PRODUCT PLATFORM INTEGRATION STRATEGIES

Supplier network integration strategies in industrialised house-building product platform development: the platform owner perspective

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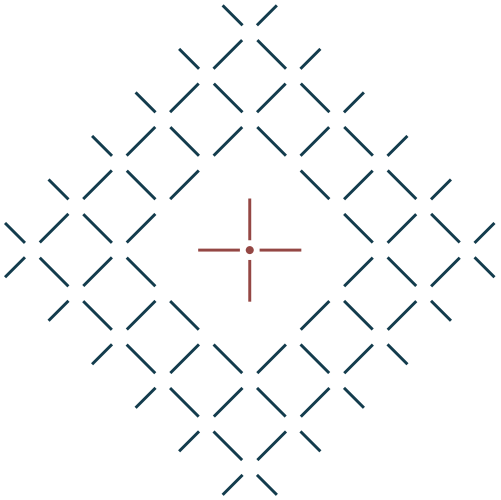
MSc Thesis Report



Product Platform Integration Strategies

Supplier network integration strategies in industrialised house-building product platform development: the platform owner perspective

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Preface

This master's thesis is an outcome of a one-year research project in the Design & Construction Management Graduation Lab of the MSc Management in the Built Environment track at the Delft University of Technology. This thesis aimed to understand the phenomenon of product platforms and their use in industrialised house-building. It also includes exploring the relationships between the platform owner and the critical suppliers who influence the platform's development.

Many people have contributed to this research in various ways throughout the process. I would especially like to thank my supervisors, Paul, Herman and Tuuli, for their insightful feedback, guidance, support and patient attitude. Thank you for asking the challenging questions and supporting me in finding my own path. I have genuinely enjoyed spending time with you and discussing all sorts of topics.

I would like to extend my gratitude to Daniel Hall for his insights into industrialised house-building during the theoretical part of the thesis. Furthermore, many thanks to all the interviewees for their valuable insights, which are fundamental to the thesis. I would also like to thank my friends, especially Danica, for all her support and mentoring, Gian Carlo, Natalia, Tjessy and Olivia for sharing this incredible time with me. It would not have been possible without you. And above all, I would like to thank my parents and grandma for their unconditional support and for always encouraging me to pursue my goals.

Krystof
Delft, June 2022

Abstrakt (CZ)

Industrializovaná výstavba domů (IHB) je způsob výstavby, který spojuje know-how mnoha společností, které standardizují část své výroby v rámci společné produktové platformy a propojují ji pomocí jednotného rozhraní. Tímto způsobem si organizace mohou adaptovat přizpůsobení produktu na míru při zachování výhod hromadné výroby. Tyto platformy vytvářejí sítě dodavatelů, které umožňují efektivnější uchovávání a využívání znalostí, což vede k neustálému zlepšování vývoje produktu. Firmy, které jsou v tradičním stavebnictví konkurenty, spolu v rámci IHB spolupracují na jedné platformě. Integrační strategie, které vlastník produktové platformy využívá k integraci této dodavatelské sítě, však nejsou v akademické obci dostatečně prozkoumány. Kromě toho aspekty produktových platforem v IHB, které mají být integrovány, nejsou dostatečně popsány. Tato diplomová práce tuto mezeru zaplňuje doplněním stávajícího výzkumu a provedením případových studií z praxe. Dvě případové studie hodnotí dodavatelské sítě v rámci platformy, úroveň jejich integrace a roli dodavatelů při vývoji produktové platformy. Lokalita těchto platforem se liší; jedna má sídlo ve Švédsku a druhá v České republice. To poskytuje širší rozsah studie a variabilitu prostředí. Ve třech strategických úrovních je objeveno několik cílů a výzev pro integraci, které ovlivňují formulaci strategie. Diplomová práce poskytuje rámec strategie integrace pro vlastníky platforem, kteří usilují o vytvoření takové produktové platformy. Rámec usnadní vlastníkům platformy orientaci ve způsobech budování a integrace vztahů v dodavatelském řetězci. Dále jsou představeny čtyři strategie prvků produktové platformy.

Abstract (NL)

Geïndustrialiseerde woningbouw (IHB) is een bouwmethode die de knowhow combineert van vele bedrijven die een deel van hun productie standaardiseren binnen een gemeenschappelijk productplatform en dit verbinden met een eengemaakte interface. Op die manier kunnen organisaties productaanpassingen doorvoeren en tegelijk de voordelen van massaproductie behouden. Bovendien creëren die platforms toeleveranciersnetwerken die een efficiënter behoud en gebruik van kennis mogelijk maken, wat leidt tot een voortdurende verbetering van de productontwikkeling. Bedrijven die in de traditionele bouw concurreren in IHB werken samen binnen het platform. De integratiestrategieën die de eigenaar van het productplatform gebruikt om dit leveranciersnetwerk te integreren, zijn echter onderbelicht bij academici. Bovendien zijn de aspecten van de te integreren IHB productplatforms onvoldoende beschreven. Het onderzoek vult deze leemte op door bestaand onderzoek aan te vullen en casestudies uit de praktijk uit te voeren. In twee casestudies worden de leveranciersnetwerken in het platform, de mate van integratie en de rol van de leveranciers bij de ontwikkeling van het productplatform beoordeeld. De plaats van herkomst van deze platforms verschilt; het ene is gevestigd in Zweden, het tweede in Tsjechië. Dit zorgt voor een breder studiegebied en variabiliteit van de setting. Verschillende doelstellingen en uitdagingen voor integraties worden ontdekt in de drie strategische niveaus die de strategieformulering beïnvloeden. Het proefschrift biedt een raamwerk voor integratiestrategie voor platformeigenaars die ernaar streven een dergelijk productplatform op te richten of te versterken. Het raamwerk zal het voor platformeigenaren gemakkelijker maken om te navigeren in manieren om relaties op te bouwen en te integreren in de toeleveringsketen. Verder worden vier strategieën voor productplatformelementen geïntroduceerd.

Abstract

Industrialised house-building is a delivery method that combines the know-how of many companies that standardise a part of their production within a common product platform and connect it with a unified interface. This way, organisations can adopt product customisation while keeping the advantages of mass production. Furthermore, those platforms create supplier networks that enable more efficient retention and exploitation of knowledge, leading to continuous improvement in product development. Firms that in traditional construction compete in IHB collaborate within the platform. However, the integration strategies that the product platform owner utilises to integrate this supplier network are underexplored by academics. In addition, the aspects of the IHB product platforms to be integrated are not sufficiently described. The research fills this gap by complementing existing research and conducting case studies from practice. Two case studies assess supplier networks in the platform, their level of integration and suppliers' role in product platform development. The place of origin of those platforms differs; one is based in Sweden, and the second one is in the Czech Republic. It provides a broader scope of study and variability of setting. Several objectives and challenges for integrations are discovered in the three strategic levels that influence the strategy formulation. The thesis provides an integration strategy framework for platform owners who strive to establish or strengthen such a product platform. The framework will make it easier for platform owners to navigate ways to build and integrate relationships across the supply chain. Furthermore, four product platform element strategies are introduced.

Keywords:
Strategy, Supplier Networks, Industrialised Housing-building, Product Platform, Platform Owner

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Executive Summary

1 – Introduction

At a time of increasing material and human resource costs, we need to think again about how to increase efficiency in the construction industry. Despite its undeniable advantages, industrialised house-building has failed to overcome barriers and become widespread. The most significant of these include a relatively fragmented construction scene with contractors focusing primarily on single projects. Second is the low level of product customization, which prevents more significant variability in construction while maintaining the benefits of mass production. To address these barriers, many companies are creating technological or product platforms seeking to profit from established supplier relationships (Hall, Lessing, & Whyte, 2022; Lessing, Hall, & Pullen, 2019).

Industrialised construction is a strategic direction that focuses on consolidating knowledge gained from product development and design through standardisation. Individual products are repeated on many projects, thus enabling continuous improvement. It also creates strong and often long-term relationships between product owners and suppliers. In many other industries, companies create product platforms for this purpose. Platforms allow companies across the supply chain to benefit from a shared network of information (Choudary, 2021). Platform owners are looking for strategies that will benefit from the networking of the supply chain and the standardisation of products and processes (Winch, 2003). This approach might increase product offering for a lower price but high quality while ensuring customisation to end-user preference at scale. By working in multidisciplinary teams, participants gain shared knowledge about technical aspects, customer requirements, product design and manufacturing.

Despite growing awareness of strategic management importance in the construction industry (Hasegawa, 1988; Price & Newson, 2003), its application is not very common, as companies focus mainly on project planning (Hunger & Wheelen, 2003). It has focused on project planning rather than business strategy development (Chinowsky & Meredith, 2000). While there are usually two main approaches to strategies, which can be divided as external, comparing a company to the competition, and internal, looking at the company's resources, today's trend is to combine them. Not only that, but firms often cooperate intensively with each other, and their profits are directly influenced by the performance of the entire group of partner firms (Grant, 2018). An organisation's platform strategy determines how it delivers value to its target audience. A well-designed platform business can help create and capture the new economic value and scale the potential for learning across entire ecosystems or supplier networks (Church, 2017; Dubois & Gadde, 2000; Gawer, 2014).

In the product platform context, three strategic levels can be found; at the top is an organisational level; next is a product level (also, business level) and thirdly, production (operational level) (Wheelwright, 1984; Kim & Lee, 1993). The business direction, acquisitions, and allocation of resources to business units are addressed at the organisational level. The second and third levels deal with how to achieve these goals. For example, production strategy includes strategic aspects related to sourcing production methods and their impact on the rest of the organisation.

Leading companies across industries tend to collaborate with their supply chain partners at multiple levels to achieve exceptional synergies and benefits from integration activities (Kim D.-Y., 2013). Supplier integration can lead to suppliers acting as strategic collaborators or partners. The integrative approach can occur on all introduced strategic levels. There is usually a strategic acquisition within the supply chain from an organisational level perspective, i.e., vertical or horizontal integration. The product level is mainly concerned with forming close or loose relationships with suppliers within the platform strategy. Also, it involves standardisation. While some processes in product development appear more beneficial to standardize, for others, it would lead to undesirable constraints (Kim D.-Y., 2013). At the production level, it can be a choice between in-house production or outsourcing (Ford & Farmer, 1986).

In summary, it can be said that academic literature recognises centralised and decentralised supplier networks with three degrees of integration in the construction industry. Integration of them into a platform of an organisation is beneficial for many reasons, especially in product development. Additionally, integration strategies occur on three levels related to organisation, product, and production. Moreover, it would improve the design for the successful development and production of industrialised houses by exploring the ecosystem created by the product platform, interactions within this supplier network, and the integratory role of platform owners.

Problem Statement

In recent years, research has been looking at the benefits of prefabrication. It has also addressed the barriers, challenges, and lack of implementation. Some research has looked at strategies to overcome these challenges or what strategy to choose for a given investment project. Many studies have looked at the implementation of platform thinking and call for greater integration. However, little attention has been paid to a platform owner as a central integrator. There is a call for more investigation of the organisation and interaction in industrialised house-building product platforms and supplier network relationships. Dominantly, academic literature is missing an exploration of what aspects or areas of the product platform to integrate concerning supplier networks.

