised and managed with the purpose of creating and capturing value on a one-time basis (Hall. et al., 2022). Traditional construction project management is fragmented (horizontal, vertical, and longitudinal). Industrialised construction introduces a solution to manage the fragmentation through a product or platform approach. The development of a product platform enables a new form of longitudinal continuity where the com-

panies must ensure a fit between market segment requirements and the offerings of their platform (Hall. et al., 2022). One of the new business models for project delivery using the product platform approach that is currently observed in the market is digital system integration. This business model has a particular characteristic where the stakeholder's network forms a core-periphery structure.

The core-periphery structure focuses on community roles and centrality, which is integral to understanding the link between node position and function in networks (Polanco and Newman, 2023). The core represents the focal firm that needs to have the ability to bring its partners (periphery) into the roles and positions in order to achieve the focal firm's plan for its value creation and capture. Thus, the focus is on a focal firm. From time to time, the ecosystem might expand if the focal firm is able to attract more partners, which helps to develop the product platform.

Another characteristic of digital system integrator as a business model, the companies use principles of capital-light industry 4.0 supply chain, where the manufacturing technology is owned by periphery supply chain partners. Having this allignment in the platform ecosystem requires a big effort for the co-creation of new products. It takes more time to build consensus for new product platform development across the ecosystem (Hall. et al., 2022). A typical platform ecosystem structure for a real estate project is shown in Figure 2.9.

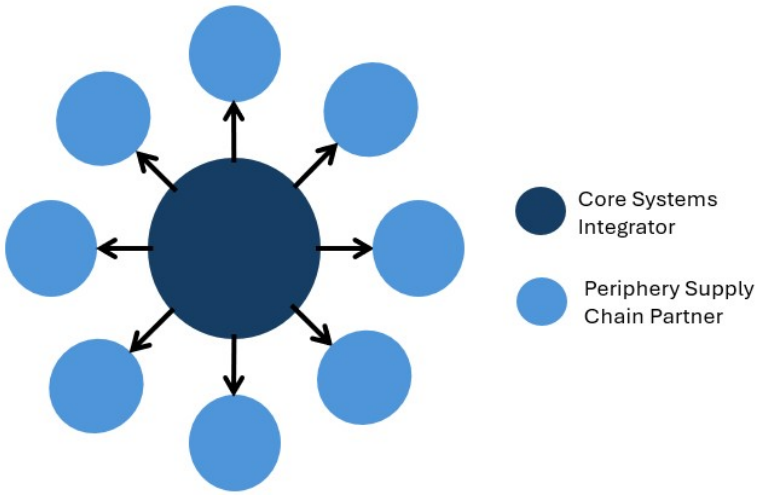

Figure 2.9: Stakeholders Network: Core-Periphery Structure (adapted from Hall. et al., 2022)

3

Methodology

The aim of this research is to address the question, “How do industrialised construction companies enhance ecosystem collaboration in product platform development?” which has the objective of understanding the dynamic partnership between actors in the ecosystem during product platform development. The objective is suitable for exploratory research. Exploratory research enables a comprehensive investigation of the topic, discovering the process management of the product platform development.

In the pursuit of comprehensive learning, a qualitative approach is ideal for exploratory research in order to grasp the actual meaning of the collected data. A qualitative approach is better for capturing and interpreting verbal data than quantitative data by providing deeper insights into human experiences and perceptions. This approach also gives reflective and descriptive results for a societal context.

For this research, primary and secondary data will be collected. The primary data will be obtained by conducting interviews with different actors of construction companies that are developing product platforms. The secondary data will be obtained from the literature study (academic and grey literature). All the data which is needed for this research will be gathered mostly through existing literature and the connections among the interviewees.

3.1. Research Design

This research will be done in the form of a cross-sectional study design. A case study is suitable for studying phenomena in which extant research might not be well explained and has no direct control over the behavioural events from the researcher (Zhou, 2024; Yin, 2017). Interviews were used as the primary data source.

A review of the literature has informed the development of a conceptual framework, which provides the theoretical foundation for the data analysis. This framework will serve as the basis for generalising findings in the discussion chapter. Additionally, it has been designed to guide the criteria for selecting case studies and formulating interview questions. Furthermore, the conceptual framework has been generated to examine the product platform development process during the data collection and analysis.

To enhance the robustness and external validity of the research, a multiple-case study approach has been adopted (Herriott and Firestone, 1983). Three case studies have been selected based on both literal and theoretical replication logic. All three cases contain with a product platform development in Europe. More specifically, the study targets existing construction firms that have digital systems integration as their business model. The difference between the cases is the company’s background, shown in Table 3.1.

Table 3.1: Case Studies

Case Study	Company's Service	Location	Annual Revenue
Company A	Land Developer	Denmark	$4.3M
Company B	Software Developers	Netherland	$5.2M
Company C	Contractor, Land Developer	Switzerland	$150.8M

Individual case studies were conducted separately and analysed to get a cross-case conclusion. The cross-cased analysis was done to recognise patterns across the individual cases to deliver the findings in a report. Across-case comparison in the multiple-case study can help support that emergent findings can be replicable (Eisenhardt, 1989).

Individual interviews were conducted (from 27th May to 9th July) to describe their personal perception and knowledge of their product platform development process. Semi-structured online face-to-face interviews were done using Microsoft Teams, taking a duration of approximately 60 minutes each. The interview participants, representing their respective companies, were selected based on their position and role at the specific company so as to allow different perspectives and experiences. A minimum of four people per firm were interviewed, each with a different role. This was accomplished with each case study except for one, company A, where only 3 interviews could be gained. Additional context for Case A was provided through participation in another research study, where the researcher had the opportunity to sit in on three additional interviews as an observer. A total of 12 interviews (details shown in Table 3.2) were used to collect empirical data. **Appendix I** present the flow of questions asked to each of the interviewees.

Table 3.2: Correspondence Details

Company	Participant	Position	Background
A	1	Co-Founder	Industrial Design, Chief Design & Construction, Sales and Marketing Modular Building Products
	2	BIM Engineer	Construction Architect, Civil Engineer
	3	Head of Development (Manufacturer)	Civil Engineer
B	4	CEO	Political Science, Entrepreneur
	5	Head of Projects and Partnerships	Industrial Product Designer
	6	Engineer	Carpenter
	7	Engineer	Architecture
C	8	Design and Innovation Manager	Architecture, Computational Designer, Structural Engineering
	9	Digital Design and Innovation Manager	Architecture, Data Science
	10	Process Manager	Civil Engineer
	11	Product Designer	Civil Engineer
	12	Engineer (Engineering Company)	Structural Engineer

Sometimes, interview sessions may not always be sufficient to gather comprehensive primary data. One of the solutions to this limitation is the use of data triangulation. According to Bhandari (2022), triangulation in research means using multiple datasets, methods, and/or theories to address a research question. The main purpose of using data triangulation in qualitative research is to enhance the credibility and validity of the study by cross-verifying information from different perspectives. Data triangulation can be done in various ways, such as content analysis of social media posts, surveys, and field observations. In this study, data triangulation was done using content analysis of the social media approach, such as the official company website, the official company's social media, webinars, and books. Additionally, requesting the companies to cross-check or verify the accuracy of the data or findings is part of the data triangulation. For example, sending back a diagram to the company for review, requesting corrections or additional information as needed. Examples of data triangulation are shown in Table 3.3.

Table 3.3: Data Triangulation Examples

Nu.	Resource	Data or Information
1.	Company's Official Website	Company's profile, product platform information
2.	Company's Social Media (LinkedIn and YouTube)	Product platform information, collaborators information
3.	Webinar: Bridge the Gap "From Modularity to Circularity" on Nov 16th, 2023	Company's approach on product platform to enhance the application of circular economy principles
4.	Book: Circular Construction for Urban Development	Company A product platform, Collaborators information
5.	Website: https://growjo.com/ (access 22 July 2024)	Company's annual revenue

3.2. Data Analysis

An explanatory data analysis approach was taken to investigate the nature of certain relationships (Decoteau, 2017), specifically examining the connections between ecosystem organisation forms and the use of orchestration mechanisms in developing a product platform for this study. The conceptual framework provided the foundation for the data analysis, which utilised a multi-grounded theory approach to incorporate and extend existing theories, such as the product platform development framework (The Product Platfom Rulebook, 2023) and orchestration framework (Havinga et al., 2023; Parida et al., 2019), contribute through their explanatory power in condensing the theory and to not only derive the theory from the raw data (Goldkuhl and Cronholm, 2010). Through this approach, this study aimed to provide support for existing theories within the literature.

Preliminary interview transcriptions were conducted via Microsoft Teams and subsequently reviewed and corrected manually by the researcher. This data was supplemented with information from company websites. Both the interview data and website information were analysed using atlas.ti through content analysis, with coding organised according to the themes outlined in the conceptual framework, as detailed in the following paragraph.

The second level analysis follows. First, three key elements were created: ecosystem, orchestration, and boundaries. Ecosystem and orchestration were generated deductively from the existing theory while the boundaries were generated inductively during the data analysis. First, the ecosystem theme then was split into two categories: resource and type. The resource category consisted of two subcategories: in-house and outsourced. The type category contained two sub-categories: business and innovation. Second, the boundary theme was split into business and design categories. The business category consisted of geographical scope, competitive advantage, and cost, while the design category contained regional building codes, sustainability and circularity principles, and building functionality.

The last theme is orchestration, which consists of readiness assessment and orchestration mechanism. The readiness assessment consisted of three sub-categories: external trend, internal business, and partner. The orchestration mechanism contains four sub-categories: standardisation, nurturing, negotiation, and ownership. Detail of the coding themes, categories, and subcategories during data analysis is shown in Appendix II.

Once the interview transcripts were coded, the initial analysis for each approach was consolidated under the established coding schemes, with additional sub-categories providing insights specific to that organisational approach. The first level of analysis was then followed by a second level, which examined the relationships between themes and codes within the empirical data for each organisational approach. Subsequently, a cross-case analysis was conducted to compare and integrate data across each case within the sub-categories, leading to cross-case conclusions. These conclusions were then compared and validated against existing literature and the findings from the conceptual framework to assess their accuracy and identify any potential weaknesses. After addressing any confirmations or flaws, the insights gained were used to refine the theory and suggest directions for future research.

Weaknesses of the research design may be the collection of data from mainly lead firms and partial partners, whereby not collecting data from the perspective of all actors in the ecosystem. Furthermore, another weakness may be variations of the company's product platform targeted market locations. They all are in the European market; maybe different markets like the UK, Singapore, South America, and China have additional cultural aspects that might affect their capacity to use the orchestration mechanisms. Nonetheless, despite these limitations, the data still reveals valuable insights into the research question.

4

Case Studies

This chapter describes three companies that are developing a product platform to deliver real estate projects. The objects that will be discussed are the company's background, its position in the platform ecosystem, and its process to develop a product platform.

4.1. Company A

Company A is a real estate company founded in 2021 to demonstrate a more sustainable and inclusive way of developing cities that balance the interests of people, the planet, and profit. The European real estate company, which is based in Denmark, is setting out to develop urban communities with inclusivity, liveability, and sustainability at its core. Company A role is not just a developer but also the operator of the building. The company was founded by a group of experienced professionals in real estate investments, sustainability, circularity, and urban development.

The decision to switch from a project approach to a product approach comes from the company's challenges in delivering an urban development project. The company noticed repetitive activities in the design phase, and several crucial activities, such as volume studies analysis, were done by inexperienced employees. In addition, incomplete drawings are also a challenge faced by the contractors that reflect poor handover management during the design phase. These conditions were seen as problems in improving productivity and limiting the environmental impact of the construction sector that may caused by an under-investment in innovation. Thus, they are pursuing new technologies to improve the performance of the construction industry and the company itself.

4.1.1. Product Platform Development

Company A is delivering a Building Delivery System (BDS), a hybrid prefab system, with timber frames, combining volumetric and panelised systems in the defined building elements and apartment catalogues that come with kitchen, bathroom, and furniture catalogues. The defined building elements in apartment catalogues contain all building information, such as construction details, materials, and technical installations. Furthermore, the prefab building elements are designed to support different apartment types with restricted flexibility to accommodate local building regulations, tenant experience, and building efficiency.

Then, these catalogues will be generated using automated building configurators (see Figure 4.1) that enable to optimise layouts and building performances; including Mechanical, Electrical, and Plumbing (MEP) installations. However, they are still in the process of creating their configurator, which can help them to include circularity and sustainability aspects in the design, such as carbon estimation, energy demand simulation, and volume optimisation. Not only that, the fixed set of prefab building components is directly linked to the suppliers of these. And the professional team uses their digital version to design the buildings. Therefore, the configurator is not handed off to the architect yet, and design rules are still manually configured.

> **"You will not go to the level where you can change the floor. We also design not only the layout of the apartment but also the installations." (A.2)**

To deliver this system, company A uses Revit to build its building elements for apartment catalogues, while for the configurator, currently, they are in beta version using Rhino and Grasshopper. With this system, company A aims to do 75% of the building works offsite in controlled manufacturing facilities.

Figure 4.1: Company A BDS Configurator (source: Company A Website)

4.1.2. Company's Ecosystem

Company A reflects them as a knowledge company enabled by partnerships where they build a network of partners to deliver their product platform. Parties that are involved in developing company A's BDS (shown in Figure 4.2) are the following:

- **In-House Team**
  The company has a small internal professional team that created the BDS and takes care of its correct implementation and use by external parties. This small team consist of four people with backgrounds in civil engineering and architecture. However, the expertise varies from modular design, digitalisation, sustainability, and urban planning. The team leader has a long journey in constructing hospitality buildings, like hotels. His experience and additional expertise in industrial design and manufacturing helped the company set the company's mission of delivering sustainable urban areas.

- **Outsource Expertise**
  Company A is a young company with the limitation of its resources to do such innovation. Therefore, company A needs additional features for its team. The periphery partners are chosen in repetitive collaborations and involved as early in the process as possible. They collaborate with external architects, engineers, and several other advisory services. This collaboration helps the company in providing integrated design solutions and life cycle assessment (LCA) calculations. The external team works directly for company A and works in close cooperation with the manufacturing supply chain.

  Company A faced challenges in its product platform development by employing two architects working on the same project with different designs. This led to confusion and hindered the creation of a cohesive product platform. Thus, company A decides only to work with one architect.