Research questions

Given the problem statement, literature review and the thesis objectives, the main research question is:

MRQ: "What are the strategies to integrate supplier networks to product platform development in industrialised house-building?"

In order to answer the main research question, it is necessary to obtain sufficient knowledge from two sub-questions formulated as follows:

SQ1: "What are the critical aspects of product platform development?"

SQ2: "What are the types of supplier network relationships in a product platform development?"

2 – Methodology

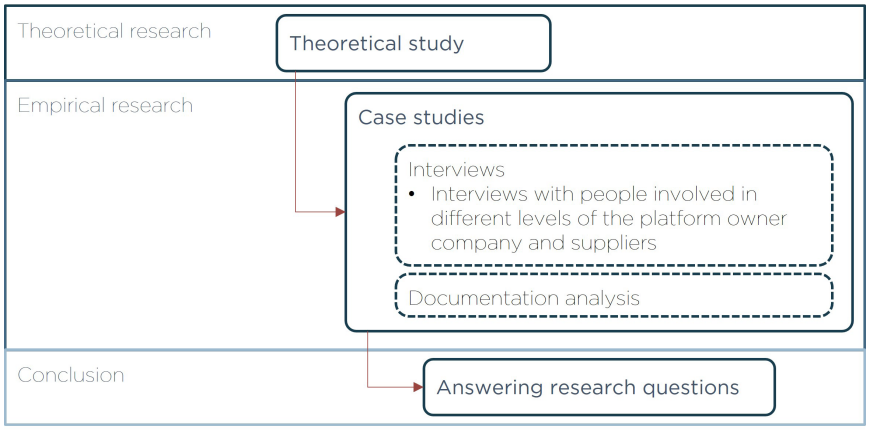


Figure 1

Research design (Source: author)

This thesis is based on qualitative empirical research focused on gaining knowledge and generating explanations using a descriptive methodology to understand the research problem. Accordingly, this research is designed based on three components. First, literature review; second, empirical research; third, conclusions (Figure 1).

Theoretical research

In the first part, the theoretical study established a theoretical framework. This form is quite broad and allows for a thorough exploration of the studied concepts. The information gathered was essential to develop a comprehensive understanding of what is already known from previous research and to develop a basis for subsequent empirical research. Additionally, it established a research gap that was filled with this thesis. Furthermore, the first sub-question could be answered through a thorough theoretical study.

Empirical research

The empirical research strived to adjust and complement the theoretical framework. It is based on a qualitative study. Firstly, market research was conducted to explore the market practice. Next, two case studies were analysed, mainly by interviews. Those case studies provided a distinctive integrative approach based on their nature. The assessment framework of case studies remained identical to obtain the most comprehensive data.

Case studies

The empirical research was designed as a multiple-case design to ensure the quality of this thesis, including construct validity, internal and external validity, and reliability (Yin, 2009). The study was based on two cases of product platforms that have integrated their supplier network. The analysis included interviews with all three strategic level managers involved in platform development and critical suppliers.

Case A operates in multiple markets, but its original place is in Sweden. It is a well-established product platform with over a thousand housing units a year produced. The platform owner's approach is strongly integrative. This trend has further deepened with the development of a digital platform for sharing the learning aspects of the product platform. The platform owner groups and controls a significant part of the value chain in-house. It utilises internal resources, including product development, production

facilities and business operations. The overall control is an essential part of their business. Partners and suppliers related to Case A maintain long-term relationships. It enables a stable production system with predictable prices and quality.

Case B is a developing product platform located in the Czech Republic. The motivation to deliver affordable housing played a significant role in shaping a supplier network and a product design. Case B represents the product platform that utilises broader cooperation between multiple critical suppliers. The platform owner controls the development, but many tasks are outsourced. The Case B product platform can be considered a semi-opened platform with a more supply-chain organisation. The platform owner governs the know-how and other protected parts of the product developed by platform partners.

3 – Findings

The main findings that resulted from the theoretical and empirical research are presented in Figure 2.

Platform owners seek to create a network effect by attracting suppliers to the platform. The size or volume of production is what matters in attracting new entrants. The guarantee of a specific buy volume or stability of subscription is an attraction for product platform suppliers. When demand is high, the primary concern of platform owners is to attract and retain suppliers. Another option is the openness and sufficient flexibility of the platform that allows for the entry of more participants from the supplier side. An example of this is the multi-stakeholder ecosystem, which enables the development of standardised component interfaces.

Another finding is that the primary competitors are developers from the traditional construction industry. Traditional developers have significantly more flexibility, which they can use to build in various land conditions or municipal requirements. A similar challenge for platforms is posed by designers, for whom the industrialised way of building is relatively new and with whom they lack enough experience.

Moreover, the four platform elements (knowledge, relationship, component, and process) were identified in the literature. Each of them is essential for platform development and integration. The elements provide the platform owner with an interface to navigate and target their resources more efficiently. Elements play a critical role at the operational strategy level. This strategic level specifies how aspects interact to satisfy the implementation of the strategy at the business level, thus the overall integration of the product platform.

Additionally, the case studies have shown that the closest suppliers, those most integrated into the platform's operation, are selected by the platform owners on a similar basis as traditional construction. Tendering or a long selection process prevails over the free flow of suppliers as is expected on digital-based platforms such as Amazon or Uber. However, this might not be an issue as interviewees justified this approach with a long-term stable relationship.

Finally, municipalities play a significant role in the product platform development. Their power influences various aspects of the product and thus impacts the supplier participating in the platform. Therefore, municipalities or other governmental bodies should be involved from the beginning of the development, as it can reduce inefficiencies of the process.

The integration of supply networks occurs at all three strategic levels, as the theoretical and empirical research results have shown. While it is mainly about supplier acquisition at the organisational level, there are more diverse ways of forming relationships with suppliers at the other two levels. Three basic characteristics are associated with each; closed to open for the product level and integrated to non-integrated for the production level.

Four element integration strategies

Four basic element integration strategies were developed based on empirical findings.

Component strategy: This strategy is sensitive from several points of view. Firstly, the supplier network is primarily influenced by the technical system solution design in this case. The strategic goals of this strategy are to adapt a product to different environments and customer preferences. Additionally, the goal is to optimise the off-site manufacturing processes to enable streamlined production while ensuring high product quality and viable investment and operating costs. The objectives of the component strategy are binding and differ significantly in the case of 3D spatial modules or 2D panel solutions. This element is also strongly influenced by market availability in the case of the supplier and by the calculation of investment costs, which have a significant impact on production volumes or the construction of own production capacities. The component element is strongly influenced by two enablers: off-site manufacturing and logistics. This strategy might lead to quasi-integrated or non-integrated relationships leading to more open or ecosystem supplier networks.

Relationships strategy: This strategy involves long-term relationships that are built across the supplier network. Relationships can be built by acquisition, contractually or as an ecosystem. Therefore, it depends on the product platform type and the governance style of the platform owner. The integration of stakeholders is mainly related to the closed or semi-open platform as they tend to develop tighter and long-term relationships. This approach can lead to several tiers of suppliers, with the most essential having a close (integrated) relationship with the platform owner. Further, this group of suppliers is involved in decision making within the platform or actively involved in product development.

Process strategy: This approach adopts a significant integration of digital technologies across the product platform involving the supplier network. The main objective of this strategy is to develop a digital platform that would unify various aspects of the platform. However, it requires fully standardising the use of ICT enabler and dealing with several barriers such as software/process misalignment, technical solutions, or know-how development & protection. The supplier network might be broad or closed depending on introduced standards. Ecosystem (industry-wide) platforms have more relaxed standards, while closed platforms require relatively unified solutions. Supplier networks are formed closer to the platform, and often only the critical suppliers need to standardise on a full scale.

Knowledge strategy: This approach involves two enablers: technical system development, KPIs, and experience reuse. The strategic goal is to create a common platform of knowledge. Furthermore, the strategic goal is to capture the product lifecycle experience that can be reused to improve a product. This element may pose a challenge, especially for new platform owners. To acquire the required knowledge, owners can choose from two strategic options; firstly, to develop it in-house, or secondly, to opt for outsourcing. However, the aim should be to ensure that the know-how remains on the platform. The integration strategy of knowledge management aims at integrating aspects essential for the functioning of the platform. In the case of an open platform, knowledge management becomes a collaborative ecosystem, and suppliers are mostly quasi-integrated. For certain types of platforms, mainly closed, so-called firm-based platforms, and in the case of a fundamental type of activity, there may be an acquisition by the platform owner. This approach leads to integrated suppliers.

4 – Conclusions

Theoretical and empirical research has shown that organisations in industrialised house-building are looking for ways to integrate the supply chain through product platforms, thereby creating supply networks. However, there was a lack of knowledge about which areas of the product platform needed this integration.

As mentioned earlier, the goal of the thesis is to explore critical elements of product platforms. Next was to investigate the relationships between suppliers and product platforms and describe supplier network types. Lastly, the fourth objective was to formulate the integration strategies for supplier networks and product platforms.

Accordingly, to answer the main research question – **What are the strategies to integrate supplier networks to product platform development in industrialised house-building?** – the study suggests that the integration strategies need to be organised by strategic level into organisational, product and production levels. The organisational level defines the direction of industrialised house-building. At the product level, the product platform integration strategy is created. The production strategy level integrates the platform elements. On this level, it can be said that organisations have two strategic option extremes for the four elements of the platform. Eight strategic enablers influence these. Thus, individual suppliers can be integrated, quasi-integrated, or non-integrated. It follows the openness of the platform on the product level.