- **Manufacturing Supply Line**
  Since the focus of the company is a land developer instead of a manufacturing company, Company A decided not to procure a factory. They decide to have partnerships with manufacturing companies and suppliers (raw material, product) in the detailed engineering of the prefab building components to suit the manufacturing capabilities. In addition, the manufacturing companies not only do the production, but they will carry out the assembly of the elements as an integral part of their scope work. These companies operate under a long-term framework agreement that gives them the comfort of a pipeline of projects in return for their early and proactive participation in developing BDS.

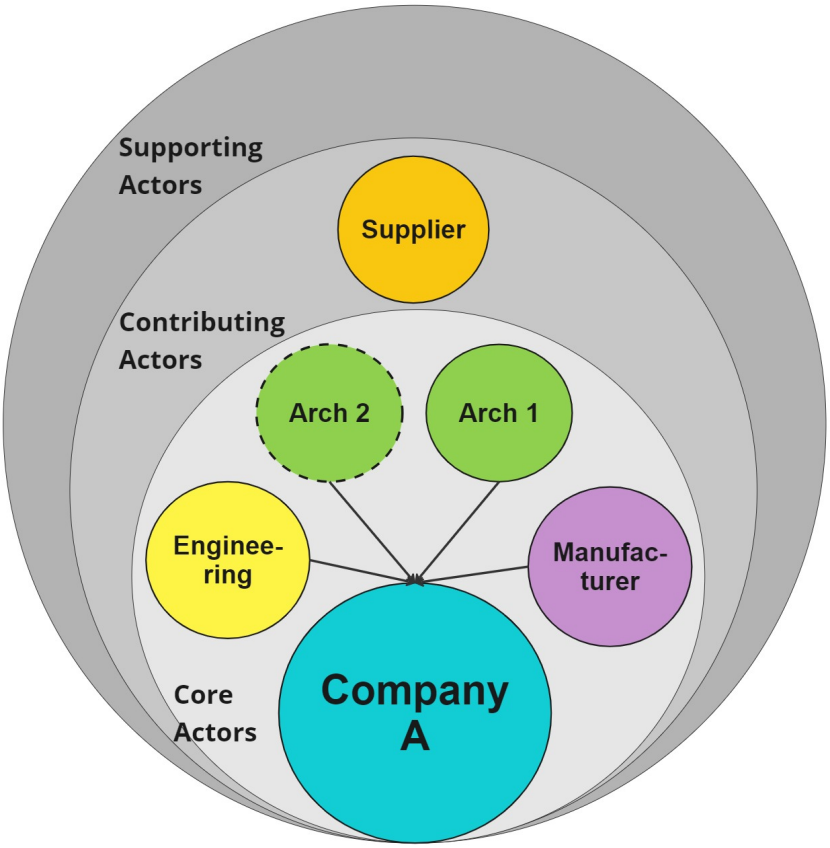

Figure 4.2: Company A Ecosystem

4.1.3. Change Management

Ecosystem Readiness Assessment

Company A realises that transforming the construction industry from project-based to product-based is challenging due to numerous issues that must be addressed. These issues include tested material specifications, ensuring structural integrity, and assembly method options. These challenges bring about legal and liability issues that lack established practices. The complexity affects conventional manufacturing techniques, design practices, and from construction to disposal. Therefore, implementing interdisciplinary collaboration offers the potential for developing integrated solutions to achieve ecosystem goals. One of the goals is based on Danish building regulations, which is to bring down the entire carbon footprint of the building system to a certain number.

In the early phase, company A organised a small event to gather various experts, such as architects, developers, contractors, engineers, and experts in industrialisation construction. The event discussed challenges in the construction industry and brainstormed how industrialised construction, particularly product-based, will help overcome those challenges.

> **"I've started to organize a small event where I invited architects and developers and contractors and then engineers and other advisors. And I asked a very simple question Who's responsible for the project." (A.1)**

Orchestration Mechanism
Standardisation activities in Company A's ecosystem involve establishing industry requirements and pursuing technological standard co-development with selected partners. As the Winner of the Sustainability Achievement of the Year 2024 in Denmark and a certified B corporation, Company A has a strong commitment to ensuring its capabilities and gaining partners' and clients' trust. To find the best partner that fulfilled the required standards, they created a competition to select an architecture company for collaboration. This competitive process ensures that the best architectural expertise is integrated into their ecosystem, enhancing overall quality and innovation.

> "**They did the competition actually, it was an architectural competition." (A.2)**

Nurturing activities include sharing knowledge and creating new routines to enhance the development process. For instance, according to company A, the product library serves as the continuous technical platform for the kit of parts that are manufactured and delivered to the site. A key strategy for Company A to scale up its product platform is to attract more manufacturing supply lines to collaborate with them. Having diverse suppliers and manufacturers allows Company A to explore a wide range of materials and machines, fostering innovation. Throughout all project phases, including building operations, all learnings are logged and captured by various parties and brought back to the R&D team. This continuous feedback loop helps optimise building components to higher standards and resolves any remaining issues for future projects.

> **"What I run in parallel of each project is what I call a lessons learned database. If they come across stuff that they don't like or do like them, it's ending up there. Which of these things do we think have value for us? Which of these things really require us to change the product we have and give us a better outcome for whatever reason" (A.1)**

The negotiation mechanism is crucial due to the challenge of finding the right partners, such as the limitation of experts or experienced manufacturing companies. Changing from a project-based approach to a product-based approach is difficult. For example, trade-offs were made with the manufacturing company by offering long-term partnerships in exchange for close cooperation, with Company A assuming the role of overall owner and project manager. This arrangement was necessary because the current manufacturing company had its own construction manager.

> **"You can not maintain a manufacturing facility based upon a project. You have to base it on long-term partnerships because that's the only way to get a consistent demand on your production lines. And so you need a few long-term agreements with partners that will all sign in for a couple of years." (A.1)**

4.2. Company B

Company B is a Dutch company that provides a digital building system and collaborates with various third parties for the manufacturing process. Since 2018, B's existence as a company is to accelerate construction industry transformation by digitally integrating the building chain around a standardised, industrial building system. The company does not deliver parts or modules, but a set of extremely detailed 3D models through their digital building system.The focus is to integrate from design to realisation. Employing a digital twin approach to building data, tracking the entire life cycle of components, and aiding in maintenance, replacements, and future construction projects are services offered by the company. Its commitment to design for disassembly, efficient material use, adaptability, and a digital-driven approach to design, construction, and management made its role important in the platform ecosystem.

> **"We have a pretty strange bit business model position in the chain. People are either an architect or a developer or a factory. We are none of those." (B.4)**

Company B started in 2014 as an architecture company that wanted to deliver sustainable housing products. Their first approach was to deliver recycled shipping containers as the frame for the house

equipped with battery technology, heat pumps and windmills on the roof. However, Company B found that their market/client was not interested in the idea of using recycled shipping containers for housing because it was not sustainable enough and not qualified for housing (materials and size). Furthermore, Company B did not consider and test the soundproofing and energy quality of their shipping container as a housing product. This failure became their pivot point, to do sustainable building systems with existing energy technology.

4.2.1. Product Platform Development

Company B's product platform, .home, is a modular building system optimised for efficient use of materials, stability, sound, fire, and design flexibility. These modules use lightweight materials, such as Laminated Veneer Lumber (LVL) for supporting structures and mineral wood for insulation in the façade. From .home, company B has realised apartments, terrace houses, and villas with their clients. With the building system that they develop, Company B helps to provide architecture design guidelines and manufacturer production process (see Figure 4.3). The modules have their 3D models with high levels of detail, generated with their self-developed software that is filled with a growing database of proven geometric elements into a new design.

.home is a set of kit parts with a high level of details of modules interface that was developed using Rhino and Grasshopper. For example, every screw is visible in the model with the precision of notch or slope angle milled to the beam. These details are the result of expertise and feedback during product design and testing. Company B's configurator is not only designed to generate .home modules, but it also acts as software for CNC milling. It shows that even though company B is a software developer, their service is to make sure that the product can be assembled. The configurator covers from design to production.

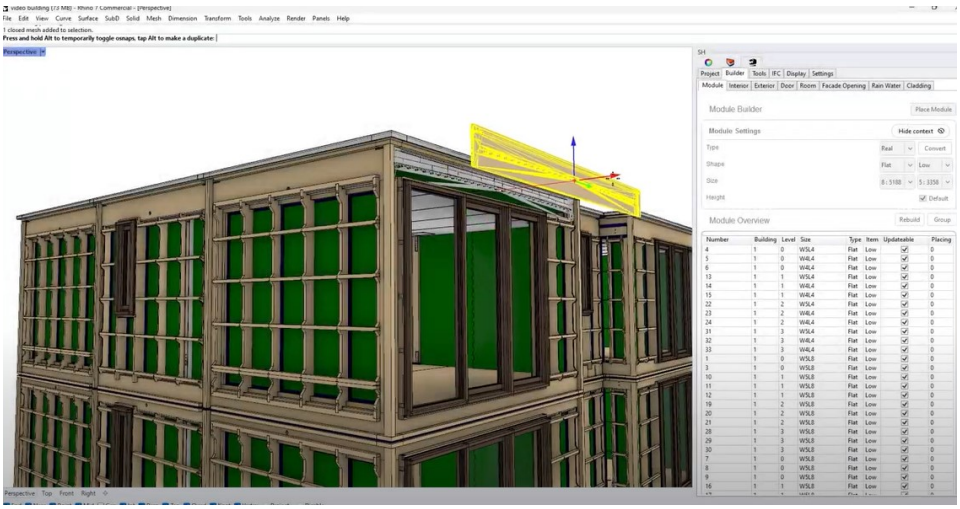

Figure 4.3: Company B Configurator (source: Company B (Youtube Channel)

4.2.2. Company's Ecosystem

Company B has in total around 30 employees with various expertise where. They develop their building system with their own resources. It gives them full ownership of the building system. Details on Company B's building system developer (shown in Figure 4.4) are the following:

- **In-House Team**
  Company B has four teams that collaborate with each other, which are the software team, engineering team, BIM modelling team, and business development team. The employees have backgrounds not only in architecture and civil engineering but also in industrial engineering and software development. Mostly, the employees have interdisciplinary skills, such as architects who learnt software development, structural engineers who did automation engineering, and an engineer/carpenter who did a lot of experimenting with timber material and manufacturing processes.

- **Outsource Expertise**
  Since the company already have various backgrounds that support their work, company B did not do any outsourcing. However, during the product development, they work together with a certification company for fire testing and soundproofing. This company will give constructive feedback for company B's product improvement. Company B's clients, such as property developers with the supply chain for manufacturing, are also giving feedback after operating the physical product.

- **Manufacturing Supply Line**
  In the early phase, Company B needs a client to invest in developing the building system. They had a pipeline project with a construction company in the Netherlands that wanted to go to industrialised construction. This construction company considered the main producer of 3D modules in the Dutch market, has an assembly hall. The pipeline project was to deliver 100 individual houses over 4 years, where every 6 weeks, a new house would leave the factory. This circumstance gives an opportunity for company B to evaluate and improve the building system every six weeks. After that, Company B keeps working together with their client, which are either property developers or manufacturing companies.

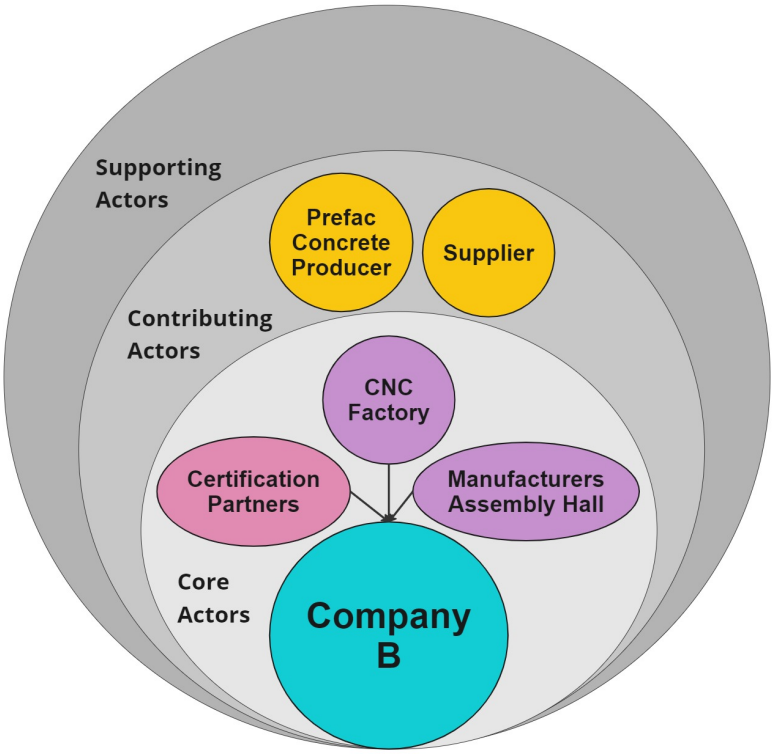

Figure 4.4: Company B Ecosystem

4.2.3. Change Management

Ecosystem Readiness Assessment

Construction industry trends in the Netherlands, particularly in real estate development, are towards industrialisation construction. Company B's original business was an architecture company. The company's interest in delivering sustainable housing is aligned with the benefits offered by off-site construction. Then, the company re-evaluate the company's resources and the Netherlands's industry opportunities. For example, the company looked at the preferred materials to work with in the Netherlands, which is timber, whereas in other countries, it could be a challenge to use that material. From company B's resources that have various backgrounds in manufacturing industries, civil engineering, and architecture, the company decided to provide design and consultant services for delivering a product-based on housing projects.

Orchestration Mechanism
Standardisation activities involved formulating and establishing industry requirements. One of the fundamental aspects of their standardisation is using CNC milling for production, ensuring this technology is the bare minimum manufacturing technology. Therefore, company B also develops software to optimise CNC milling production of assembly hall capabilities. Company B also delivered the building system as a physical product and was certified for fire testing and soundproofing.

> "**You need the concept that is able to be built in a factory setting, and at the same time, you have to use less biobased material as possible." (B.6)**

Nurturing activities include in development of new routines and processes. For example, the company secured a contract requiring the construction of a 7-story building, even though their system was initially designed for only 5 stories. This challenge creates growth in their product platform capabilities. The company provides a flexible working environment, which, although it sometimes leads to a lack of perceived management, ultimately allows for innovation and adaptability.

> "**What we had is how do we go above 5 layers, and then that's basically a sprint with the engineers and the software team and the advisors to find out how we could solve this problem and then to make sure that we have enough faith that the solution works and that we can make it make it happen and that this was about a four-month trajectory together with the developer and the partners, where a lot of different disciplines were involved to make sure that we could tackle that" (B.4)**

> "**I have never felt that there is management as such because everybody is working towards the company's goals. There are people with leading roles. Let's say if you have to put it in words, there are no hierarchies in the office. Everybody knows there what they want to do, and sometimes they come up with new ideas, and then we work towards the betterment of it." (B.7)**

Negotiation mechanisms are critical as Company B expands into new markets, such as the French market. This expansion involves significant trade-offs and setting standards for new partners. For example, one of company B's clients designs a concept but relies on Sustainer to supply the system. The client manages a network of fabricators to produce assemblies that will use Company B's software. This approach introduces a new manufacturing standard, eliminating unknown risks for new assembly hall partners. It will become easier to scale the number of assembly halls and, at the same time, more options to procure modules from different places in the same system.

> **"They have a concept they design, but they don't have their own system. So we supply the system, and then they have a network of fabricators who can produce the assemblies" (B.4)**

4.3. Company C

Company C is a Swiss Real Estate and construction services company with activities in development and civil engineering. As a leading construction and real estate service provider, C develops, builds, and manages homes, workplaces, and infrastructure in many countries, such as Switzerland and Germany. One of their business unit, real estate products, deliver modular wooden buildings designed as scalable products instead of one-off projects. Their model aims to optimise maximum value creation along the entire lifecycle for end-users, investors, and operators alike.

"…rely on multidisciplinary approaches, end-to-end digitalized processes and agile, partnership-based planning methods, and maintain an intensive dialogue with people and society. Our know-how in sustainable construction enables us to be particularly future-proof".

Therefore, in the early phase of the development, they did market research and had branding experts to acknowledge the market trends and needs. In addition, they collaborate with other company who has experience in the automotive industry to create the road map for the real estate product division. The division received proper training to set each activity, timeline, responsibilities, and main task.

4.3.1. Product Platform Development

Company C decided to shift from one-off projects to scalable products by applying building solutions that are intended for multiple locations, each time configured to the project and site-specific needs. They deliver building solutions with timber frames for two products that use the platform approach, which are hotels and residential housing. The hotel's designs are done using a sequence of 3D modules, while the residential housing uses a combination of 3D modules and 2D panels. The design also includes the structural system and MEP system that fit market targets in Switzerland, Germany, and Austria. Company C aims their products to be high quality, sustainable (circular and energy efficient), and flexible.

To enable the design properly, company C developed its configurators that can initiate design configuration for the site feasibility study and planning phase. The design configuration covered several factors, such as building factors, location factors, and environmental factors. For building factors, required inputs like the number of rooms, number of floors, and room mix are needed. The site location information and site boundaries are also incorporated. Then, the environmental factors, such as sunlight, shading, and noise, are incorporated according to specific requests. These inputs are then automatically generated to find the optimal configuration based on several criteria. The criteria vary from site efficiency, design ratios, cost of the building, circularity index, and carbon footprint.

The configurator itself is a desktop version based on Rhinoceros 3D modelling software and Grasshopper visual programming software (See Figure 4.5). The main purpose of this configurator is to support the early design phase as a planning tool for site feasibility studies, preliminary building design, and cost estimation. However, the interface detail between systems and production level of details is not currently covered by the configurator.

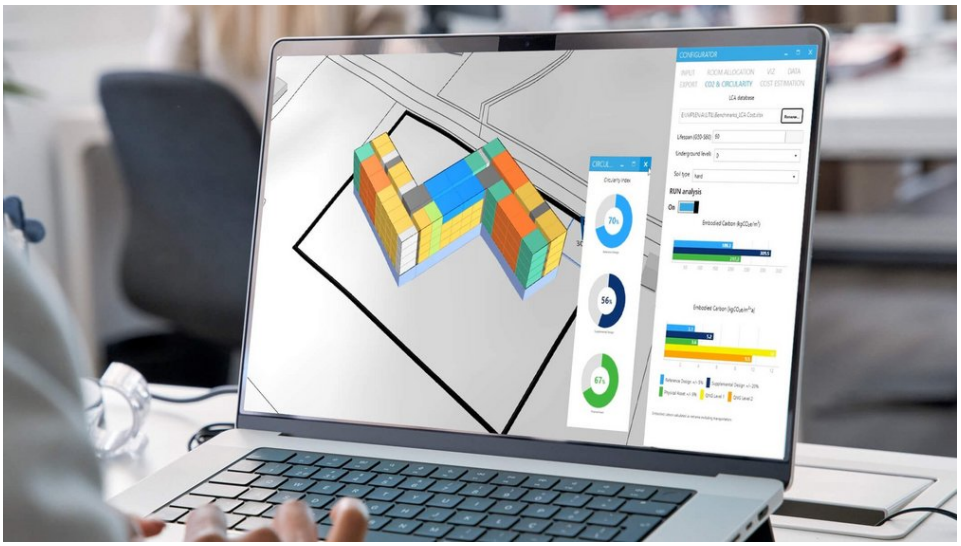

Figure 4.5: Company C's Product Platform Configurator (Source: Company C's website)

4.3.2. Company's Ecosystem

With the company's resources and reputation, Company C aims to build a shared ecosystem, a digital platform that adds value to people and the environment. They build their supply chain for Switzerland, Germany, and Austria markets. Visualisation of company C's collaborators can be seen in Figure 4.6.

- **In-House Team**
  Company C has a dedicated real estate products team under the real estate division in 2021. This team consist of 10 people who consider themselves as a startup inside a big company. These people come from various backgrounds, such as architects and structural engineers, with various core skills. Those skills include product management, product development, computational design, supply chain management, circular economy and ESG, customer centricity, and product delivery.

- **Outsource Expertise**
  Working together with Company C's partners helped them gain a lot of knowledge and speed up their product platform development. For example, during the early stage of the real estate products team, the team collaborated with a consultant firm from the automotive industry to build a road map for real estate products. The team also collaborates with an engineering company from Germany and Switzerland because of their familiarity with building regulations in each of their respective countries.

  > **"We are a small team where we have our core, let's say core skills and knowledge. And then we have a big ecosystem of partners, both for design and for production." (C.8)**

  Company C employed two engineering companies, one based in Switzerland and the other based in Germany, to develop company C's product platform. These companies share their personnel, allowing them to allocate resources flexibly. When the Swiss team required additional personnel, the German team could provide support, fostering resource sharing across borders.

- **Manufacturing Supply Line**
  Manufacturing partners that know about the modular approach are also one of the collaborators. Company C need production partners to deliver their physical products. This way, the manufacturers and suppliers can contribute to how to deliver the product in the most efficient way.

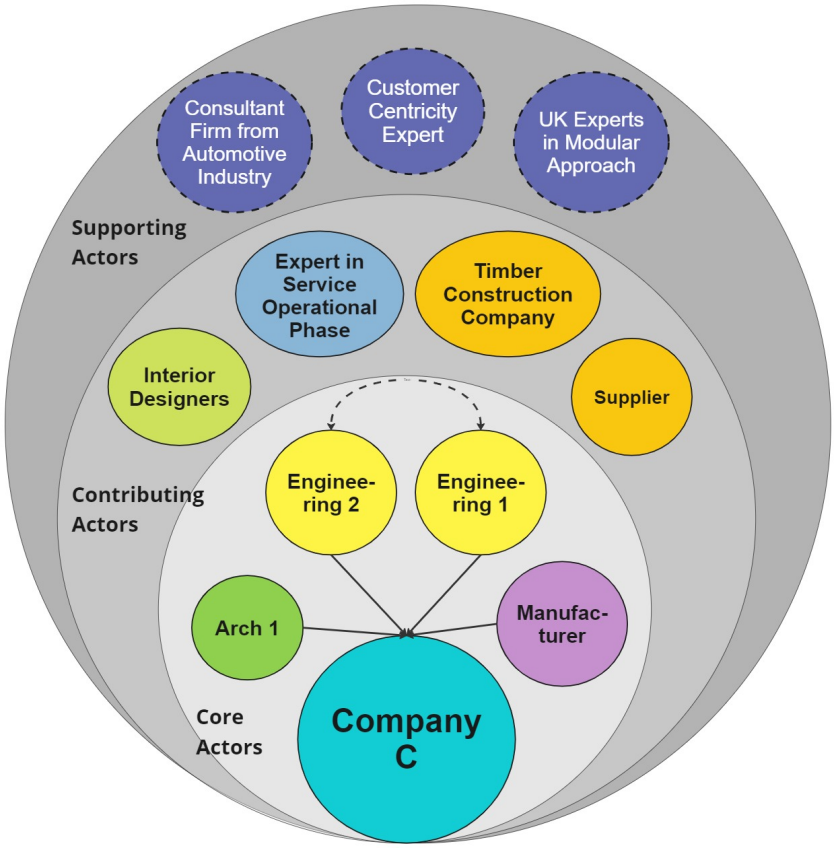

Figure 4.6: Company C Ecosystem

4.3.3. Change Management

Ecosystem Readiness Assessment

When the real estate products team was created, they had the purpose of providing new services in the development of strategies and tools needed to implement the real estate products. Shifting from a project approach to a product approach will resulting a new business model. To achieve this, they did

market research in their market region (which are Switzerland, Germany, and Austria) to identify the market demands and trends and the building regulations that are different for each country, and also tried to map their partners or potential partners.

The first thing that the team was to collaborate with a consultant firm from the automotive industry to build company C's roadmap of real estate products. This consultant firm from the automotive industry was considered to have a very high knowledge of a platform approach and experience in industrialised construction. The team received proper training to build their road map, consisting of a timeline, activities, responsibilities, main tasks, and so on. It makes sense for them to involve experts.

> **"We had the collaboration with the consultancy consultant firm, which is special, specialised in this type of project, is a company from the automotive industry with very high knowledge on a platform approach, industrialised construction and so on." (C.8)**

Then, the team spent their first year figuring out what product type they wanted to deliver for which market. For example, residential offices were found a lot than hotels. But then hotels seen to hold a potential in scalability. Then, they decided to do hospitality product, which is a hotel. Then, they set the building constraints, such as structure and materials. Interview sessions were incorporated as part of the market research to find building values (priority services, price, comfort, etc) directly from potential clients. Government regulations, such as reducing net greenhouse gas emissions by at least 55% by 2030 and climate-neutral by 2050, are also considered in the building design constraints.

> **"For instance, for interviewing clients and even users of the building so future tenants. asking them questions about what they value the most in the building. What? They're willing to pay for. So with that, the services that they need and those that are not the priority and so on." (C.8)**

Finding the right partners to collaborate is important. Since Company C is a big company, they already have relationships with some of their partners. Not only partners in their region but also outside the region, like the UK, who have a lot of expertise in a modular approach in the construction industry. The team took time to select the right partners that have experience in the way that the team want to work and have the same understanding on the goal to achieve.

> **"We have even partnered from the UK, which are expert in modular approach." (C.8)**

Orchestration Mechanism
Regarding standardisation activities, Company C's real estate products received Circular Globe certification that recognised the development of the standardised real estate products in accordance with the principle of the circular economy as "advanced". In selecting partners, Company C also has a policy to not directly appoint one partner without forced screening the market and has 2-3 proposals to compare and select. Furthermore, Company C focuses on the importance of *branding* to standardise its own products and guarantee its scalability.

> "**If you develop a brand, you can say that all hotels built within this brand have the same performances, quality standards, and so on. Somehow, the client will have this idea of the product being high value, well built, and so on. So, the moment that you set the brand, I work in a certain way to guarantee a certain standard with the brand." (C.8)**

Nurturing activities involve significant in-house investment in resources to develop in-house solutions. Company C's investment in product development is not only done by themselves but also by their investors, whom they invite every time they pass a milestone. During the collaborations, since Company C has a lot of partners, they held weekly meetings and used an open digital platform to keep track of the progress and changes. During weekly meetings, usually, there is a discussion or exchange of main ideas with all members of the collaborators. Progress updates are quite a structured conversation. Company C also asks them if their partners have any obstacles, blockers, or particular problems and who can solve these problems across the team of partners. Outside weekly meetings, there are also technical meetings with specific partners to discuss details or specific issues.

> “**We have an investor or investor representative that we invite every time we close the cycle. There are two different groups, depending on what we want to achieve on what kind of feedback we want to get” (C.9)**

> **“We had the proper training” (C.8)**

> **“We have weekly meetings with all the partners where we exchange main ideas. We ask if they have any obstacles, blockers or particular problems and who can solve these problems across the team of partners.” (C.8)**

Company C collaborate with two engineering companies, one from Switzerland and one from Germany. These engineering companies are working together by sharing resources in terms of personnel. Both engineering companies have the same expertise; the difference is only about knowledge about building regulations. Part of the negotiation mechanism involves the alignment of goals between the collaborators. So, the engineering companies try to balance the workload for their personnel.

> **“We’re responsible for the German calculations. Then there’s also another structural engineer who is going to be responsible for checking what’s happening in Switzerland because it’s slightly different, but not majorly. we all one design team, we all work together. Sometimes they work more and sometimes we work more and vice versa. it comes down to who has resources available at what time. To be honest, I mean we both try and work it out and balance each other out where we can do more or less over the long term.” (C.12)**

5 Analysis

This chapter discusses a cross-case analysis of three cases and generalised results that look into the process management of product platform development. Furthermore, it presents the comparison of each case studies on ecosystem strategy and boundaries. The section followed by change management focused on orchestration strategy.

5.1. Product Platform Development Process

Developing a product platform in the construction industry is perceived as an innovative solution with failure risks. Mostly in the construction industry, large-scale investment can lead to failure risks due to various factors, such as mismanagement. Based on interview results, some of the interview participants talked about ways to develop a product. Either go wide or go in-depth. A wide strategy is seen as giving more options to various clients. Currently, it offers more flexibility but shallow development details because it serves different kinds of product segments at the starting point. On the other hand, an In-depth strategy is perceived as focusing on certain restraints or rules, such as a specific market and product and developing it with a high level of detail in a clear, narrow path. Thus, deciding on one of these strategies is important to consider.