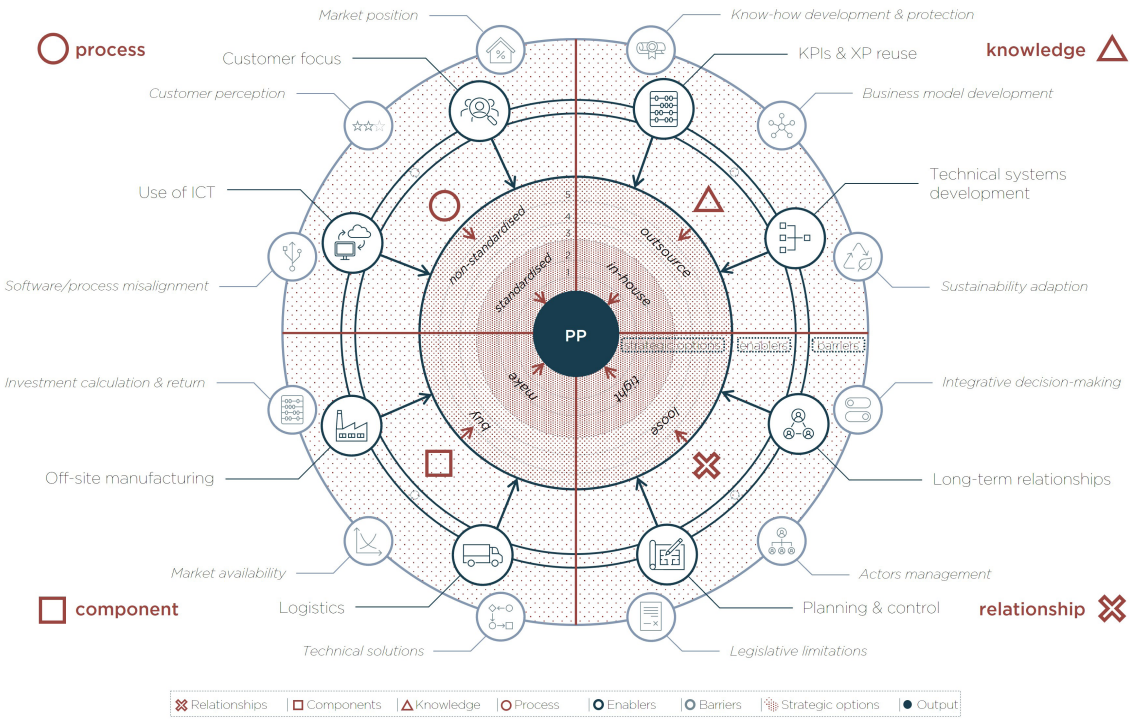


Figure 2

Integration strategies framework (Source: author)

According to this study, there are four general strategies for integrating supplier networks in platform elements. These strategies have different implications for standardisation, joint knowledge creation, component production, and relationship proximity. At the same time, these strategies are influenced by the constraints that shape the resulting strategy. These include Component Flexibility (to broaden the variety of components by developing a standardised component interface). Next, Integration of Suppliers (building tight long-term collaboration and enabling suppliers to participate in decision-making). Furthermore, the Digitalisation of Platform Processes (standardising processes during a product lifecycle). Lastly, Knowledge Governance (integrating commonly developed knowledge into the platform).

5 – Contribution of the Research

This thesis contributes to the design and construction management field and strategic management by providing knowledge about aspects of product platforms in industrialised house-building. The main contribution of this thesis relates to supplier network integration strategies by identifying elements and aspects of the product platform and recognising barriers to those strategies. It proposed the integration strategy framework that illustrates the different elements and their relation to the supplier network in line with research goals.

The thesis provides insights into the product platforms' problematics from the supply-side perception. It creates a more comprehensive view of the topic as the studied topic is relatively novel to strategic management in the construction industry. It provides valuable theoretical and practical information that can assist managers and higher executive officers in industrialised house-building in taking strategic decisions and leveraging the attributes of supplier network integration to product platforms.

6 – Recommendations for Future Research

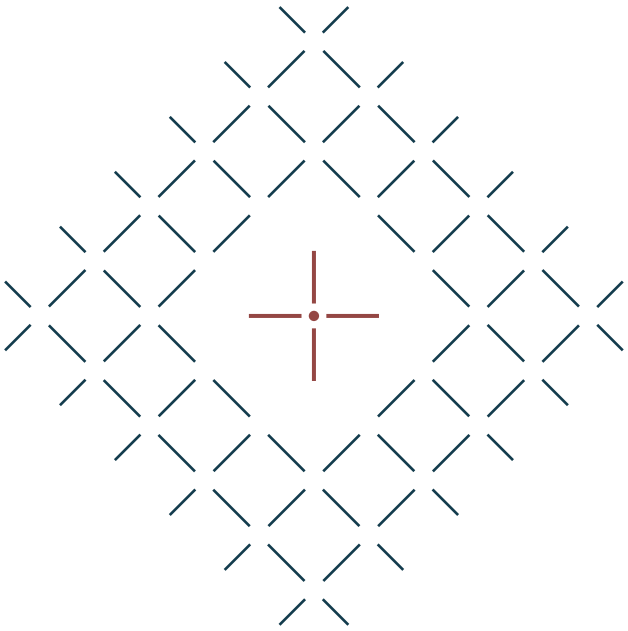
The findings from this thesis are bound to certain limitations concerning the context, timing, and methodology, which provide an opportunity for future research.

Firstly, the findings are influenced by the country's social, political, historical, and economic context. Therefore, further research should focus on more cross-border case studies that account for the difference in context.

Next, concerning the scope of this thesis, further research should focus on the demand side. This thesis focuses solely on the supply side, and there is little consideration of the demand side. The demand side is an essential and quite integral part of business relationships.

Additionally, this work focused on product platforms with residential construction. Thus, further research should focus on innovative projects, other construction typologies, or construction digital platforms. At the same time, the importance of individual enablers of IHB, such as advanced ICT use, has not been explored in-depth in this thesis. Their combination related to a different degree of supplier integration should be further explored.

Finally, several promising product platform projects that have received much investor attention have failed recently. This phenomenon needs further investigation. It seems clear that product platforms will continue to evolve, so it is worth following the case studies presented here in line with this work. It could yield further insightful findings.



– 1 –
INTRODUCTION

1 – Introduction

Industrialsed house-building is a relatively newly established method of construction. Despite its undeniable benefits, many barriers do not allow it to become more widespread. These include, firstly, a relatively fragmented construction scene, with contractors focusing primarily on individual projects. Second is the low customization of products, which prevents the construction of a greater variety of buildings while maintaining the benefits of mass production. To address these barriers, an increasing number of companies are creating technological or product platforms seeking to profit from established supplier relationships (Hall, Lessing, & Whyte, 2022; Lessing, Hall, & Pullen, 2019). Nevertheless, these concepts are poorly conceptualised concerning industrialised house-building, as is the integration of suppliers into such platforms.

In recent years, technological platforms have been gaining more attention from academic and professional communities. While companies from the digital sector such as Microsoft, Google or Facebook are most often behind this wave of popularity, platforms can also be found in other sectors. Statistics show that these can be powerful companies, such as the hospitality sector (e.g., Airbnb) or online shopping (e.g., Amazon). At the same time, those are companies driven primarily by the demand side. On the other hand, companies that develop a product platform optimise product development and create solid relationships with their critical suppliers. Such platforms can be found in industries such as pharmaceuticals, automotive, or aerospace (Choudary, 2021; Mosca, Jones, Davies, Whyte, & Glass, 2020).

Although platforms have been around for some time, there is no uniform definition of platforms in the literature. The same concerns industrialised house-building, which is usually interchanged with prefabrication. Before introducing these concepts further, it should be said that they are linked by the creation of shared space or the redefinition of buyer-supplier relations (Kim D.-Y., 2013). Platform thinking thus emerges as a possible approach to enable mass production while allowing for greater customization through greater integration of suppliers into product development (Gawer, 2014).

Platforms are often governed by platform owners. Those can be real estate developers, construction firms or new disrupting start-up companies. Today, many companies entering this segment are spin-offs of established construction companies (Lessing, Hall, & Pullen, 2019). The platform owners' role may vary depending on the openness of the platform, but in general, they manage and coordinate the development of the products and cocreate the strategic direction (Mosca, Jones, Davies, Whyte, & Glass, 2020).

Industrialised house-building product platforms

The construction industry is known for its conservative approach to innovation or adaptation on a broader scale (Hall, Whyte, & Lessing, 2020). Significant changes rarely occur in this sector leading to low effectiveness and rising costs. In addition, firms face little continuity of acquired knowledge. The obtained knowledge and experience from problem-solving remain with individuals, not diffusing in the organisation (Winch, 2010). Also, there is often a lack of post-delivery evaluation as construction teams break up as soon as the work is completed (Hall, Whyte, & Lessing, 2020). Thus, construction companies shift from one project to another with a plan-build-deliver scheme and restrain themselves from more significant R&D investments (Ahola, Ruuska, Artoo, & Kujala, 2014). On the other hand, it is vital to recognise substantial innovation in the construction product sub-sector.

Compared to the traditional construction delivery method, industrialised house-building tackles those imperfections. Despite its many advantages, it remains a niche method (Steinhardt & Manley, 2016). Also, industrialised house-building (IHB) is a construction concept that is by no means new. Builders have been trying to simplify the complexity of construction projects for a long time (Lessing, 2006). It was not until the 1960s and 1970s that IHB saw a significant breakthrough. At that time, housing manufacturers primarily focused on the mass production of their products with a low emphasis on variety or originality, providing customers with more options in customisation (Špačková, 2014; Hall & Vidén, 2005; Berggren & Wall, 2019; Barlow & Ozaki, 2005). Despite its cost and delivery effectiveness, the former type of production led to monotonous, widespread products. Concurrently, customer preferences have evolved and demand more options and original designs. They require highly reliable product quality with a certain level of customisation (Lessing & Brege, 2015).

Therefore, housing developers are continuously looking for ways to increase clients' participation in the shape of their future housing without reducing the benefits associated with industrialised house-building (Wolters, 2001). A fundamental principle in combining high efficiency while maintaining a certain degree of variety is sharing a product platform. In a general sense, the platform creates a space where others can stand while driving actions. A platform is an artefact that enables businesses to create value through several means, such as interaction with the supply side (Chan, 2020).

Platforms allow companies across the supply chain to benefit from a shared network of information (Choudary, 2021). Organisations typically emerge as competitors in a tender are working together to develop a single platform. In the construction industry, a platform is usually taken to be a community that shares given parameters of standardisation, creating a product platform (Hall, Whyte, & Lessing, 2020). This approach reduces complexity and maintains or increases product variability if properly implemented (Winch, 2003). At the same time, it leads to increased speed of product production, reduced development costs and increased product reliability (Muffato & Roveda, 2000). In IHB, the fabrication of such a product platform is a modular house that has emerged from an industrialised creation process.

To this end, developers, or so-called platform owners, are looking for strategies that will benefit from the networking of the supply chain and the standardisation of products and processes (Winch, 2003). This approach might increase product offering for a lower price but high quality while ensuring customisation to end-user preference at scale. Platforms also encourage social and technical learning. By working in multidisciplinary teams, participants gain shared knowledge about technical aspects, customer requirements, product design and manufacturing. Nevertheless, the pressures

for integration for a firm pursuing a high level of platform strategy are very different from those for integration for a firm pursuing a low level of platform strategy (Koufteros, Vonderembse, & Jayaram, 2005).

Integration strategies

Various research papers conclude the importance of strategic management within the construction industry. Abu Bakar et al. (2011) summarise their research with general findings; companies should analyse their external environment to identify threats and opportunities while examining their internal environment to assess organisational strengths and weaknesses. Above all, they emphasise that organisations need to restructure their business strategy to remain competitive in the long run. The changing environmental factors should be according to the prevailing circumstances to maximise efficiency and minimise costs (Abu Bakar, Tufail, Yusof, & Virgiyanti, 2011).