From three case studies, the companies are using a deep strategy where they put design boundaries in developing their product platform. Design boundaries include regional market, building functionality, and product development degree. Regional market and building functionalities were identified after assessing market trends. The regional market reflects on the geographical scope, which affects building codes as design boundaries, while building functionalities, such as hospitality and residential housing, also affect spatial design and sustainability or circularity principles as design boundaries. Although they have similarities in product degree, each company have a different characteristic of their platform mobilisation degree.

Type of Product and Mobilisation Degree

Product platform development comparisons between the three companies are shown in Table 5.1. The table includes details of product platform development degrees, strategies, and design boundaries. All companies are using the software Rhino 7 and Grasshopper to build their configurator. Additional software like Revit also used to support their design.

Company A named their product platform as Building Delivery System in the form of apartment catalogues. The customisation degree is limited to only the type of room and its spatial position that is given in the catalogue. This degree of product falls on Assemble-to-Order (ATO). Currently, Company A is developing a configurator that makes their standardised components will be digitally-enabled. The configurator will also make the different systems digitally enabled, particularly the MEP system with structure/architecture system. How this configurator mobilising platform utility falls on Type 2 because the current process of their Building Delivery System is a digitally-enabled system interface but only for one type of building function, which is an apartment. Additional features in the Company A configurator will include spatial design optimisation, sustainability and circularity index, and cost simulation.

Similarly, Company C introduced their product platform in two portfolios, where each portfolio has its own branding to classify the product family. The customisation degree is limited to only the number of rooms, floors, and other spatial function areas, such as the basement. This degree of product falls on Assemble-to-Order (ATO). Recently, Company C just launched their configurator that has similar features to Company A. However, the configurator does not make the interface system digitally enabled, and for now, it only can do one portfolio. Even though the interface system is not yet being digitally enabled, it does not mean Company C does not design the interface system. This description suits a Type-1 platform mobilisation through a digital platform.

Company B's product platform focuses on developing building systems for different types of buildings, such as apartments and supermarkets. Instead of a physical product as the end form, Company B's end product is a building system that has a higher level of customisation compared to companies A and C. It has a correlation with the company's business, where A and C are real estate developers, while B is not a real estate developer. The customisation degree is high enough where freedom of choosing dimension and size is given to build the building. This degree of the product falls on Make-to-Order (MTO). Company B's configurator allows the user to configure a building design using standardised designs based on Company B's system, which includes a kit of parts and a component interface. Its digitally-enabled interface between each module component has high details for manufacturing production and cost calculation. Currently, company B is developing additional features, such as carbon footprint calculation. How this configurator mobilising platform utility falls on Type 3 because the current process of their Building System is a digitally-enabled component interface for different building systems

Table 5.1: Product Platform Development Process: Comparison

	Company A	**Company B**	**Company C**
Product Type	• Building Delivery System • Modular Core, panelised exterior • Apartment	• Building System • Wooden modular system • Houses, apartments with max 5-7 floors, supermarkets	• Building System • 2D Panels, 3D Modules, Timber Frame • Hotel, Housing
Product Degree	ATO	MTO	ATO
Platforming Degree	Type 2	Type 3	Type 1
Platform Features	• Digitally-enabled interface (MEP and architectural) for 1 type of product • Spatial/Volume Optimization (ongoing) • Sustainability & Circularity Index (ongoing)	• Digitally-enabled design rules for various products • Inter-module connections with a high level of detail for manufacturing • Sustainability & Circularity Index (ongoing)	• Digitally-enabled kit of parts for 1 type of product (hotel) (ongoing for housing) • Spatial/Volume Optimization • Sustainability & Circularity Index
Starts	2021	2014	2020
Market Target	DK	NL	CH, DE, AT

Table 5.1 – *Continued from previous page*

	Company A	**Company B**	**Company C**
Development Team Composition	Outsource	In-House	In-House and Outsource
Current Phase	Catalogues (apartment, kitchen, bathroom, furniture)	Configurator 6.0	2 product portfolios, 1 configurator
Scaling Strategy	Gather product information from manufacturers to enrich the library	Approach many assembly halls to connect with many clients	Branding

To accommodate future project requirements, each company needs a scaling strategy that allows for a high degree of configuration. An early strategy for developing a product platform involves undertaking projects with different variant goals, such as apartment projects with varying room layouts and building areas. This variety helps pave the way for enhancing the product platform by addressing different complexities and market demands. For instance, expanding from a 5-floor to a 7-floor building introduces new challenges and opportunities for refinement. Additionally, different regions or countries have unique regulations and building codes that require adjustments, further enriching the platform's adaptability.

Other scaling strategies include gathering product information from various suppliers or manufacturers to enrich the library of the product platform configurator. This approach ensures that the platform remains up-to-date with the latest products and technologies, providing a comprehensive resource for future projects. Additionally, approaching multiple assembly halls to connect with a diverse range of clients can help expand the platform's reach and applicability. By engaging with various stakeholders and incorporating their feedback, companies can continuously improve the product platform, ensuring it meets the evolving needs of the construction industry. This holistic approach to scaling not only enhances the platform's functionality but also fosters innovation and collaboration across the ecosystem.

5.2. Product Platform Ecosystem

The product platform development purpose is to reduce longitudinal fragmentation in the construction industry, particularly in urban building projects like apartments, hotels, and housing, where a lot of task repetition is required. These projects involve a clear chain of command and defined roles and responsibilities, ensuring that tasks are completed in a sequential and organised manner. The ecosystem of an urban building project includes various stakeholders like architects, engineers, contractors, and suppliers, all working within this structured framework.

In contrast, product platform development projects focus on creating standardised components or systems that can be reused across multiple building projects. This approach aims to reduce redundancy and improve efficiency by minimising repetitive tasks. Unlike the hierarchical nature of urban building projects, product platform development emphasises collaboration over hierarchy. These projects involve close cooperation with various partners, including engineering firms, technology providers, and manufacturers, fostering innovation and flexibility.

The transformation of building projects from a traditional project-based strategy to a product platform development method has a substantial effect on stakeholder engagement. In the hierarchical structure of urban building projects, stakeholders such as architects, engineers, contractors, and suppliers operate within clearly defined roles and responsibilities, ensuring tasks are completed sequentially and efficiently. However, because they are recurring processes, they frequently result in inefficiencies and redundancies. In contrast, the product platform development approach fosters a collaborative environment where stakeholders work closely together to create standardised components or systems that

can be reused across multiple projects. This collaboration encourages innovation and flexibility, as stakeholders from various backgrounds, including engineering firms, technology providers, and manufacturers, contribute their expertise to develop efficient and innovative solutions.

From a business orientation perspective, the traditional approach focuses primarily on completing individual projects within budget and on time, emphasising efficiency and cost-effectiveness. However, the product platform development approach shifts the focus towards innovation and long-term value creation. By minimising redundancy and improving efficiency through standardised components, companies can reduce costs and enhance productivity. Moreover, this approach encourages continuous improvement and adaptation, as stakeholders collaborate to develop new technologies and processes that drive innovation. This shift from a pure business orientation to an innovation orientation not only enhances the overall ecosystem's productivity and robustness but also positions companies to achieve sustainable growth and competitive advantage in the construction industry.

5.2.1. Ecosystem Strategy

The construction industry is often perceived as not yet mature because of its fragmented supply chain and relationships. This condition presents opportunities for companies exploring the implementation of product platforms, which have shown success in other industries, such as automotive. Developing a product platform is seen as providing a niche solution that allows businesses to focus on specialised segments and leverage the assets of other firms, driving value creation and innovation. However, companies must navigate their dependence on keystones and dominators within the ecosystem. For instance, Company B, identified as a niche player, can develop specialised expertise while relying on keystone companies like A and C for broader ecosystem stability (see Figure 5.1). Based on data collection (literature review, interview session, and data triangulation), three companies were identified with the reasoning below.

Companies like B, which are small and focused, embody the niche strategy, developing their intellectual property and processes independently. Their specialised expertise in creating advanced design solutions allows them to drive innovation and value creation within the ecosystem. In contrast, Companies A and C adopt keystone strategies by sharing intellectual property with partners, facilitating faster development through collaborative efforts. Companies A and C act as keystones, centralising resources and managing relationships to stabilise and grow the ecosystem. Additionally, Companies B and C serve as hubs, providing a single face to the customer and orchestrating the ecosystem's activities, whereas Company A, as a land developer, likely functions as a hub by connecting various stakeholders in the early design phase, although it could also be seen as a spoke depending on its collaborative dynamics.

Shifting from a project-based to a product-based approach in construction necessitates a new business model, integrating both niche provider solutions and hub roles. This approach involves coordinating multiple stakeholders from the outset and fostering interdisciplinary collaboration to address challenges such as material specifications, structural integrity, and assembly methods. The change to a product platform not only redefines company roles but also leverages the collective strengths of the ecosystem, enhancing innovation and efficiency in the construction industry. This alignment with ecosystem strategy literature underscores the importance of strategic positioning and role adaptation in achieving successful product platform development.

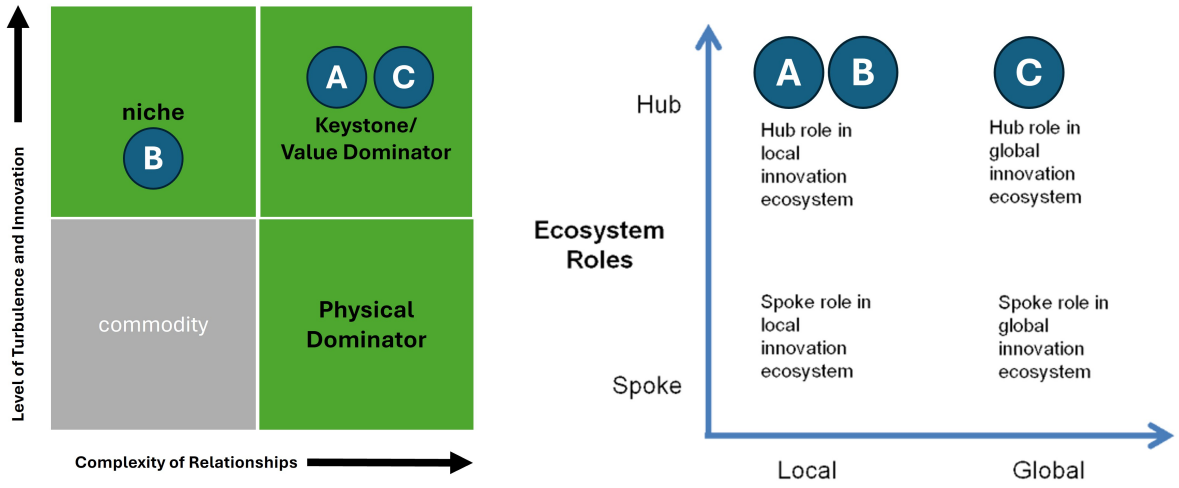

Figure 5.1: Companies Map Based on Roles and Position

5.2.2. Roles and Responsibility

If the ecosystem is healthy, individual participants will thrive. In business, that is because the companies, products, and technologies of a business network are, like the species in a biological ecosystem, increasingly intertwined in mutually dependent relationships outside of which they have little meaning. All companies have their own roles in the construction industry (the bigger picture, compared to the product platform team). It hinders responsibility as an actor in the construction industry.

Companies A and C holds the keystone and hub function of regulating ecosystem health in the construction industy. Being the leader of the ecosystem makes them have more responsibilities to ensure a stable ecosystem and to secure their own survival and prosperity by creating and sharing the value with other participants in the ecosystem. Developing a product platform is seen as one of the solutions for others in the ecosystem. Keystone creates momentum and leaves the vast majority of value creation to others in the ecosystem. Companies A and C did it in their own ecosystem and selected their partners carefully. They lead their partners as integrators to achieve their goal that benefits the supply chain. However, there is also danger that comes with the benefit. If the keystone companies absorb too much value created by other members of the ecosystem, it might bring down the ecosystem. Thus, keystone companies share their value by balancing their generosity with the need to keep some of that value for themselves.

Different circumstances happen to company B where it has developed specialised capabilities that differentiate it from other companies in the industry. This company focus on creating sustainable building systems that can support land developers, manufacturers, and architects in the design phase. Niche players represent the bulk of the ecosystem and are responsible for most of the value creation and innovation. Naturally, this company dependent on other business, it needs to analyze its ecosystem and identify the characteristics of its keystones (current or potential). Despite their highly specialised strategies, niche players usually face conflicts with others. One of the conflicts is with Keystone's movement, where improving the ecosystem's health sometimes comes at the expense of a niche member. However, differentiation provides a powerful defense. Company B provides a high-flexibility service that weakens the strong ties with a keystone. Furthermore, Company B having full ownership that leverage their freedom position. Thus, company B have the freedom to enter another ecosystem, making the keystone have to stay fair and under control.

5.2.3. Ecosystem Boundaries

The findings from the study highlight the challenges faced by companies operating within different ecosystems and diverse strategies to cope within. *Cost* becomes the main boundary for any company. The need for upfront investment in innovation projects presents financial risk of returns uncertainty, influencing strategic decisions and development paths. The domino effect of cost considerations demon-

strates how different parts of an ecosystem are connected, showing that financial limitations can affect other strategic areas like expanding into new regions and coordinating with partners.

> **"I will say one big boundary realistic one is cost." (C.8)**

Each company operates in *different regional markets*—Denmark, the Netherlands (with expansion into France), and Switzerland, Germany, and Austria respectively. Each region's unique building codes, regulations, and design preferences necessitate a tailored approach to product platform development in the construction industry. This local adaptation, combined with global market knowledge, enhances the competitive advantage of each company within its specific ecosystem.

> **"When we started, we wanted to start at the same time in Denmark, Netherlands, and Finland. In the end, with all the Ukrainian war, we had to close down some markets, and we stayed so far only in Denmark." (A.2)**

Competitive advantage also varies significantly among the companies. Company B's approach of full ownership over its intellectual property while fostering independence and control results in a slow journey in product platform development as the company relies solely on its internal resources. On the other hand, Companies A and C secure intellectual property from their partners through partnership agreements, in trade of a stable stream of projects and continuous income for their collaborators.