Moreover, unlike other industries that produce large numbers of the same units, such as the automotive industry, the construction industry is almost exclusively focused on building one unique product/project (Winch, 2010). Despite growing awareness of strategic management importance in the construction industry (Hasegawa, 1988; Price & Newson, 2003), its application is not very common, as companies focus mainly on project planning (Hunger & Wheelen, 2003). It has led to a focus on project planning rather than business strategy development and, therefore, alienation of project management across construction, design and development companies. Consequently, project management also receives more space in the scientific literature than strategic management (Chinowsky & Meredith, 2000).

In general, the approach to strategies is evolving. While there are usually two main approaches to strategies, which can be divided as external, comparing a company to the competition, and internal, looking at the company's resources, today's trend is to combine them. Not only that, but firms often cooperate intensively with each other, and their profits are directly influenced by the performance of the entire group of partner firms (Grant, 2018). The integrative nature of a strategy is emphasised by Seth & Thomas (1994) and the plurality of goals by Grant (2018). Further, an organization is usually considered a single company, but in the increasingly interconnected community of platform thinking, an organization is described as a collaboration of multiple companies (Choudary, 2021). An organisation's platform strategy determines how it delivers value to its target audience. A well-designed platform business can help create and capture the new economic value and scale the potential for learning across entire ecosystems or supplier networks (Church, 2017; Dubois & Gadde, 2000; Gawer, 2014).

Further, strategies do not emerge at just one level. Organisations formulate strategies in response to a context to deploy resources to achieve a valuable output. Each level is an input-output system that maximizes its efficiency and effectiveness through strategy. In the product platform context, three strategic levels can be found; at the top is an organisational level; next is a product level (also, business level) and thirdly, production (operational level) (Wheelwright, 1984; Kim & Lee, 1993). The business direction, acquisitions, and allocation of resources to business units are addressed at the organisational level. The second and third levels deal with how to achieve these goals. For example, production strategy includes strategic aspects related to sourcing production methods and their impact on the rest of the organisation. Product strategy includes strategic aspects at the organization level addressing markets, competitive advantages, target groups, customization, and business models (Lessing, 2015). Nevertheless, the link between those levels in platform strategies is ill-described in the academic literature.

Leading companies across industries tend to collaborate with their supply chain partners at multiple levels to achieve exceptional synergies and benefits from integration activities (Kim D.-Y., 2013). Supplier integration can lead to suppliers acting as strategic collaborators. The integration can manifest itself in two ways. First, product integration is manifested by gaining authority to design, develop, or assemble parts. Subsequent process integration; with sufficient depth of involvement in the product development process, suppliers can also be involved by their customers in internal processes to understand the nature of the project better and contribute their knowledge and experience. Suppliers have valuable information and expertise that can be invaluable in product development. Many studies have shown that integrating them early in the product development process has been more beneficial (Koufteros, Vonderembse, & Jayaram, 2005). For the purpose of this thesis study, product and process integration are considered indistinguishable.

The integrative approach can occur on all introduced strategic levels. There is usually a strategic acquisition within the supply chain from an organisational level perspective, i.e., vertical or horizontal integration. Within the platform strategy, the product level is mainly concerned with forming close or loose relationships with suppliers. Also, it involves standardisation. While some processes in product development appear more beneficial to standardize, for others, it would lead to undesirable constraints, such as limiting suppliers or reducing product adaptability (Kim D.-Y., 2013). At the production level, it can be a choice between in-house production or outsourcing (Ford & Farmer, 1986).

In principle, when developing and manufacturing products, companies can choose to develop and manufacture parts in-house and purchase development and manufacturing capacity on the market (Karlsson, Nellore, & Soderquist, 1998). According to Ulrich & Ellison (2005), in non-integrated or specialized supply chain structures, the system architect (developer or platform owner) determines whether to outsource only production tasks or production tasks too. Most development and production tasks are outsourced to external partners in such formations. Changing design rules can be a motive for outsourcing or internalizing activities.

Supplier networks

Langlois & Robertson (1992) identified two forms of networks: centralised and decentralised. The first one is suppliers bound to a leading firm which formulates design rules (compatibility standards) and might differ from one leading firm to another. Decentralised networks are manifested by suppliers matching the demand of different customers (firms); thus, the standards are defined by (component) manufacturers or assemblers. Most traditional construction companies operate in such a decentralised network.

As mentioned above, platform owners as system architects can opt for in-house development or buy development and production from external suppliers. Between the vertical integration and vertical supply chain specialisation, extremes can be found in options of a vertical or horizontal network of suppliers. These can be named quasi-vertical integrated networks. Their benefit is a combination of vertical integration and vertical specialisation. Additionally, this supplier network can enable companies to modularize product and production systems (Karlsson, Nellore, & Soderquist, 1998).

Traditional project-based networks are considered non-stable, non-integrated supplier networks. Collaborative agreements in any form at the level of multiple projects aimed at developing, producing, and distributing products are defined as quasi-integrated relationships (Zollo, Reuer, & Singh, 2002). If the two firms directly downstream

in the supply chain do not sell or buy a particular component from other firms and the firms cooperate at the multi-project level - a fully integrated supply chain structure exists (Harrigan, 1986).

To summarise this section, it can be said that academic literature recognises centralised and decentralised supplier networks with three degrees of integration in the construction industry. Integration of them into a platform of an organisation is beneficial for many reasons, especially in product development. Additionally, integration strategies occur on three levels related to organisation, product, and production. Moreover, it would improve the design for the successful development and production of industrialised houses by exploring the ecosystem created by the product platform, interactions within this supplier network, and the integratory role of platform owners.

1.1 Problem Statement

Traditionally, construction project development is split into several specialised companies that execute their part during its life cycle. Therefore, their business strategy is relatively limited and often concentrates on project planning (Hunger & Wheelen, 2003). While in traditional construction, the project team falls apart as soon as the project is finished, and the individual players disperse to other sites. A low level of knowledge capturing and a strong industry fragmentation burdens structural innovation substantially (Hall, Whyte, & Lessing, 2020). It possibly leads to higher costs associated with reoccurring product development. Industrialised house-building represents a different approach to project development by maintaining the network of suppliers across several projects and building a standardised product.

Additionally, research from other industries has shown that product design and supply chain structure are complementary. The alignment of those two leads to better performance (Baldwin & Clark, 2000; Brusoni, Prencipe, & Pavitt, 2001). Academics have explored this relationship and found that a modular architecture with standardised interfaces allows the companies that supply them to specialise. Fully specified interfaces defined in rules allow firms to perform their development, production, and marketing tasks autonomously and concurrently (Sanchez, 2000).

Analogous to standardised product designs, in shared business networks, activities in specialised groups or firms tend to remain integrated and based on tactical linkages, while the linkages between these groups are achieved through the transfer of standardised information (Strugeon, 2002). In the construction industry, there remains a solid reluctance to collaborate across projects in the long term (Larsson, Eriksson, Olofsson, & Simonsson, 2014). Despite much attention to vertical integration, examples from other companies show that other strategies have not been adequately researched and described. Research is needed on how product platforms promote collaboration between companies in the value chain and suppliers moreover their integration. Also, the challenge remains to understand the forces that lead to a collaboration of the supplier network and platform owner and what to integrate them into the product platform development.

Moreover, research has been looking at the benefits of prefabrication for many years, for example, lower labour costs, speed of construction, and knowledge retention. It has also addressed the barriers, challenges, and lack of implementation (Musarat, Alaloul, & Liew, 2021; Silvia, 2020; McRobert, 2018; Gann, 1996). Some research has looked at strategies to overcome these challenges or what strategy to choose for a given investment project (Larsson, Eriksson, Olofsson, & Simonsson, 2014; Gibb, 2001). Concurrently, new technologies enable unprecedented interconnectivity within a single platform in the relationship between vendors and the end customer (Church, 2017). Thus, current platforms are redefining the buyer-supplier relationship.

However, little attention has been paid to a platform owner as a central integrator. There is a call for more investigation of the organisation and interaction in industrialised house-building product platforms and supplier network relationships (Hall, Whyte, & Lessing, 2020). Many studies have looked at the implementation of platform thinking and call for greater integration (Dubois & Gadde, 2000; Wu et al., 2021; Wang, Qin, & Zhou, 2021; Popovic, Schauerte, & Elgh, 2021; Abu Bakar, Tufail, Yusof, & Virgiyanti, 2011; Silvia, 2020). Studies also focused on the perspective of product design in an integrated product platform (Jansson, 2013). However, academic literature is missing an exploration of what aspects or areas of the product platform to integrate concerning supplier networks.

The purpose of this thesis is to fill the introduced niche. It focuses on an analysis of product platforms that distinctively integrate supplier networks. Subsequently, it aims to create a strategic framework for construction and development companies to create or rework their product platform. Insights gained by this research should facilitate more knowledge in supplier network types in industrialised house-building. Furthermore, companies could utilise the framework to expand or create new product platforms and relationships. The framework will be based on practical and theoretical knowledge obtained from several companies and the information gained from the scientific literature.

Two case studies were analysed to reach research objectives. The thesis investigates two product platforms with different integrative approaches located in distinct countries, focusing on platform owners. This setting allows exploring the drivers and barriers they face. Additionally, it provides insights into their motivations, means and objectives that form the integration strategies of a supplier network. Several interviews were conducted with representatives of the platform owner during the case study. The professional area of these interviewees varies from an organisational to an operational strategy level. In addition, interviews were conducted with representatives of the suppliers. The analysis offers a deeper understanding of the role of the platform owner in interacting with the supplier network within the product platform. The thesis revisits recent developments in product platforms in the construction industry and contributes to the theory of what integration strategies are consistent with the knowledge gap described above.

1.2 Research Questions

Given the problem statement formulated in the section above, the following main research question and sub-questions are introduced. The main research question goal is to explore strategies that platform owners utilise to integrate supplier networks. Sub-questions will be first answered to the knowledge supporting the main research question.

The relationship between the research questions is illustrated in the figure in section 3.1, while each question has its deliverables. The aggregate knowledge will lead to a strategy framework creation. The research methods section provides the complete relationship between the questions, findings, and conclusions.

The main research question is formulated as follows:

Main Research Question

What are the strategies to integrate supplier networks to product platform development in industrialised house-building?

In order to answer the main research question, it is necessary to obtain sufficient knowledge from two sub-questions. It will bring a more profound understanding of various aspects of such a complex field. The research sub-questions are as follows:

Sub–question 1

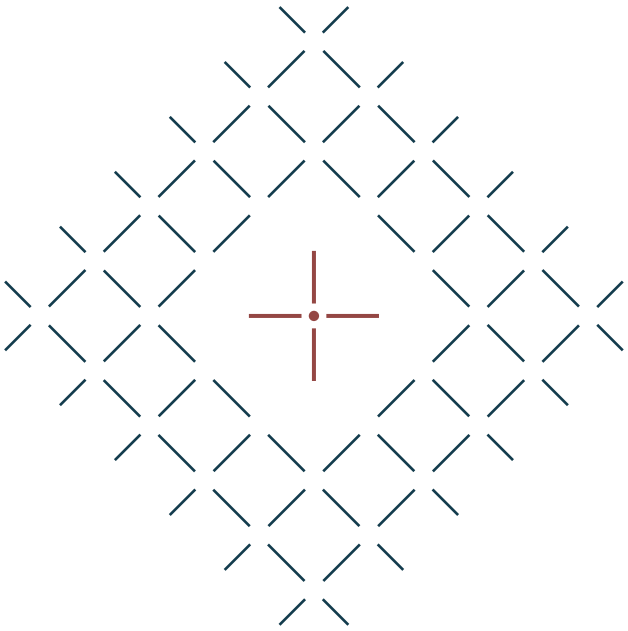
What are the critical aspects of product platform development?

The first sub-question investigates crucial aspects of product platform development. Each aspect is usually assigned to a particular process in the supplier network. Therefore, it is essential first to describe them. This sub-question can mostly be answered from the academic literature.

Sub–question 2

What are the types of supplier network relationships in a product platform development?

The second sub-question links supplier(s) and aspects of the product platform. The role in the process is thus defined. Practical research is required to explore those relationships. Relationships form supplier networks to the product platform. However, not every network is the same across various platforms. Some suppliers may be fully integrated and have an essential role in the entire process, while others may play only a marginal role and have very little involvement in developing the product platform. At the same time, more integration does not mean a more successful platform.



– 2 –
THEORETICAL FRAMEWORK

2 – Theoretical Framework

The theoretical framework chapter is to provide more in-depth knowledge about researched concepts. The result of this study is a formulation of a theoretical framework facilitating answers to research questions. Moreover, it discovers and defines the main concepts in this thesis; (1) industrialised house-building product platforms and (2) supplier network integration strategies. Defined concepts are then synthesised and generalised to form a supporting theoretical framework.

2.1 Industrialised House-building Product Platforms

Industrialised house-building, also referred to as IHB, represents a holistic approach often interchanged with prefabrication or off-site manufacturing. However, as is shown in the following subsections, the IHB is constituted by several aspects. Those are required to establish and maintain a production system utilised by an organisation. Such organisations can be one firm or a collaborative network of multiple companies (Lessing, 2015). IHB forms a subgroup of the architectural, engineering and construction industry (AEC). As an alternative to traditional project-oriented delivery methods, IHB is a product-oriented strategic approach of an increasing number of construction organisations (Popovic, Schauerte, & Elgh, 2021).

The industrialisation of AEC emerged as a reaction to societal and business environment changes. Those changes started a mass production of housing that lowered cost and a production time in the second half of the twentieth century. However, mass customisation emerged due to the massive production of unified and often unfriendly prefabricated housing development. Growing demand for customisation challenged manufacturing companies to develop customisable offerings while keeping the benefits of mass production (Lessing, 2006). It resulted in product platform development. Product platforms (PP) are used across various industries and can be described as a balance between commonality and distinctiveness embedded into product and process solutions (Robertson & Ulrich, 1998).

The following sections provide the historical development and introduction to industrialised house-building. Furthermore, platform thinking is introduced, and its implications for product platforms in industrialised house-building are presented.

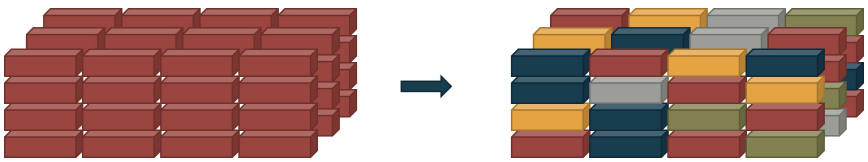


Figure 3

From mass-production to mass-customisation (Source: author)

2.1.1 Industrialised House-building

Industrialised house-building is an established concept among academics and practitioners. However, historical developments have caused some terms to be confused or misused. IHB is often used as a synonym for industrialised construction (IC). However, IC is a superordinate term that brings together industrialised construction to some extent. It can involve infrastructure construction, such as bridges and pipelines or building construction. Furthermore, IHB is often associated with off-site building elements production or prefabrication (Goulding, Pour Rahimian, Arif, & Sharp, 2015) which is one of the aspects that define this construction segment. IHB includes several more aspects, not just production (off-site/prefabrication) but also management, design, procurement, and marketing (McRobert, 2018; Hall, Lessing, & Whyte, 2022).

The commonly used definition of IHB these days is the one developed by Lessing, stating:

"Industrialised house-building is a thoroughly developed building process with a well-suited organisation for efficient management, preparation and control of the included activities, flows, resources and results for which highly developed components are used to create maximum customer value" (Lessing, 2006, p. 93).

As seen in Figure 4, Lessing's definition recognises nine aspects: process planning and control, technical systems development, off-site manufacturing, logistics, long-term relationships, ICT technology, customer focus, re-use of experience, and all-encompassing continuous improvement.

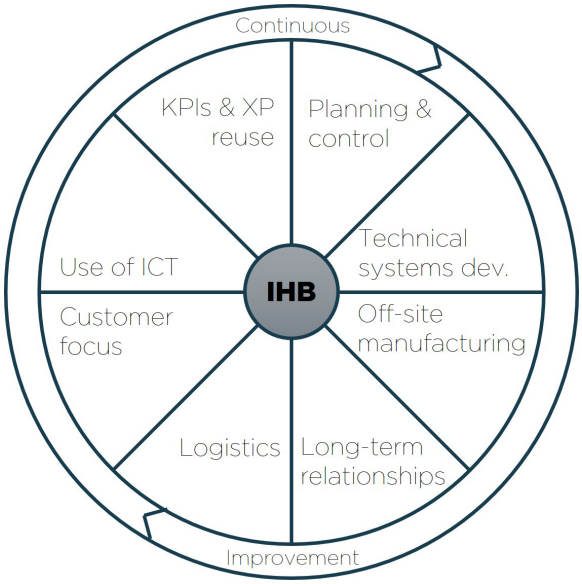


Figure 4

Industrialised house-building theoretical framework (Lessing, 2006)

Figure 4 illustrates the distribution of the nine aspects of the product platform. The eight main aspects start with planning and control and then proceed clockwise concerning process and development. **Planning and control** involve developing a coherent design, production, and assembly structure. Management of relationships and processes is to attain the goals and value delivery. Furthermore, process and project management roles must be clearly defined to secure continuity and desired performance. Management of suppliers is critical for coherent output. Planning is also related to legislative requirements that significantly impact the resulting outcome (Lessing, 2006; Larsson, Eriksson, Olofsson, & Simonsson, 2014).

Technical system development involves the product development process. The design process aims to optimise production and develop an appealing product for customers. It should minimise defects, eliminate waste production and provide a certain adaptability degree. This aspect requires expertise in many areas, such as structural coherence, electrical and sanitary installations, or façade systems. The development of this aspect creates unique know-how. At the same time, the knowledge gained from completed projects serves as input for the further development of individual systems (Popovic, Schauerte, & Elgh, 2021; Lessing, 2006).

The next is the **off-site manufacturing** aspect. Predefined building components are manufactured in controlled conditions with a high level of completion to reduce necessary on-site assembly. Manufacturers use advanced equipment and production processes, i.e., robotisation. Nevertheless, it represents one of the most significant investments for IHB organisations; thus, the market availability of suitable suppliers is limited (Shibani, Agha, Alharasi, & Hassan, 2021). Off-site production is also considered the most significant contributor to sustainable construction, thanks to reducing waste through optimised production processes or, for example, workplace health and safety (Wu et al., 2021).

Production is followed by **logistics** both related to off-site and on-site processes. Production includes purchasing, material handling, supplier engagement and transportation. On-site activities then include final assembly and completing works. Logistics are directly influenced by factory location and technical systems that might limit specific means of transportation. Deliveries to the factory and the construction site must be adequately planned, which leads to the application of, for example, the just-in-time principle (Lessing, 2006; Goulding, Pour Rahimian, Arif, & Sharp, 2015).

Long-term relationships describe the formation of mutual and long-lasting relations among participants. It is considered to improve the efficiency of both development and production by embracing knowledge sharing. This aspect shapes the supplier network (Dubois & Gadde, 2000). Participating companies join a team based on specific criteria to create good conditions for cooperation to achieve common goals and create value for the customer. Through long-term collaboration, a structure of participants is created, which makes collaboration more accessible and faster. Without tendering as in traditional construction and evaluating contractors and designers, time and financial resources can be saved (Lessing, 2006).

Customer focus is a significant process aspect of IHB. Through market research, market perception investigation and customer feedback, it secures that the right product of the right quality and cost is produced for the end customer. Moreover, it influences product design and thus production concepts with a precise aim of delivering value to a customer (Lessing & Brege, 2015; Lessing, 2006).

The **use of ICT** enables industrialised processes which rely on transparent information sharing. This aspect can involve tools for data sharing, utilisation of advanced BIM modelling, automation and robotisation of production processes (Lessing, 2006). Data-driven companies are becoming more

and more common. They use digital platforms to connect customers and suppliers and benefit from the value created by interacting on such platforms (Chan, 2020).

KPIs & experience reuse (XP) refers to improvements across the entire product development and production set based on feedback received throughout the product life cycle. This aspect requires the involvement of all participants. The knowledge gained needs to be analysed and improvements implemented. In IHB, a product is usually developed in generations and then produced on a project basis. Improvements can also be implemented in progress, for example, in production processes (Lessing, 2006; Goulding, Pour Rahimian, Arif, & Sharp, 2015).

The IHB definition can be extended for three phases of the successful IHB model that Lessing & Brege (2015) recognised. It includes first market research, which identifies customers and their needs. The second phase is the product and platform development to meet customer needs. The last phase involves increasing predefined and prefabricated production and balancing the investment with product volumes. Those are essential elements of IHB business and should be followed by every company to develop their market activities successfully.

Much of the research has been conducted in Sweden or Scandinavia, as this region has a greater concentration of IHB companies and customer acceptance than most of the other developed countries (Larsson, Eriksson, Olofsson, & Simonsson, 2014; Lessing & Brege, 2015; Popovic, Schauerte, & Elgh, 2021; Dubois & Gadde, 2000). Additionally, attention to the prefabrication aspect is given by British and other international authors (Lessing, 2015). Little attention is paid to the supplier relationship in the IHB organization. Nor does the research focus on countries with a rich post-war prefabricated construction heritage in Eastern Europe. A comparison of IHB in developed Sweden with the Czech Republic thus offers opportunities for a deeper exploration of the concept.

2.1.2 Historical Development of IHB Product Platforms

Industrialised house-building (IHB) is not a new concept in the construction field. The era started in the 1950s with massive development in the late 1960s and 1970s with a massive construction wave driven by the urgent need for affordable housing in countries with a growing population. Several governments introduced their programmes to promote construction. In Sweden, the Million Homes Programme promised to deliver 100 000 homes each year over the following ten years (Hall & Vidén, 2005). The central government directly coordinated the massive, prefabricated construction in the Czech Republic with specific power delegated to local bodies. It was related to the national industrialisation programme and the urbanisation of various areas across the country. Those efforts resulted in the construction of homes for over two and a half million citizens (Špačková, 2014). Governments were deeply involved in both countries.