> **"One of the reasons why so many of these projects end up in court is because we have chopped the development process in very small pieces, and we have given the direction of these pieces or the ownership of these pieces to various parties." (A.1)**

> **"We listened to the markets in the beginning and we developed over time, you know we we didn't scale up super fast like a lot of companies." (B.5)**

> **"We own the intellectual property of what we are developing. 100%, so the partners have to agree that the property is ours." (C.8)**

The size of the company also plays a crucial role in shaping its strategic approach. Company B, being a small firm with limited resources, requires its employees to possess multidisciplinary skills and flexibility in their roles. This contrasts with Company A, a real estate developer who prefers collaboration to achieve its vision, while Company C, a larger entity with substantial monetary resources, still opts for collaboration despite having the capacity to enhance its in-house capabilities. These differences reflect how ecosystem characteristics, such as competitive advantage and orchestration, influence the management of boundaries and strategic decisions within different business contexts.

5.3. Change Management

Having a new business model requires change management at the firm level and/or the ecosystem level. Knowing that collaboration with other partners to deliver a product platform, necessarily encourages stronger partner alignment around mutual objectives. Therefore, further discussion about orchestration strategy is discussed below.

5.3.1. Orchestration

Part of a firm strategy is to create opportunities through enabling access to resources and capabilities. Thus, the ecosystem orchestrator can determine, based on their capabilities, how they exert power by controlling resources, such as intellectual property. The results of each case study will be reflected according to Hurmelinna-Laukkanen and Nätti (2018) classification of orchestrator.

Type of Orchestrators

From the case studies, all companies have similar businesses/activities in improving their competitive advantages and profitability. Thus, all companies show that they anre *a player orchestrator* with their typical management activities, such as promoting mobilisation, setting agendas, and coordinating. The following paragraphs inform ways of companies conducting activities as an orchestrator.

Promoting mobilisation is reflected in orchestration mechanisms, such as selecting the network participants and defining the network. This includes increasing or reducing the number of partners and searching for partners outside its core business. *Setting agendas* can be seen in creating the product development roadmap, where timelines, tasks, responsibilities, etc, are defined. *Coordinating* activities include monitoring the progress in weekly meetings or urgent technical meetings and allocating tasks to other network members.

Resource Mapping
As an orchestrator, the company needs to identify its internal resources and industry resources to build its ecosystem. In developing a product platform for the urban buildings market, multi-disciplinary expertise is needed. Insights from three case studies are summarised to provide what are the backgrounds, skills and actors needed for product platform development.

To set the course for the type of product to develop, it is important to understand the market and potential clients. *Customer centricity* plays a role in this process by conducting market studies to gather information about potential client's expectations and preferences regarding the products they intend to purchase. The market feedback guides the company in aligning its product development efforts with client needs, ensuring a higher likelihood of market acceptance and success.

In scenarios where the company lacks experience in industrialization and modular products, but faces substantial targets, the risk of failure can be mitigated by leveraging external expertise. Hiring *a consultancy firm* with experience in developing product platforms can be beneficial. Such firms can guide in creating a roadmap for product platform development, training the company to identify and set goals, define activities and tasks, and clarify roles and responsibilities. This external support ensures that the company is well-prepared to meet its objectives efficiently and effectively.

The development of a product platform necessitates the involvement of several key actors, including architects, engineering companies, manufacturing companies, and material and product suppliers. Each actor plays a specific role during the product platform development, particularly in the conceptual design phase, which involves the creation of the kit of parts, interfaces, and design rules. *Architects* are responsible for the initial conceptual design, ensuring that the functional aspects of the product align with market demands and client expectations. *Engineering companies* provide the technical expertise necessary to ensure the structural integrity and feasibility of the designs, collaborating closely with architects to translate design concepts into viable products. *Manufacturing companies* operate factories that produce the components and assemblies needed for the product platform, ensuring that production processes are efficient and meet the required quality standards. Meanwhile, *material and product suppliers* provide the necessary materials and products that form the building blocks of the platform, maintaining a steady supply chain and ensuring quality to support the manufacturing process.

Product management differs from project management in several key aspects. While project management focuses on completing a specific project within defined constraints such as scope, time, and cost, product management is more concerned with the overall vision, strategy, and product lifecycle. This distinction necessitates the involvement of professionals with specialised roles, such as *product managers*, *product designers* and *product delivery*.

The creation of a product platform extends beyond physical components to include digital tools that facilitate design and manufacturing processes. Digitally-enabled product platforms often use software such as Rhino 7, Grasshopper, and sometimes Revit. These tools allow for the development of configurable and adaptive designs. While anyone can use these software tools, a background in architecture or civil engineering is typically required to engage in computational design effectively. *Computational designers*, often architects, utilise these tools to create sophisticated, adaptable designs. However, engineers with computational design skills can also contribute significantly. To expedite software development, the inclusion of *software engineers* is advantageous, providing the technical expertise needed to enhance digital tools and streamline the development process.

5.3.2. Transformation Management
The interview sessions extracted information on how product platform owners/orchestrators organise their ecosystem. The orchestration strategy includes the readiness assessment, both from the internal

team of the company and the external partners in the company's ecosystem. Furthermore, various mechanism was identified as part of a reflection on the orchestration strategy.

a. **Readiness Assessment**
To strive in the industry, every company needs a robust strategy that enhances their adaptability and resilience in an evolving market. Thus, the first step is to systematically evaluate their strategies by doing an ecosystem readiness assessment, which involves external and internal assessments.

- **External Trend Assesment**
To effectively change from a project-based to a product-based approach in the construction industry, it is crucial to first conduct a thorough external market trend assessment. Understanding market demands and regulatory requirements is fundamental. For instance, Company A recognised the importance of adhering to Danish *building regulations* aimed at reducing the carbon footprint of buildings to 4kg CO2/m²/year. Similarly, Company C undertook extensive *market research* in Switzerland, Germany, and Austria to identify regional market demands and regulatory trends. This included understanding client preferences and potential market segments, such as the decision to focus on hospitality products based on market potential. Conducting *workshops* to gather insights from various industry experts, as done by Company A, is an effective strategy to understand and address industry challenges and trends. Similarly, Company B assessed the preferred materials and industry opportunities in the Netherlands.

- **Internal Business Assessment**
For a successful transformation to a product-based approach, companies must first assess their original business model and core competencies. This involves understanding their foundational strengths (resources and skills) and aligning them to support the new business model.

  For instance, a company originally focused on architecture, like Company B, can leverage its design expertise and sustainable housing knowledge to deliver building systems as a design guideline for architects and production software for manufacturers. By aligning their existing resources with the benefits of industrialised construction, they can offer new services such as design and consultancy for product-based housing projects.

  Similarly, real estate developers like Company A can utilise their extensive experience in building and project management to address the challenges of shifting to a product-based approach. By fostering interdisciplinary collaboration within the company, they can develop innovative solutions that integrate various internal departments and expertise, supporting their new business model aimed at reducing the carbon footprint of building systems.

  A construction firm like Company C, which expanded its business from only delivering real estate projects, now wants to become a developer as well. Then, the focus should be on creating dedicated teams to develop strategies and tools for implementing real estate products. By collaborating with experts from other industries, such as the automotive sector, they can build comprehensive roadmaps that align their internal capabilities with the new product-based approach. This helps in identifying the right product types and market segments to focus on, ensuring a smooth change to the new business model.

- **Partner Assessment**
Identifying and collaborating with the right partners is a critical component of ecosystem readiness. Companies need to map out potential partners who have the necessary expertise and share similar goals to support the company in reaching its goals. For example, Company C collaborated with a consultant firm from the automotive industry to leverage their knowledge in product platform approaches and industrialised construction. They also did *web searching* to find the right experts, even if the experts were not from their region. This partnership enabled them to develop a comprehensive roadmap for their real estate products.

Similarly, Company A organised a *competition* to screen potential partners that fulfilled the standard requirements. Effective partner assessment ensures that companies have access to the required resources and expertise to successfully implement their new business models.

b. **Orcestration Mechanism**
Product approaches in the construction industry generally implement different processes compared to the traditional approach. In traditional construction, each stakeholder often operates in silos, with limited interaction and dependence on o ne another. However, in a product-based approach, stakeholders are deeply intertwined, creating a network of interdependencies. This means that the actions, decisions, and performance of one stakeholder can significantly impact the others. This condition affects the need for greater reliance on the orchestration mechanism to align all actors in the ecosystem. To ensure the ecosystem is well organised, diverse orchestration mechanisms are presented.

- **Standardisation Mechanism**
Standardisation mechanisms typically involve establishing the requirements, co-developing technological standards with partners, and ensuring compliance through certifications. For instance, Company A focuses on sustainability and technological standards, selecting partners through *competitive processes* to integrate the best expertise. Company B emphasizes CNC milling technology and develops software to optimize production, ensuring their building systems are *certified* for fire testing and soundproofing. Company C's real estate products adhere to circular economy principles, as recognised by their Circular Globe certification, and they have a *company policy* on selecting partners to ensure objectivity and alignment with their standards. Furthermore, Company C shows the importance of *branding* to standardise its own products and guarantee its scalability.

- **Nurturing Mechanism**
The challenges that partners face in developing the ability to undertake the new activities that underlie their planned contributions are perceived as the nurturing mechanism. The case studies show that nurturing mechanisms involve significant investment in resources, development of new routines, and fostering innovation through collaboration.

  Company A emphasizes knowledge sharing and creating new routines to enhance their development process. They maintain a product library as a technical platform for their kit of parts and attract diverse manufacturing supply lines to foster innovation. By logging and capturing learnings throughout all project phases and feeding this information back to the R&D team, they continuously optimize building components and resolve issues for future projects. These nurturing mechanisms ensure that companies can effectively scale their product platforms and maintain a competitive edge in the market.

  Company B focuses on developing new routines and processes to enhance their product platform capabilities. By taking on challenging projects, such as constructing a 7-story building when their system was initially designed for 5 stories, they drive growth and adaptability. Their flexible working environment encourages innovation, even if it sometimes leads to a lack of perceived management, ultimately fostering a culture of continuous improvement.

  Company C exemplifies this by investing heavily in product development and maintaining structured weekly meetings with partners to discuss progress and address any obstacles. This collaborative approach, supported by an open digital platform, ensures continuous improvement and problem-solving across the ecosystem. Furthermore, the company invest in developing its internal capabilities by training its resources.

- **Negotiation Mechanism**
The goal of the negotiation mechanism is to ensure partners' willingness to undertake the required activities and raise questions of priorities and incentives for participation. Company A, for instance, offers *long-term partnerships* to manufacturing companies in exchange for close

cooperation, assuming the role of overall owner and project manager. This approach helps overcome the challenge of finding experienced partners and ensures a cohesive change from a project-based to a product-based approach.

Company B, expanding into new markets like France, sets new manufacturing standards and manages a network of fabricators to mitigate risks and streamline the production process. This strategy facilitates the scaling of assembly halls and provides *more procurement options*, enhancing flexibility and efficiency.

Company C's negotiation mechanism involves collaborating with engineering companies from different regions, sharing resources, and aligning goals to balance workloads and leverage regional expertise. By fostering transparent communication and regular goal alignment, Company C ensures that all partners are working towards common objectives and promoting a cooperative environment.

- **Ownership Mechanism**
  Ownership is a critical factor in business strategy, often perceived as an asset that can be leveraged by the owners. Full ownership provides companies with the leverage of greater control over setting standards and can prevent opportunistic behaviour during partnerships. However, this comes at a cost. Lead firms must bear significant early investment costs to develop their own product platforms and ecosystems. These firms take on the risk of these investments, aiming to align ecosystem partners with their vision.

  By creating its product platform from the ground up independently, including the building system and configurator, Company B was able to attain complete ownership. With this strategy, they possessed total control over their standards and intellectual property. In contrast to businesses with shared ownership, it also resulted in slower growth. For example, Company B turned down an offer from a prospective partner who wanted full rights to the company's intellectual property because control and standards were more important to them than quick cooperation. The case demonstrates the trade-offs associated with retaining complete ownership: although it protects sensitive data and authority, it could restrict partnership possibilities and slow expansion.

  Conversely, Companies A and C opted for a collaborative approach to ownership, sharing intellectual property with partners. This strategy accelerates growth by leveraging the expertise and resources of multiple stakeholders. However, it introduces challenges in ensuring the security and proper use of shared knowledge. Detailed contracts and strict agreements are essential to prevent misuse or leakage of information. This collaborative ownership model allows for faster ecosystem development but requires careful management of intellectual property rights and partner relationships.

6

Discussion

In this chapter, the findings from the literature and interviews are discussed and analysed. The results include the product platform development process, product platform exosystem, and change management. Furthermore, the chapter explores the scientific and practical implications of the research, along with a consideration of its limitations.

6.1. Result Interpretation

Developing a product platform offers an opportunity for construction companies to deliver projects more efficiently, particularly by addressing the industry's inherent fragmentation. For companies aiming to transform from traditional project-based approaches to a more standardised product-based model, especially through the development of product platforms, understanding the necessary strategies and steps is crucial.

a. **Iterative Development Strategy**
   The findings aligned with suggestions from (Zhou, 2024) that construction companies can develop different types of platforms and deploy such platforms into a specific project. Furthermore, The product platform can be developed using an iterative approach. Company C initially built their first portfolio and then built the second portfolio that shares 60% of the first portfolio's components. Additionally, Company C developed different configurators for each of their portfolios. Similarly, Company B continuously updates their product platform, incorporating more details with each new project. Overall, the companies utilise their evolving platform elements to deliver projects iteratively based on projects or customer requirements.

b. **New Roles Introduced**
   Harala et al. (2023) note that such change often requires new expertise and hybrid skills, with roles and responsibilities evolving as companies enter new ecosystems. This is evident in Company B, where engineers with backgrounds in architecture or civil engineering have spread their roles into software development. Similarly, Company C introduced roles, such as product managers and product designers, which are typically uncommon in the construction industry. Company A manufacturers also had the experience to design modular products that won a competition and were awarded with the project.