Standardisation and partial automation enabled to use of unskilled workers with lower wages. In addition, the highly standardised solid construction supported the use of unified processes to speed up construction. Industrialised construction was associated with concepts such as system building, prefabricated construction, or prefabricated buildings during the post-war era. Automation and digital technologies entered prefabricated construction later in the 1980s (Lessing, 2006).

Despite many similarities, the historical development differs between Sweden and the Czech Republic. In Sweden, technical building systems developed from closed technical building systems that several prominent companies owned to open liberal building systems with market orientation. It was marked by a significant decrease in demand in the 1970s. In the following decade, open systems entered marked supported by

information technology and automation to produce elements (Berggren & Wall, 2019). However, the prefabricated production has never stopped but transformed with time.

In the meantime, Czech building systems started as more open and experimental technical building systems. During so-called normalisation in the 1970s, the communist regime increased the demands for rationalisation, quantity, and financial savings in construction. Systems thus became closed and provided by only a small number of big state-owned companies. In the 1980s, architects manifested their resistance to uniformity. Prefabricated houses thus acquired various postmodern interpretations outside technical building systems. With the fall of communism, construction stopped, and this building system was almost forgotten (Skřivánková, 2017; Špačková, 2014).

Developments in the new millennium differ significantly between the two countries. While in Sweden, companies are building on history and improving it further, in the Czech Republic, only a few companies mainly focus on custom prefabrication of certain elements, such as balconies and staircases. Swedish companies themselves are pushing for the gradual industrialisation of construction to reduce costs and increase quality (Lessing, 2006). Much research has been devoted to these activities (Lessing & Brege, 2015; Popovic, Schauerte, & Elgh, 2021; Berggren & Wall, 2019).

Prefabricated family houses are encountered in the Czech Republic to a lesser extent. These are often produced in model series from standardised wooden or concrete components. It is similar to Sweden, where this kind of housing also differs from the rest of the construction industry. Smaller companies often produce single-family houses in both countries (Lessing, 2006; Kovarova, 2019).

2.1.3 Platform Thinking & Product Platforms

Platforms have gained much attention in the past two decades. The digital environment produces one platform after another. The most valuable companies, such as Microsoft (operational system as a software platform), Google (mobile OS as a digital platform), or Facebook (social media platform), are behind the promise of digital platforms. Likewise, most unicorns, start-ups valued at over a billion dollars when entering the stock market, base their success on platform creation, i.e., Airbnb (hospitality platform) or Spaces (workspace platform). Digital platforms thus lead the current discourse (Chan, 2020).

Nevertheless, companies that develop a (product) platform optimise product development and create solid relationships with their critical suppliers. Such platforms can be found in pharmaceuticals, automotive, or aerospace industries. The AEC industry is no stranger to the concept of platforms either (Choudary, 2021; Mosca, Jones, Davies, Whyte, & Glass, 2020). These AEC companies often focus on the digital capabilities of platforms such as Sidewalk Labs (focusing on transforming the urban environment through data collection) or Bosh Internet of Things (an open-source IoT platform connecting smart devices). Platforms using BIM (building information modelling) are also gaining prominence (Chan, 2020).

Platform thinking is full of different concepts. There is no single definition in the literature or professional circles. However, in general terms, it can be said that a platform forms a place or a launchpad for driving actions (Chan, 2020). Indeed, by building such a platform, other businesses or individuals connect their ventures with the platform, build their products on top of it and cocreate value. Platforms often rely on the power of network effect. A growing number of active users attracts more of them (Bonchek & Choudary, 2013). This effect can be observed, for example, on a shared office space platform such as WeWork or Spaces.

The concept of platforms has been applied to various business activities at different scales, from the product level, through product systems, industrial supply chains, markets, and industries, to groups consisting of several industries. Platforms are of various kinds, reflecting the nature of the industry. In ICT, companies often use technological platforms, so automotive and other physical industries use product platforms. Nevertheless, they all share three common things (See Figure 5). The first is the core assets. They are the stable or integral part of the platform and do not change across projects. Next is a set of peripheral components. There the variety increases and can be freely combined with core assets. The third thing is an interface that enables the components to connect. This combination gives companies the freedom to offer various products and services while still benefiting from economies of scale (Mosca, Jones, Davies, Whyte, & Glass, 2020).

Concerning industrialised house-building, Lessing (2006, pp. 170-173) distinguishes two types of platforms – Technical and Process platforms. The technical platform represents the physical segment of the platform. From it, kit-of-parts is produced. Process platforms are formed by process modules and tools that support the technical platform in compelling issue solving. Both parts of the platform create a framework for con-tinuous project development.

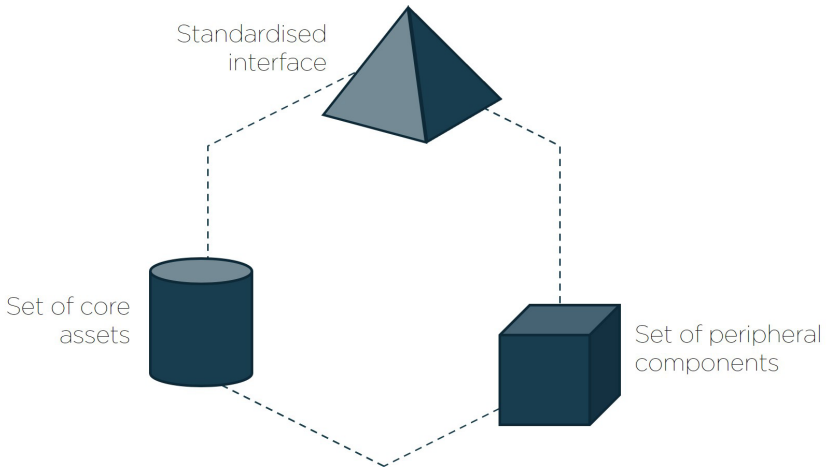


Figure 5

Three platform assets (Adapted from Mosca et al., 2020)

Figure 6 shows the continuous improvement driven by experience from each project. It is implemented back to improve the offering. Closed platforms often work with versions just like, for example, mobile phone manufacturers. Figure 6 shows that prototyping is essential in development. From it, the first generation of products is introduced to the market. When enough feedback is gathered, the improved, new generation is implemented.

While many of the digital platforms known and presented here focus on business-to-customer (B2C), or primarily the demand side, the construction industry is inherently focused on the supply side. Supply chains are a significant influencer of platform creation. The thesis research focuses on product platforms, considering the scope of this thesis. These are usually associated primarily in a business-to-business (B2B) context.

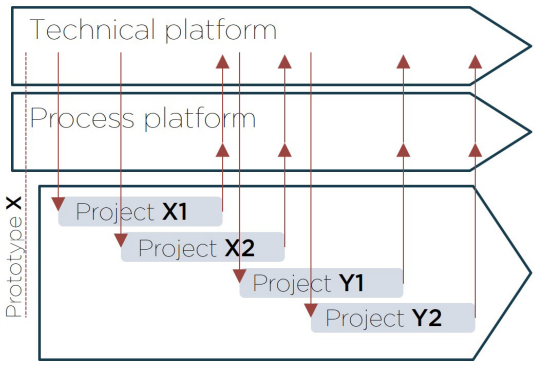


Figure 6

The process model for IHB
(Lessing, 2006)

Product platforms

Product platforms move the AEC industry from a construction to a manufacturing mindset. Such platforms create a set of core assets and standardised interfaces embedded in the platform while using a set of peripherals to produce different products (Mosca, Jones, Davies, Whyte, & Glass, 2020). According to Gawer (2014), the commonality of systematically repeating components across different products and creating a product family allows economies of production to occur. The systematic creation and exploitation of economies of scale in innovation can be seen as one fundamental platform-based new product development principle.

Robertson & Ulrich (1998, p. 20) define a product platform as four elements shared by a set of products – components, processes, knowledge, and people/relationships. All four elements must be fulfilled to create a functioning platform. Each element can be described as follows:

Components
are parts of the design of a product. Moreover, those are tools and fixtures to create parts.

Processes
involve the design of production and supply chain processes. It also includes the manufacturing and assembly of components.

Knowledge
can be the design know-how, technology application, production techniques and experience gained during execution.

Relationships
include people in teams, relationships between teams, within an organisation and with suppliers.

Product platform design

In their studies, Gawer (2014) and Baldwin & Woodard (2009) underline that the platforms they studied share a common structural characteristic: a modular technological architecture. Baldwin and Woodard (2009) consider platforms to have a particular type of technological architecture that is modular and structured around a core and periphery. Thus, a platform is made up of stable core elements of the product system and complemented by variable peripheral components (Baldwin & Woodard, 2009, p. 24)

Thus, facilitating innovation is what platforms as modular systems are particularly suited to. A central object of the modularity literature is that modular product architectures facilitate innovation (Baldwin & Clark, 2000). First, modularity helps manage complexity: by breaking down a complex system into discrete components that communicate with each other through standardised interfaces within a standardised architecture (Gawer, 2014).

Open, stable, and versatile interfaces (e.g., mass customisation) are key to platform stability and diversity. These interfaces facilitate and manage interactions between the platform and its complementary components and may be the only aspects that remain truly stable over long time periods (Mosca, Jones, Davies, Whyte, & Glass, 2020). The interface specification is important because it allows innovation to occur independently on either side of the interface. In this way, core and peripheral manufacturers can create value and competitive advantage, helping platforms become sustainable if they actively adapt to the market (Gawer, 2014).

According to Ulrich (1995), components of product architecture can be tightly or loosely coupled. The distinction of two extremes can be distinguished as modular and integral architecture. The modular architecture allows functional elements to be placed directly next to each other, creating a physical structure using physical components and a shared standardised interface. In contrast, an integral product architecture involves complex mappings between functional elements and physical components and coupled interfaces between components. In the case of integral product architecture, a change made to one of the components requires a change to the other components for the entire product to function correctly. For example, when modules exchange information, energy or loads, such interdependencies can have a significant potential impact on the functioning of the interconnected modules if one of the modules changes and design changes may require close coordination between module

suppliers (Gibb, 2001; Ulrich, 1995). In contrast, components are interchangeable, autonomous, loosely coupled, and individually upgraded in modular product architecture because interfaces are standardised.

Developing design rules agreed upon across the core product platform suppliers is required to secure the product modularity. The designer of one module (specific set of product parts) can use those design rules to make modifications without disturbing other module designers (Baldwin & Clark, 2000). The system's modularity enables an open platform structure, leading to firms' lower integration. Additionally, it promotes a loosely formed network of firms (Sanchez, 2000). It can be said that firm-to-firm integration is not always required to deliver a better product if design rules are followed. Figure 7 shows the application of design rules to product platform three assets.

If the design rules radically change an existing modular product (system innovation), system integration is required, and the companies involved must reconnect their complementary capabilities. Integration tasks are manageable for companies if they have sufficient knowledge of the system level of the platform. Although more integrated relationships are less effective in the short term, they provide more knowledge exchange and mutual learning opportunities (Langlois & Robertson, 1992).