   Despite the similarities in services between Company A and Company C, both are land developers that develop their product platforms; Company A has not introduced key roles such as product managers and product designers like Company C. Company A, traditionally a land developer, relies heavily on external partners for design and construction, maintaining control through regular oversight but without dedicated roles. This reflects their focus on strategic vision rather than direct management of construction processes. On the other hand, Company C, which started as a contractor, has more operational complexity, necessitating specialised roles to manage both construction and product platform development. Ulrich and Eppinger (2003) emphasizes the

importance of specialised roles in managing product development processes. For company A, introducing these roles could streamline the development of their product platform, bringing greater efficiency and scalability, especially as the product platform matures and the need for internal coordination grow.

c. **Company Size as an Influence Factor on Platforming Strategies**
Company size, as reflected in annual revenue, does have an influence on platforming strategies. Company A, within less than 5 years, is close to finishing its first version of a configurator, achieving a Type 2 platforming degree. Company B, which started way earlier than other companies, has focused on developing a Type 3 product platform to provide more flexibility to diverse clients and ensure the manufacturers can produce the physical products. Meanwhile, Company C, covering a broader market region than both Company A and B, is currently at a Type 1 platforming degree with its configurator.

This variation in process highlights that company size alone does not determine platform mobilisation. While larger firms like Company C have more resources, they often face organisational complexity and bureaucratic layers that might slow decision-making and platform development. Managing multiple markets adds further challenges, as Company C must adapt to different regulatory environments, diluting its focus on platform advancement. On the other hand, Company B's smaller size and narrow focus on the Netherlands, along with its earlier start in 2014, allowed it to concentrate resources more effectively, achieving the highest level of platform mobilisation. The company has made progress with a more concentrated effort compared to Company C. Company C's multi-market strategy may have been driven by the need for early profits to fund platform development.

d. **Product Platform as a Negotiation Mechanism**
Caputo et al. (2018) emphasise the importance of governance systems in defining ecosystem boundaries, and all three cases illustrate how different governance choices, ownership versus collaboration, impact the speed of innovation. The alignment strategies employed by Companies A and C allow for leveraging external expertise and resources, thus driving development processes. Thus, the product platform is used as a strategic resource on the company-wide level to achieve a competitive advantage.

Followed by product platforms as a strategic resource, product platforms might, therefore, represent a part of company strategy. Developing a product platform will not automatically ensure sustainable business outcomes. Any flaw in strategic decision on a product platform related to design and target market definitions can result in multiple risks. To avoid such risks, companies need to incorporate product platforms into the overall company strategy development (Harland et al., 2018).

The findings show that ownership mechanisms often overlap with negotiation mechanisms, particularly in the context of product platform development (see Figure 6.1). Havinga et al. (2023) identify ownership as a distinct orchestration mechanism without considering the product platform itself as a negotiable resource that could be leveraged during the negotiation process. Ownership of the product platform gives companies leverage during negotiations, allowing them to obtain advantageous terms on intellectual property, profit-sharing, and long-term partnerships. To reflect its role in negotiations more precisely, a new subcategory within the negotiation mechanism by Parida et al. (2019) is suggested: using product platforms as leverage.

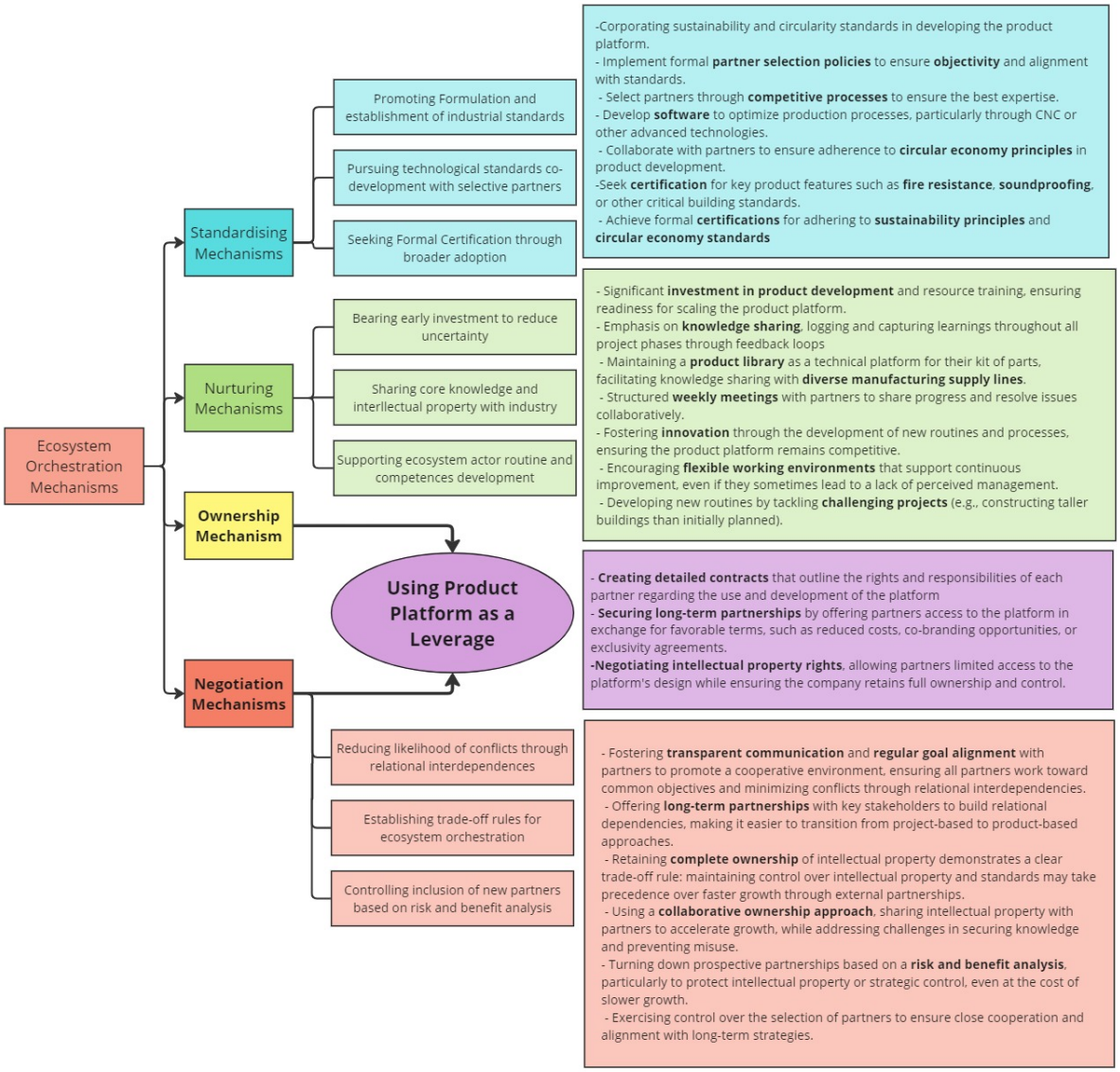

Figure 6.1: Orchestration Mechanism for Industrialised Construction Companies in Developing Product Platform

e. **Orchestration Mechanism Usage Distribution**
Orchestration mechanisms are important for aligning partners in a construction ecosystem. However, not all companies prioritise them equally due to their specific roles and limitations. As keystones, Companies A and C are responsible for stabilising their ecosystem, while Company B, a niche player, focuses on adding specialised value. These differences are reflected in how each company performs across the three orchestration mechanisms: standardisation, nurturing, and negotiation.

Company A and Company C share the same focus in their orchestration mechanisms. They focus most on standardisation, where both companies focus heavily on maintaining industry standards and ensuring the quality and scalability of their product platforms. For company A, this focus aligns with their roles as a land developer, where controlling sustainability and compliance is crucial. Similarly, Company C excels in standardisation, backed by substantial capital investment and internal resources, allowing them to set industry-leading standards like the certification that they received. However, negotiation is the weakest mechanism for both Company A and Company C. Despite their role as keystones, which requires fostering ecosystem-wide collaboration, Company A's negotiation strategy is rigid and transactional, limiting the depth of their relationships with partners. They rely on external collaborators to execute projects, but Company A's "take it or

leave it" approach hinders long-term strategic growth. Company C, on the other hand, faces different limitations. While its financial independence strengthens its position, Company C invests considerable effort into strategic negotiation to ensure its vision aligns with partners. However, the complexity of aligning multiple stakeholders can make negotiation more resource-intensive, slowing decision-making, and requiring continuous effort to maintain long-term partnerships.

Company B, as a niche player, exhibits a different focus. They focus most on negotiation, where they succeed in securing favourable terms with clients, particularly in new markets. Their focus on protecting their IP aligns with their business strategy of maintaining control over their innovations. However, company B's nurturing mechanism is less attention due to limitations on investing in internal capabilities.

The difference between Company A (and, by extension, Company C) and Company B lies in their emphasis on negotiation and nurturing. Company A and C put not much in negotiation, though for different reasons: Company A relies on rigid strategies and transactional relationships, while Company C, despite their financial independence, invests considerable effort into aligning their vision with partners. However, the complexity of managing multiple stakeholders can make Company C's negotiation resource-intensive, slowing decision-making. Company B, on the other hand, struggles with nurturing due to its protective stance over intellectual property. Instead of focusing on open collaboration, Company B should invest more in developing its internal capabilities, ensuring it maintains control over its IP while fostering internal innovation.

In the future, these companies must enhance their weakest mechanisms to remain competitive and sustainable in a dynamic construction ecosystem. For Companies A and C, improving negotiation is crucial to unlocking deeper collaboration with partners, enabling them to harness external innovation and align their ecosystems more strategically. For Company B, enhancing internal nurturing capabilities through focused investment in innovation and training will ensure sustained adaptability and innovation, strengthening its position in the ecosystem. Without addressing these weaknesses, each company risks missing opportunities for growth, innovation, and long-term ecosystem health, all of which are essential for their future success.

f. **Ecosystem Difference**
All companies reflect their distinct roles and ecosystems within the construction industry. While each company leverages a network of actors, the nature of these alignments and their strategic focus differ, showing the varying degrees of platform development and service delivery.

Company A and Company C both play the role of keystone players in their ecosystems. As keystone players, these companies take on a central role in orchestrating their networks and driving project delivery. They rely on niche players, such as architects and engineers, and physical dominators, like manufacturers, to execute their projects. Their ecosystems are primarily focused on project delivery, leveraging specialised actors to meet specific construction demands. This alignment is a reflection of their role as keystones, where they guide and coordinate the efforts of various actors to ensure successful project outcomes. However, their ecosystem alignment is largely geared towards delivering individual projects rather than focusing on a broader product platform approach.

On the other hand, Company B plays the role of a niche player in the ecosystem. As a niche player, Company B provides specialized services that complement the broader efforts of keystone players. In addition to collaborating with niche players like architects and engineers, Company B works with certification partners and a CNC factory (a physical dominator), enabling it to offer services beyond traditional project delivery, such as product certification and customisation. The alignment of Company B's ecosystem is centred around its role as a service provider, with a focus on technology-driven solutions and compliance. By aligning with actors who specialize in certification and customization, Company B's ecosystem supports its ability to offer value-added services, positioning it as a niche player that enhances product flexibility and ensures compliance within the construction ecosystem.

When the ecosystems of Company A, Company B, and Company C are considered together, a more comprehensive view of the actors involved in product platform development emerges.

Each company contributes distinct actors to the broader ecosystem, illustrating the diverse roles required for successful platform development. For example, Company C's supporting actors play a crucial role in laying the strategic foundation for platform development, offering insights and guidance to establish platform-based business models. Meanwhile, Company B's certification partners are instrumental in testing and validating the platform's physical products, providing feedback to improve platform design. Importantly, the absence of certain actors in a company's ecosystem diagram does not imply that those actors are not involved. In some cases, these actors may not have been mentioned during interviews or may be considered less central to the development process. However, these actors still contribute significantly, albeit in more indirect or contextual ways, supporting the overall product platform development.

6.2. Product Platform Development Ecosystem Alignment Framework

To provide a clearer understanding of how industrialised construction companies can develop their product platform, this research proposes a comprehensive yet simplified decision-making framework. This framework outlines the steps and considerations for industrialised construction companies changing to a product-based approach, covering external and internal assessments and orchestration mechanisms. By following this framework, companies can navigate the complexities of developing a product platform by ensuring decisions are aligned with long-term business growth and managing collaboration with ecosystem partners in the construction industry. To have a clearer view, the framework displayed in Figure 6.2 will be exposed to understand the process of product platform development.

This framework can be helpful during the company's preliminary study to decide whether they want to develop a product platform or not. Additionally, this framework will also help to maintain the collaboration or partnership with various options of orchestration mechanisms. Companies can use it as an evaluation tool to see what can they improve in their management.

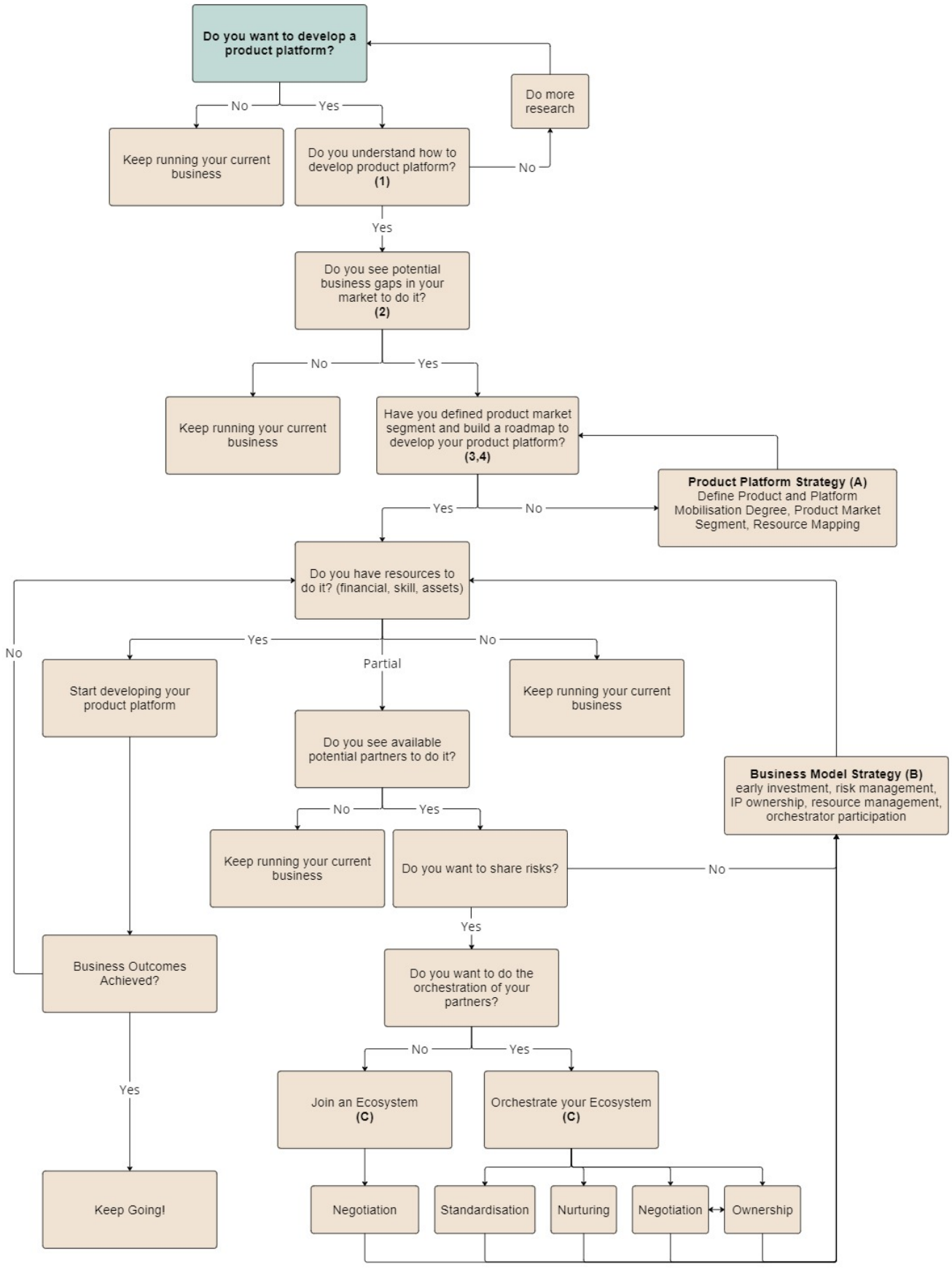

Figure 6.2: Product Platform and Platform-Based Products Development Framework

Details on every boxes are explained below.

(1) **Business Evaluation**

- **Product Platform Concept**
  Understanding the concept of a product platform, such as its components, principles, competency, and capabilities. The goal of using the product platform is to streamline project delivery by reducing fragmentations.
- **Strength and Weakness**
  Evaluating the company's strengths and weaknesses. Identifying areas of strength as leverage to gain competitive advantage, including having the product platform itself. Additionally, recognizing weaknesses allows the company to address gaps and improve its capabilities.

(2) **Market Research**

- Market trends and technological trends
  Following the market and technological trends to align the company's business strategy with the client's expectations and industry standards devolvement.
- Competitors
  Analysing competitors helps to identify market positioning.
- Opportunities and Threats
  Assessing the benefits and challenges of deploying the product platform. Furthermore, evaluating the potential advantages and risks associated with the product platform, including competitive pressure and market acceptance.
- Regulation and policy
  Understanding relevant regulations and policies for compliance and leveraging potential support.

(3) **Strategic Planning**

- Outcomes
  Defining value creation goals and desired outcomes from the product platform that aligns with business objectives.
- Boundaries
  Setting clear business and product design boundaries to provide a structured roadmap for product platform development. A roadmap helps to manage scope, resources, and milestones.

(4) **External Assesment**

- Current and potential client needs
  Understanding the needs and preferences of current and potential clients to ensure the alignment of the product platform with market demands and to enhance client satisfaction.
- Current and potential partners
  Screening potential partners and investors to support the company's goal by collaboration, resource sharing, and/or financial support.

(A) **Product Platform Strategy**
Decision factors on how to build and develop the product platform

- · Market segment target
  Deciding market regions and building segments, whether to go wide or go in-depth.
- Product degree
  Defining the degree of standardisation and flexibility in the product platform to balance customisation with efficiency. (see Figure 2.3)
- Platforming degree
  Planning on platform utilisation in configuring or automating the product design components (kit of parts, interfaces, design rule) through digital delivery effectively.

- Resource Mapping
  Assessing the company's available capital, skills, and expertise to determine readiness for product platform development and identifying areas that may require external support. Resulting in a resource portfolio as the sum of all firm-controlled resources (tangible and intangible assets) (Sirmon et al., 2007).

(B) **Business Model Strategy**
Decision factors on how to develop the product platform and to set the business model:

- Early investment
  Planning the necessary upfront investment required to develop the product platform.
- Failure risk
  Assessing and mitigating the risk of failure is crucial for sustainable development and long-term success.
- Intellectual property ownership
  Determining the ownership and control of intellectual property. Have full ownership on your own or buy it from your partners, or share ownership with your partners.
- Resource Management
  Identifying and mapping the necessary skills, expertise, assets, and partnerships to build a product platform. Then, decide on how to develop the resources (in-house or outsourced).
- Orchestrator Participation
  Choosing the company's role in the ecosystem, whether as a player orchestrator and/or sponsor orchestrator.

(C) **Orchestration Mechanism**
Ways to organize company's ecosystem during the development process:

- Standardisation
  Establishing industry standards and common practices to ensure consistency and quality across the product platform. Getting recognition (product certification or award winner) could be seen as the early step of a standardisation process.
- Nurturing
  Supporting the development of internal and/or external capabilities through training, collaboration, and resource allocation. Knowledge management by setting a feedback loop is also seen as a way to improve the capability.
- Negotiation
  Managing relationships and expectations with partners and stakeholders to align goals and facilitate cooperation. One example is having long-term partnership that is followed by a product scalability strategy.
- Ownership
  Ensuring clear ownership and control of intellectual property and outcomes to protect investments and foster trust among partners.

6.3. Contributions of the Research

The main purpose of this research is to make a contribution to both academia and practical applications within the construction industry, particularly in product platform development. The study seeks to address current challenges in developing a product platform from the process management perspective. Furthermore, the findings will not only enrich academic literature but also offer practical benefits to be implemented in the field.

Theory Contributions
This research provides theoretical contributions that enhance the understanding of ecosystem orchestration and product platform development strategy, particularly within the construction industry. These contributions enrich existing knowledge by linking ecosystem roles to orchestration mechanisms, in-

corporating product platforms as strategic assets in negotiation, and demonstrating how company role and size affect platform mobilisation degree.

First, this study relates distinct orchestration mechanisms to the roles of companies in their ecosystem. The current findings show that keystone firms responsible for ecosystem stability emphasise standardisation and nurturing mechanisms to maintain control and facilitate partner development. On the other hand, niche players concentrate more on negotiation mechanisms as their service in the ecosystem often relies on forming strategic partnerships. This contribution extends ecosystem theory (Adner, 2017; Iansiti and Levien, 2004); by connecting actors' roles with orchestration mechanisms, providing a clear understanding of how various companies manage their interactions with the ecosystem.

Second, the incorporation of product platforms into the negotiation mechanism is shown in the findings. Product platforms have been viewed as operational tools, but this research demonstrates how product platforms can be used as strategic assets in ecosystem negotiations. Particularly, niche players may leverage their product platforms to negotiate favourable terms and secure long-term partnerships within the ecosystem. This adds to the strategy of negotiation mechanisms (Parida et al., 2019) by introducing the product platform as a critical factor in shaping negotiation outcomes. It gives companies a new strategic perspective on how to leverage their platform capabilities to increase productivity and enhance their negotiation power within the ecosystem.

Third, the research contributes to the understanding of company size and its influence on platform mobilisation. Despite having more resources, Company C, the largest firm, only achieved Type 1 platform mobilisation degree, while the smaller company C reached Type 3 (the most advanced level). This suggests that factors such as organisational complexity, focus, and agility might play a more critical aspect than size in determining platform success. The findings challenge the assumption that larger firms will naturally lead in platform mobilisation, highlighting instead the importance of concentrated efforts and streamlined operations. Smaller companies with a narrower focus and more agile structures may progress further in platform development despite having fewer resources. This understanding contributes to the literature on platform mobilisation by showing that organisational focus and internal alignment are equally, if not more, important than size in achieving platform maturity.

Practice Contributions
The framework offers companies a systematic approach to assessing the feasibility of adopting a product platform strategy. It provides holistic steps for assessing whether to invest in product platform development and guides companies through the decision-making process. This helps companies make informed choices and reduces uncertainty in their strategic planning. Furthermore, the framework serves as a tool for assisting their ecosystem management. It helps organisations identify areas for improvement, refine their strategies, and enhance collaboration with partners, resulting in more efficient and effective product platform development.

6.4. Limitations

Although the goal of this study was to offer new insights into the field, it must be recognised that, like all research, it has limitations. It is essential to understand and share these limitations in order to support the study's credibility. For this reason, some of the limitations are listed below.

- The primary limitation of this study was the constrained research time, resulting in a reduced number of interviews.
- Due to the limited number of interviews, the insights on orchestration management might not explored deeply.
- Some of the stakeholders in each company's ecosystem are missing. A study that can have all the stakeholders on board will give a more holistic view of details on the partnership, particularly in intellectual property sharing management.
- The study focuses on three case studies within European industrialised construction companies with similar business models, so it's unclear if this dynamic applies across other industries or ecosystems.
- The analysis is based on subjective interpretations and may reflect the writer's perspective, which introduces potential bias.

7

Conclusions

In this chapter, the research done in previous chapters is summarised. This chapter consists of several parts. The first part is about the answer to the research question. Then, followed by recommendations and future research.

The aim of this research is to address the construction industry's fragmentation by developing and deploying a product platform approach. To be able to do that, industrialised construction companies need to strategically arrange their business strategy in creating or developing their product platform. For this research objective, the following research question was formulated.

“”How do industrialised construction companies enhance ecosystem collaboration in product platform development?”

To answer the main question, the following sub-questions are formulated, which are answered in the following sections.

7.1. Answer of the Research Question

SQ1 : What is the process flow in product platform development?

This sub-question aims to gain an understanding of the process involved in creating or developing a product platform, which is essential for setting the foundation for a successful product platform and effective collaboration. This involves the understanding of product platform concepts and principles, such as its components and capabilities, to address the construction industry's fragmentation.

The industrialisation principle was developed by adding new elements or capabilities which aligned with market demands and technological advancements. Today principle is mass customisation, where the automated production methods of mass production offer customised products. The main enabler of mass customisation is the product platform. Robertson and Ulrich (1998) defined a product platform as the collection of assets (i.e. components, processes, knowledge, people, and relationships) that are shared by a set of products. In the construction industry, they constituted modular product architectures (kit of parts), interfaces, and standard design rules for a building project, indicating potential benefits on cost and productivity. To identify the key enablers for the adoption of product platforms in construction, it is important to understand the context in which they will be deployed. Based on The Product Platfom Rulebook (2023), the construction sector has three major domains: client, project, and product domains.

Start by observing the client domain, which is identifying pipeline(s) and aggregating the demands. This is part of market research to identify opportunities and threats offered by the ecosystem in implementing product platforms. The market research results in inputs for product platform strategy as knowing what type of product is for the targeted market segment.

Continue with translating the client domain results for the product domain. In developing a product platform that can address the industry's fragmentation, the first phase is to develop a product platform followed by a platform-based product approach. Supported by the knowledge of the product platform's rules and principles, there are two components for product design consideration: product degree and platform mobilisation degree. *Product degree* reflects the level of the building system's standardisation and customisation, comprising both technical and process platforms. To explore the potential of platforms, product manufacturing processes are categorised on the Customer Order Decoupling Point (CODP), where mass Customisation focuses are between ATO and MTO. *Platform mobilisation degree* is perceived as the level of automating the final products through digital delivery. Typically, a digital configurator is built to enable the product platform components. There are three levels of platform mobilisation, which are: digitally-enabled kit of parts, interface, and design rules.

One of the product platform success factors is balancing commonality and variability. Thus, defining those two components of product design needs to consider four key areas of commonality strategy, which are technical feasibility, financial feasibility, acceptable in the market, and organisationally possible. To ensure technical feasibility and market acceptance, there is a main resource to deliver the product platform, which is a skill or intellectual resource.

The study found that there are actors and/or roles who possess the skills to develop product platforms. Those are architects, engineering companies, manufacturing companies, material and product suppliers, product managers, product designers, and product delivery. Additionally, there are other experts involved, such as sustainability and circularity experts, customer centricity, and product test laboratories. Mostly, their backgrounds are architecture, civil engineering, and industrial engineering. Furthermore, to build the digital configurator, there are computational designers and/or software developers who might have background variations. Their roles need to translate and automate the product in digital form, so basic architects and civil engineering are helpful. Typically, these roles are done by architecture and civil engineers who do automation and/or software engineers who understand how to translate it.

In summary, the development of product platforms in the construction industry involves aligning market demands with platform strategies, followed by designing and mobilising the platform through digital tools like configurators. A key challenge is balancing commonality and variability to ensure both customisation and scalability while addressing technical, financial, and market considerations. The involvement of specialised actors, from architects to engineers and sustainability experts, is essential for ensuring the platform's feasibility and alignment with industry standards. This integrated approach is critical to overcoming fragmentation and maximising the potential of product platforms in industrialised construction.

SQ2 : How do industrialised construction companies manage boundaries in the ecosystem to develop their product platform?
This sub-question focuses on identifying existing boundaries in the industrialised construction company's ecosystem. Furthermore, this question explores how industrialised construction companies develop their product platform by managing the boundaries by setting their business model strategy, including considering internal and external factors that influence decision-making.

The case studies reveal that managing boundaries within the ecosystem is a critical challenge for construction companies developing product platforms. One of the most significant boundaries companies face is a lack of resources, whether intellectual or financial. Cost emerges as the primary boundary shaping both product platform and business strategies. Additionally, the size of the company influences its ability to navigate these boundaries, as larger companies may have more internal resources but also greater complexity to manage.

To address these limitations, companies align with ecosystem partners, leveraging collaboration to fill gaps in resources and capabilities. This alignment becomes essential when companies face constraints in their internal capacities. By strategically managing partnerships, companies can distribute risks, reduce individual exposure, and foster a more resilient platform development process. The decision to either develop resources internally or acquire them through partners shapes the business model strategy, influencing the company's ability to innovate while managing risks and costs.