The success of design rules depends on how upstream and downstream businesses and the end customer accept them. However, there are two strategies that companies can choose when adapting the modularisation of a product platform. First, they can act as a system architect, product owners or integrators. They define the product, create design rules, and communicate them to their suppliers. Alternatively, a company can compete as a particular component or module supplier. They produce goods that conform to the design rules defined by the platform owner (Ulrich, 1995; Baldwin & Clark, 2000).

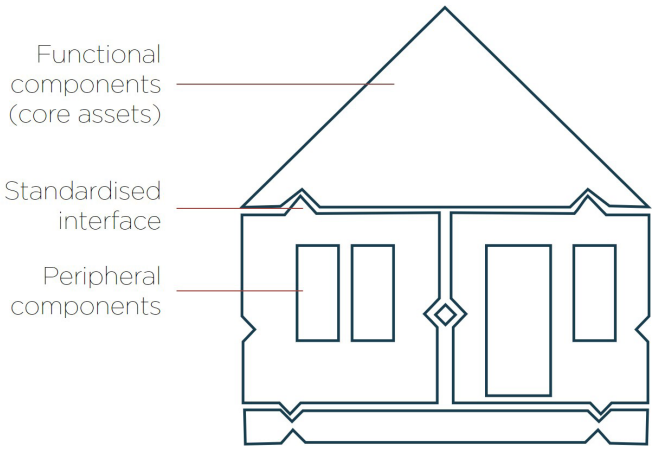


Figure 7

Design rules in product platforms (Source: author)

Product platform types and organisation

The Transforming Construction Network Plus (N+), a movement under University College London aiming to promote changes in the construction industry, provides the most up-to-date insight into platform thinking. Their product platform description (PP) recognises three types of PP – scalable, modular, and generational. Scalable PP retains its core product but scales by varying design parameters. Moreover, modular PP comprises core features or components with interchangeable peripheral modules to create distinctive products. Comparably, generational PP is prepared for intergenerational changes (Mosca, Jones, Davies, Whyte, & Glass, 2020).

Based on Gawer's (2014) study, Figure 8 shows the interchangeable environment of various platform types. Product platforms are not necessarily an object of one company. They range from predominantly firm-internal or closed to increasingly complex firm-external platforms. According to Gawer (2014), four core aspects: organisation form, interfaces, accessibility capabilities, and governance influence a platform framework that unpacks the innovation and competition interaction. The openness increases with more companies involved in development and operations. As interactions grow, platforms transform into ecosystems or industry-wide platforms with broad accessibility and weaker control over independent elements for platform owners. However, more significant participation of other companies, suppliers, and development partners encourages buyer-supplier interaction. Additionally, it suggests that closed or firm-internal platforms foster vertical integration strategies.

The left side of Figure 8 graphically illustrates principles of platform openness. It uncovers the relationship between peripheral ownership and the location of innovation. It shows that the more both aspects are in the hands of one firm, the more is the platform internal. With the increased involvement of external parties in innovation, platforms have become industry-opened. It is worth noting when creating an integration strategy. The conclusion of Figure 8 is that with an increasingly external approach, the complexity of the platform grows, thus creating more demands on buyer-supplier relationships.

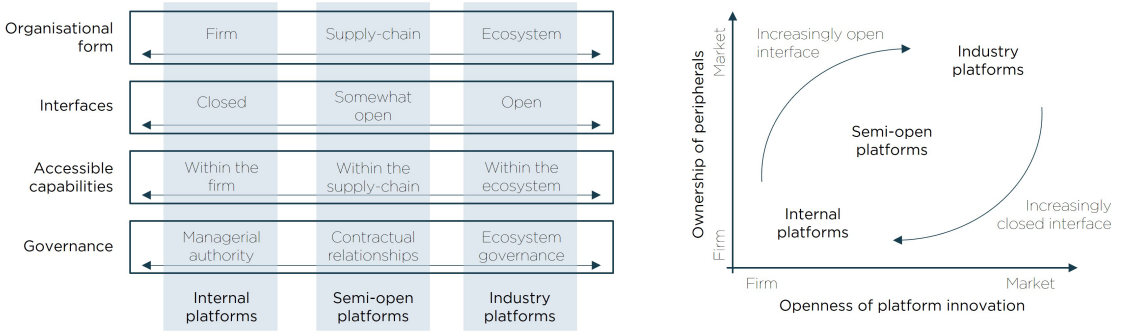


Figure 8

Openness and governance in platforms (Adapted from Gawer, 2014)

2.1.4 Synthesis of Industrialised House-building Product Platforms

Product platforms have been part of various industries for decades. Their development involves several pitfalls, but they are intended to bring a competitive advantage to the organization that implements them. At the same time, it has become apparent that they do not have to be exclusive to one company but that there are many arrangements and options for developing a product platform. Despite the incompleteness of the definition of platforms, a literature study has shown that platforms have several essential characteristics. Product platforms aim to enable mass customization while maintaining the benefits of economies of scale.

Industrialised house-building as the strategic direction of an organisation is a construction concept with a well-designed organisation and management that focuses on delivering maximum value to customers. The product platform is thus a way to implement this strategy within the context. Thus, the four elements of product platforms must together fulfil the eight aspects of IHB. At the same time, they interact with each other, and the individual aspects can be mapped to the elements. The synthesis of the individual elements and aspects is described below.

In addition, it is necessary to emphasise that none of the elements works independently. Each element plays a role in shaping product platforms. As a result, they interact with each other, which leads to the fact that changes set for one element can significantly impact the others.

Components

The modular architecture that allows a higher degree of preassembly consists of different components. Those can be either core assets or peripheral components. Their connection is provided by a standardised interface dictated by design rules and usually managed by the platform owner. The diversity of components in the modular architecture allows a high degree of substitutability, leading to mass customization (Ulrich, 1995). While the technical system design of components is dependent on a high level of knowledge, production and logistics influence the resulting variability and design.

- Off-site manufacturing is one of the aspects that relate to components. The availability of manufacturing resources and the willingness of these suppliers to participate in developing the product platform are critical to this element's success. According to Robertson & Ulrich (1998), the component element includes tooling and other equipment to produce parts too.

• Logistics is the second aspect that relates to components. Logistics enables the creation of parts off-site and their movement on-site. The possibilities and limits of logistics directly impact the final technical system or the project's economics.

Relationships

By definition from Robertson & Ulrich (1998), the relationship element of product platforms are people working on various aspects of product platform development. These people are often organized in cross-disciplinary teams, working on new product development or managing the diffusion of common solutions across various products. At the same time, it is common for suppliers to be involved in development from an early stage. Furthermore, relationships are related to other companies in the supply chain. Within this, some are more closely linked to the platform than others. This integrated approach requires looking at relationships from a long-term perspective (Muffato & Roveda, 2000).

• Long-term relationships are the prominent IHB aspect of this element. Long-term relationships allow for a better spread of knowledge and collaboration on developing components with a long-term horizon. At the same time, it allows for faster progress that is not burdened by a demanding selection process.

• Planning & control provide better coordination of all partners involved in developing the product platform. Proper planning ensures the correct allocation of resources, not only human resources. In an integrated supplier network, control is bi-directional. The partners control the product development, while the platform owner controls its direction.

Processes

Processes include how components are developed, produced and assembled into the final product. It involves obtaining feedback throughout the product life cycle to better understand internal efficiencies and customer perceptions. Digital technologies thus play an increasing role in integrating design, production, assembly, and post-assembly feedback.

• The use of ICT is an IHB aspect that provides procedural optimization. Additionally, it enables accurate data sharing across the organisation despite a large data set.

• Customer focus is essential to IHB. This aspect influences every other aspect of IHB. Therefore, each process should be linked to a clearly defined focus on a specific customer or target group.

Knowledge

Product development at IHB is a complex matter requiring expertise in various technical areas. Developing a technical system thus assumes a great deal of knowledge while creating unique platform-specific know-how. Knowledge sharing in the construction industry is usually between a local network and essential communication. The know-how and experience integration activities bridge the knowledge flow in construction organisations. Managing knowledge transfer through a central system between projects enables both short-term performance improvement and long-term benefits in the development of construction firms.

• KPIs & XP reuse is a significant aspect that secures shared knowledge from platform development. Setting organisational performance indicators for the entire supplier network provides a coherent performance overview essential for future product and process improvement.

• Technical system development manifests the combination of knowledge across the supplier network. It also retains this knowledge for continuous improvement within the platform, differentiating IHB from traditional construction.

2.2 Supplier Network Integration Strategies

The construction industry often forms temporarily project teams and coalitions that last only during the project development and execution. The knowledge gained during the process stays with individuals and is not retained by the companies involved. It prevents continuous improvement (Winch, 2010). Furthermore, construction companies heavily depend on subcontracting and suppliers of building materials. It leads to a situation where some of the major contractors can be identified as so-called quasi-firms, and this trend continues and causes the construction industry to be leading in outsourcing, among other industries (Dubois & Gadde, 2000). However, in other sectors increasing specialisation has enabled purchasing firms to improve efficiency and effectiveness by changing the nature of supplier relationships. This approach leads to solid ties formation from which suppliers benefit through the so-called network effect (Gann, 1996; Robertson & Ulrich, 1998).

Strategy is a crucial part of every business nowadays. The construction industry is primarily focused on project-based planning, lagging behind many other industries that focus on strategic management. However, this approach is changing across firms related to building. Those companies move their attitude from project planning to more elaborated strategic management (Chinowsky & Meredith, 2000). Approaches to strategies are constantly evolving as the business environment develops (Hall, Whyte, & Lessing, 2020). Therefore, it is essential to study this evolution to explore how companies in industrialised house-building retain knowledge and develop stronger ties with suppliers.

2.2.1 Product Development Relationships

Companies may choose to develop and manufacture parts in-house or purchase development and production capacity from the market in the manufacturing industries. It can be described as the two extremes of vertical integration and vertical specialisation of the value chain. Between those extremes are vertical and horizontal networks of producers – also known as quasi-vertical networks. This type of integration combines the advantages of vertical professionalisation and can be a suitable option for companies in decentralised networks and the development of modular, standardised systems (Karlsson, Nellore, & Soderquist, 1998).

In non-integrated or specialised supply chain structures, the platform owner (or system architect in the case of modular architectures) decides whether to outsource only production or design tasks. Ulrich and Ellison (2005) suggest only four ways to outsource design and manufacturing tasks. Nevertheless, changing relationships can lead to either outsourcing or internalising behaviours.

Traditional construction formations can be described as project-based relationships that are unstable and non-integrated (Winch, 2010). Long-term cooperative agreements at the multi-project level that aim to develop, manufacture and assemble new projects are defined as quasi-integrated relationships (Zollo, Reuer, & Singh, 2002). Contractors can internalise design and production or outsource them to partners. However, where the upstream enterprise supplies a particular component exclusively to one downstream enterprise so that both enterprises do not sell or buy that particular component from other enterprises and the enterprises cooperate at the level of multiple projects - we are talking about a fully integrated supply chain structure (Ulrich & Ellison, 2005).