In this decision-making process, competitive advantage plays a pivotal role. Companies must evaluate how to best leverage their skills, expertise, or intellectual property to gain an edge in the market. This involves carefully weighing the trade-offs between developing resources in-house, acquiring them externally, or sharing ownership with partners. By balancing cost, innovation, and control, companies can strategically manage their assets, enhancing their competitive advantage while ensuring that the platform development remains viable and scalable.

Managing risk is another critical factor in platform development. Companies must go beyond simply evaluating the size of potential failures and focus on risk mitigation strategies. Collaboration becomes a valuable tool here, allowing companies to distribute risks across ecosystem partners. This shared risk reduces individual exposure and creates a more resilient platform development process, making the ecosystem more adaptable to challenges and uncertainties.

Effective risk management is another key component in platform development. Beyond simply assessing potential failures, companies need proactive risk mitigation strategies. Collaboration with ecosystem partners offers an effective solution, as it enables companies to share risks across the ecosystem, thereby reducing individual exposure. This collaborative approach not only creates a more resilient platform development process but also ensures that the ecosystem can better adapt to challenges and uncertainties.

In addition, regional market targets influence a company's strategy for product platform design. The geographic region of the market determines local standards, construction regulations, and design constraints. These regional regulations shape how companies adapt their product platforms to comply with local requirements. As s result, companies must align their product platform with regional market demands to remain competitive and meet regulatory standards.

Understanding and managing ecosystem boundaries is essential for assessing a company's role and position in the construction industry. Whether a company is a keystone or a niche player, its role shapes how it approaches these boundaries and may influence its participation as an orchestrator within the ecosystem. Companies acting as orchestrators leverage their influence to align ecosystem partners and guide strategic direction to ensure the successful development of the product platform. By clearly defining and managing these boundaries, orchestrators can better align partners around shared goals, ensuring that all stakeholders are committed to the product platform development. This alignment optimises resource utilisation, mitigates risks, and fosters a collaborative environment that supports the sustainable development of product platforms and contributes to long-term business success.

By strategically addressing these boundaries and aligning ecosystem partners (see Table 7.1), industrialised construction companies can ensure that all stakeholders are committed to shared objectives. This alignment not only optimises resource utilisation and mitigates risks but also fosters a collaborative environment that supports the sustainable development of product platforms, ultimately contributing to the company's long-term success and resilience in a competitive market.

Table 7.1: Boundary Management for Keystone Companies and Niche Players

Boundary Type	Description	Keystone Companies	Niche Players
1. Internal Boundaries			

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Table 7.1 – *Continued from previous page*

Boundary Type	Description	Keystone Companies	Niche Players
Cost Boundaries	Boundaries shaped by company size and financial capacity influence how companies balance cost, innovation, and control. Smaller companies focus on optimizing resources efficiently, while larger companies make long-term investments to manage costs and support growth.	Leverage financial capacity to take on larger, long-term platform investments.	Manage costs by focusing on specific, targeted investments in niche expertise and innovation.
Resource Limitations	Managing intellectual, skill-based, and financial resources involves companies either developing these resources internally, acquiring them from partners, or sharing ownership to fill gaps. By assessing their competitive advantage, companies determine the best approach to leveraging both internal and external resources effectively.	Invest heavily in resources, hire specialized roles, and secure financial backing.	Optimize existing resources, focus on specialization, and work with limited financial investment.
2. External Boundaries			
Role Boundary	Collaborating with ecosystem partners to address resource gaps and share development risks, companies form strategic partnerships that ensure a more resilient development process. These collaborations allow companies to adapt more easily to platform challenges while filling resource gaps effectively.	Set the ecosystem standards, guide partners with clear rules, and form long-term strategic partnerships.	Adapt to keystone-set standards and negotiate short-term/project-specific partnerships with flexibility for niche expertise.

Continued on next page

Table 7.1 – *Continued from previous page*

Boundary Type	Description	Keystone Companies	Niche Players
Market and Regulatory Constraints	Navigating regional regulations, policies, and market requirements, companies shape product platform design to comply with local standards and preferences. By adapting their platforms to align with regional market needs and construction rules, they ensure compliance and maintain competitiveness.	Lead in setting and enforcing compliance with regional standards, ensuring broad platform adaptability.	Adapt niche products to comply with both keystone and regional standards, focusing on local regulations.
3. Dynamic Boundaries			
Competitive Advantage	Companies strategically use the product platform as leverage for innovation and differentiation, optimizing internal and external resources to create a competitive advantage and enhance market positioning.	Use platform control to drive ecosystem-wide innovation and differentiation; maintain IP control.	Leverage niche expertise to create specialized solutions, navigate favorable differentiation, and protect niche IP.
Orchestrator Role	Company's role determine its influence on boundaries and collaboration. Orchestrator firms guide and influence ecosystem partners to align strategies for product platform success.	Act as orchestrators, managing and leading ecosystem-wide relationships and strategies.	Adapt to the ecosystem rules set by keystone firms while maintaining niche expertise and autonomy.

SQ3 : How do industrialised construction companies ensure ecosystem alignment to enhance ecosystem collaboration?
This sub-question aims to explore how companies align their partners with the company's goals of product platform development. By implementing the proposed orchestration mechanism, industrialised construction companies can enhance collaboration within the ecosystem, ensuring that partners are aligned and working towards shared objectives in product platform development.

Industrialised construction companies must begin by ensuring strong partner alignment to enhance ecosystem collaboration. Enhancing good collaboration starts with aligning all ecosystem partners around shared goals, values, and expectations. This alignment creates a cohesive environment where each partner understands their role and contributions toward the common objectives of the product platform. Partner alignment is crucial as it enables the company's strategy to capitalise on opportunities by leveraging the resources and capabilities available within the ecosystem. To establish the alignment, industrialised construction companies can follow four orchestration mechanisms to manage the ecosystem's alignment: standardisation, nurturing, negotiation, and ownership (see Figure 6.1).

Standardisation mechanisms are a way to establish industry standards and common practices to ensure consistency and quality across the product platform. Getting recognition (product certification or award winner) could be seen as the early step of a standardisation process. *Nurturing* mechanisms help in supporting the development of internal and/or external capabilities through training, collaboration, and resource allocation. Knowledge management by setting a feedback loop is also seen as a way to improve the capability. Then, *negotiation* mechanisms focus on managing relationships and expectations with partners and stakeholders to align goals and facilitate cooperation. One example is having a long-term partnership that is followed by a product scalability strategy. Finally, *ownership* mechanisms ensure clear ownership and control of intellectual property and outcomes to protect investments and foster trust among partners.

The findings reveal that different orchestration mechanisms are emphasised depending on the company's role within the ecosystem. Keystone companies, such as Company A and C, tend to focus on standardisation and nurturing to align a broad network of partners, while niche players, like Company B, excel in negotiation and protect ownership as a means of safeguarding their specialised contributions. By adapting their orchestration mechanisms to their role within the ecosystem, industrialised construction companies can ensure alignment among partners and, ultimately, enhance ecosystem collaboration.

In summary, the company's role as either a keystone or niche player determines how it distributes emphasis across orchestration mechanisms. For keystones, the priority lies in creating broad alignment and scalability, while niche players focus on ensuring their specialised value is preserved and recognised within the ecosystem. These distinctions enable companies to foster more effective collaboration, contributing to the long-term success of the product platform

7.2. Pratical Recommendations

As construction companies explore the development and management of product platforms, they encounter various practical challenges and considerations. To support this change, it is essential to provide actionable recommendations that address key aspects of implementing product platforms. This section offers key improvements based on research findings that are aimed at helping construction companies navigate the complexities of product platform development. The recommendations focus on strategic planning, effective management of ecosystem relationships, and fostering collaboration, with the goal of enabling companies to successfully adopt and sustain product platforms in a competitive and evolving market.

- Companies should not only focus on showcasing the final product but also on sharing the process of developing the product platform, from concept to execution. This transparency provides a dual benefit: it serves as a powerful marketing tool, allowing potential clients to understand the innovation and effort behind the product, and it opens opportunities for valuable feedback. During interactions, such as Q&A sessions, stakeholders may inquire about specific aspects of process management, offering insights that can be used to refine and improve the platform development process.
- If feasible, companies can secure patents for their product platform and configurator. This will not only protect the company's innovation but also contribute to the standardisation process. Additionally, aim for product certification to gain industry recognition and validate the quality and reliability of the product platform.
- Consider the strategic advantages of integrating computational designers directly within the engineering team, rather than maintaining them as separate entities. This approach can enhance resource management by fostering closer collaboration and reducing the need for multiple external collaborators. By doing so, architects involved in product platform development can adopt an engineering-oriented perspective, leading to more cohesive and innovative platform solutions.
- Since it has innovation activities, there will be early big investment and failure risk. Understanding the targeted market segment matters. Variations of product platform development can relate to the demand certainty in market segments. This implied that the company's executives need certain product requirements, preferably from multiple market segments, before making the strategic decision to invest in a product platform.

- Having sustainability and/or circularity index, and spatial optimisation features in the product platform should be a must as a compliance act and good promotions.
- Product platforms have to be designed in such a way that they can be adjusted to time-related market changes over their usage period (Harland et al., 2018).

7.3. Future Research Recommendations

Even though this research provides insightful information, there are still a number of unexplored research directions. To explore these directions, a number of recommendations for the future are suggested. Some of those are related to the limitations of the study discussed in section 5.4. The suggestions for future study are as follows.

- Further studies should explore whether the intersection of ownership and negotiation mechanisms, with product platforms as leverage, is relevant in other ecosystems.
- Future research should investigate companies with different business models to explore how varying roles, such as physical dominators as ecosystem orchestrators, may lead to different distributions in the use of orchestration mechanisms. This could provide a more comprehensive understanding of how business models influence ecosystem alignment.
- Quantifying the distribution of orchestration mechanisms across different types of companies helps to understand better the relative emphasis placed on standardisation, nurturing, negotiation, and ownership. By developing metrics to assess how companies allocate focus to each mechanism, researchers can offer a clearer picture of how role-specific priorities impact ecosystem alignment.
- Do a case study with full participation from the whole value chain of the ecosystem. To get a direct perspective from all actors who have a direct impact on the health and behaviour of the ecosystem and the success of ecosystem transformation. The aim is to get a holistic view with more depth analysis.
- Investigate partnerships contracting models for typical companies like A and C to get more depth on orchestration mechanism analysis.
- Consider a longitudinal analysis of the type-3 platforms with a complete set of platform elements to explore the market consequences of future generations of products that might influence product platform development strategies.
- Survey and/or questionnaire for actors to see changes in roles and responsibilities difference while delivering a building with a project approach or product approach.

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A

Appendix I

Question List

A. Ecosystem

1) What role you have in supply chain and how the product lines change and all? Where are you guys in the supply chain and how do your different product lines change depending on how you partner?
2) Do you only use your company's resource or you also outsource some?
3) How you brought different manufacturers and different parts of the supply chain into the product design process? (through competition, or relationships?)
4) Who are the key roles that you think will help you and your team to be successful in delivering the product.
5) How is the division built? How do you form your team? What is the direction of your team?
6) Regarding Roles and responsibilities for your product platform development, Did you notice something changed that you already identified?
7) Do you have any requirements for your new staff?

B. Business Process

8) How did your company decide to develop offsite construction products and an associated product platform?
9) What are the steps or procedures that you've taken to develop your product platform?
10) How is the decision making process like? Like what are the factors that you need to consider to decide about making that decision?
11) What level of standardisation and repetition were you able to achieve after looking across the three countries and then trying to develop this catalog?
12) If you have to suggest a new companies to start in modular construction or product platform development, do you have any suggestion or feedback to them?

C. Boundaries

14) Do you experience any boundaries that you experience during the development?
15) Other than building regulations, sustainability and circularity principles/regulations, were there other boundaries to design your product platform?

D. Mechanism

16) How do you implement a strategy to coordinate with other actors to make sure that your goal is fulfilled?
17) Did you identify collaborators that really have a strong opinion and might risk your authorities/power/goal? How do you deal with them?
18) How do you accommodate different needs from different clients?
19) What can the management do for you to help you to escalate your product platform like maybe new stuff?

B

Appendix II

Coding Themes, Categories, and Sub-Categories

Table B.1: Coding Themes, Categories, and Sub-Categories

Theme	Category	Sub category	Quotation example
Ecosystem	Resource	In house	*"we have 6 software engineers, some are just from the software world, but most are from an architecture" (B.4)*
		Outsource	*"We outsource a lot of the work. So there are a lot more people working on the product. It's not just the core team in the company" (C.11)*
	Type	Business	*"this business unit was developed to create a product approach in the real estate division" (C.11)*
		Innovation	*"the other part is like R&D and engineering and you know, working on innovation within the building system." (B.5)*
Boundaries	Business	Geographical Scope	*"we've found that partner that we can work with and grow within the French market." (B.5)*
		Competitive Advantage	*"we have a Representative in these two countries, and they are actively acquiring plot" (C.9)*
		Cost	*"I will say one big boundary realistic one is cost." (C.8)*
	Design	Regional Building Codes	*"we compare the building codes of the different countries because they are quite different" (A.2)*
		Sustainability and Circularity Principles	*"to create the most advanced, sustainable and circular buildings in the world" (A.1)*
		Building Functionality	*"we have two products under housing. We have one product under hospitality, so hotel design" (C.11)*

Theme	Category	Sub category	Quotation example
Orchestration	Readiness Assessment	External Trend	*"we had actually a big phase of market research. for instance, for interviewing clients and even users of the building so future tenants." (C.8)*
		Internal Business	*"We started to understand what can we do in the in the real estate market? What are the opportunities?" (C.9)*
		Partner	*"the team far looking for the skills on the market" (C.9)*
	Orchestration mechanism	Standardisation	*"it was an architectural competition. I think they invited four teams and then they already onboarded them" (A.2)*
		Nurturing	*"We ask if they have any obstacles, blockers or particular problems and who can solve these problems across the team of partners" (C.8)*
		Negotiation	*"You can't expect to come into the company and only work on one specific thing" (B.5)*
		Ownership	*"the investors were like we want to own this IP there" (B.4)*