The matter of relationship has an economic aspect too. Those relationships are an investment that can increase efficiency in everyday operations and promote development. Long-term relationships allow for the gradual improvement of activities. Furthermore, they create connections with others, producing even more significant benefits. Studies of cooperation between customers and suppliers have shown that tremendous benefits can be achieved when companies adapt to each other (Gadde & Håkansson, 1994).

According to Gadde & Håkansson (1994), there are three types of adaptations. The technical adaptation links the production operation of supplier and customer. A customer might find it adequate to ask a supplier to develop a product that would fit the buying company's needs in terms of technical content or physical features. Another example of technical adaptation is a sophisticated logistics system, i.e., just-in-time delivery, which enhances operations' materials flow and efficiency. The second type of adaptation is administrative routines. Those are intended to integrate information systems and improve the efficiency of administrative operations and bureaucracy. The third is knowledge-based adaptation. In a close and long-term relationship, the customer and supplier know each other's operations considerably. In these well-developed partnerships, the skills on both sides tend to be intertwined and not easily separable. These mutual adaptations tend to bring firms closer together and are of particular importance for joint efforts in technical development.

2.2.2 The Construction Networks

It is relevant to consider relationships within an industry as networks. Purchasing companies are increasingly promoting cooperation with suppliers and between them. The concept of supplier networks is very fashionable today. In this line, working in networks is the current mantra of technological companies. At the same time, we can see many studies conducted on the topic of the network (Dubois & Gadde, 2000; Popovic, Schauerte, & Elgh, 2021; Larsson, Eriksson, Olofsson, & Simonsson, 2014). Long-term interaction with a network of suppliers should enable buyers to stimulate mutual adaptation and thus increase the benefits of the network effect (Eccles, 1981).

The research conducted by Dubois & Gadde (2000) shows two layers of supplier networks in the construction industry. The permanent network is characterised by a long-term repeating exchange of products and services with a limited number of companies. On the other hand, construction creates a temporary network with intensive coordination on-site. Moreover, the constant adjustments and modifications allow joint learning, which might lead to a network effect.

To set up a new network might be costly. However, in the long-term perspective, those costs are overweighted by (not only) financial benefits (Winch, 2010). Moreover, network effects induce a self-reinforcing feedback loop that magnifies the initial advantages of established firms and promotes the longevity of these networks (Gawer, 2014). Strong

network effects in some industries lead competing network platforms to a "winner-take-all" outcome (Lee, Lee, & Lee, 2006).

The construction industry is different from other industries in many ways. According to Langlois and Robertson (1992), two forms of networks can be distinguished in specialised non-integrated business networks: centralised and decentralised. Centralised networks are those in which suppliers are tied to a "lead" firm (as in the Japanese automotive industry). The lead manufacturer sets design rules (compatibility standards) that may vary from one lead firm to another. The lead firm plays the role of system organiser or product platform owner. In decentralised networks, however, suppliers have to meet the requirements of different customers and standards are determined jointly by component manufacturers, assemblers and users through market processes or negotiations. No one in the network has complete control, and anyone attempting to standardise in a decentralised network risks isolation if other manufacturers and users do not follow suit (Langlois & Robertson, 1992).

Most construction companies operate in such a decentralised network of suppliers and customers, using the production capacity of various external suppliers. It is challenging to operate as a leading company, a platform owner, and implement design rules for standardised product modules in such networks. It is also due to the design-build nature of the construction industry and the often-unique site conditions. Standardisation opportunities are often limited to the project level: construction projects can be considered temporary organisations. Therefore, standardisation at the multi-project level is difficult because project teams and product designs change from project to project (Langlois & Robertson, 1992; Larsson, Eriksson, Olofsson, & Simonsson, 2014).

However, adopting a platform model requires engagement with the detail of an organisation, (supplier) network, and the market. Adaptation is significant for capturing value and is deeply intertwined with an organisation's business model. However, it is the platform owner's organisation and external platform participants. They, too, must consider to what extent they want to participate and collaborate (or compete) with other platform owners (Mosca, Jones, Davies, Whyte, & Glass, 2020).

2.2.3 Strategy & Strategic Levels

Finding the most accurate strategy definition is difficult due to its complex nature. As every company evolves, it needs to set a direction that ensures it is sufficiently resilient to the surrounding competition and makes optimal use of its resources to safeguard its survival and growth. The definition of strategy varies depending on the author's point of view. Some include corporate objectives in strategy. On the other hand, some exclude them and place them somewhere within the management process. As a result, strategy is seen solely to achieve these goals. However, the most common definitions include the notion that strategy involves setting goals, allocating resources, and establishing consistency between decisions and actions. Those definitions also share a crucial aspect of strategies: long-term vision (Grant, 2018).

Individual elements of strategy need to work together. For example, Seth & Thomas (1994) emphasise the integrative nature of strategies within the organisation. Additionally, the plurality of goals is essential. Sole focus on a single goal can bring remarkable success in the short term but at the cost of failure in other areas in the long term (Grant, 2018). Furthermore, Taylor's (1911) emphasis on maximising organisational performance remains a core of strategic management until today. The strategy reflects the diverse needs of organisations in each environment for certain professions and technical skills and thus has many shapes (Chinowsky & Meredith, 2000).

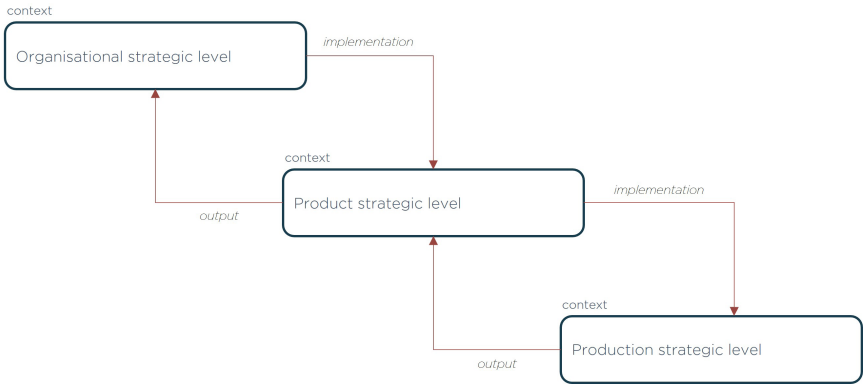


Figure 9

Nested strategic levels (Adapted from Vande Putte, 2020)

Modern views on strategy expand over single-firm boundaries. While there are usually two main approaches to organisational strategies, which can be divided as external and internal, today's trend is to combine them. It emphasises a necessity to exploit internal functions and understand external market propositions. Not only that, but firms often cooperate intensively with each other, and their profits are directly influenced by the performance of the entire group of partner firms (Grant, 2018).

Strategies do not appear at only one level. Different levels of strategy can thus be recognised. In the literature, three basic levels with a hierarchical structure are most often encountered (Wheelwright, 1984). As Figure 9 shows, organisations formulate strategies in response to a context deploying resources to achieve a valuable output. Each level is an input-output system that maximizes efficiency and effectiveness through strategy. In the product platform context, three strategic levels can be found; at the top is an organisational level; next is a product level (also known as business level) and thirdly, the production (operational) level (Wheelwright, 1984; Kim & Lee, 1993).

The business direction, acquisitions, and allocation of resources to business units are addressed at the organisational level. The second and third levels deal with how to achieve these goals. For example, production strategy includes strategic aspects related to sourcing production methods and their impact on the rest of the organisation. Product strategy includes strategic aspects at the organization level addressing markets, competitive advantages, target groups, customization, and business models (Lessing, 2015).

2.2.4 Strategies & Barriers in Industrial House-building

Strategic management requires clear communication of the corporate approach on all levels and teams. One of the core challenges for companies involved in the construction process ranging from the design, project development and investment to construction execution, is that they often use diverse vocabulary, methods, and techniques, despite all participating in the same environment (Chinowsky & Meredith, 2000). In addition, Hunger & Wheelen (2003) highlight that people on all levels should be involved in strategic management to be more effective. Employees must be involved in seeking relevant information from the environment, suggesting changes in strategy and activities to take advantage of changes in the environment. At the same time, they should work with others to improve working methods, procedures, and assessment techniques (Hunger & Wheelen, 2003). However, this is a challenge in a highly fragmented business environment that is primarily project-based rather than collaborative over the long term.

Industrialised house-building has many commonalities with other industries that produce standardised products or components. Therefore, scholars emphasise these similarities and see models from the manufacturing industry as a solution to the lack of productivity improvements in construction (Winch, 2003; Höök & Stehn, 2008; Gann, 1996). One of the most repeated is the aviation industry. However, the practice is reluctant to adopt knowledge from different fields. It could be for many reasons, for example, fragmented market or high investment costs.

Traditional construction is well-known for its single project orientation. This customer-led location-specific design leads to no repetition (Fox, Marsh, & Cockerham, 2002). Contractors build based on detailed specifications and are selected by clients work-based (Bröchner & Olofsson, 2012). In addition, there is a lack of production control over product design (Winch, 2003). This enormous complexity leads to inefficiencies and produces waste. Common to enterprises involved in industrialised construction is the formation of two strategies to decrease the complexity of construction. Those are standardisation of products (e.g., modules, interfaces, sizes) and standardisation of processes (e.g., control, procurement, localisation). Moreover, both approaches need to be continuously improved to avoid innovation failure (Bertelsen, 2004).

Each standardisation approach has its challenges. Product standardisation strategy involves designing and producing required components in a factory for assembly at the construction site (Höök & Stehn, 2008). Meanwhile, the processes standardisation strategy is more complex. It involves the design of each detail, manufacturing various components and construction on site. Processes must be created to address unique aspects of product customisation and specific construction locations (Larsson, Eriksson, Olofsson, & Simonsson, 2014). This approach requires long-term relationships and knowledge capturing. Standardisation is problematic in traditional construction, where the client rarely exploits contractors' knowledge, experience, and innovative ideas during the design phase. Application of contractor's experience in the project development often comes late, which leads to increased cost and inefficiency (Winch, 2003).

One of the challenges for prefabrication and standardisation is to find a balance between those two and flexibility. It leads to the consideration to what extent it is appropriate to prefabricate components. The degree of prefabrication falls into four categories, ranging from component fabrication and pre-assemblies to modular construction. Depending on the level of prefabrication, flexibility usually decreases, but the positives associated with prefabrication increase (Gibb, 2001). It is critical to set up all processes throughout the supply chain when deciding how much to standardise and what product will be delivered to the market. However, it might be challenging for externally oriented platform owners who coordinate development and

production with multiple essential suppliers. Therefore, Ballard & Howell (1998) highlight this element of the strategy. According to them, it is necessary to standardise planning procedures, design management processes and equipment installation. This approach might increase flexibility while getting the most benefits of advanced prefabrication.

Industrialised house-building does not just offer a wide range of how prefabricated a given building will be. Research from many firms involved in the construction of prefabricated housing has shown that firms often band together to gain a competitive advantage over their competitors (Larsson, Eriksson, Olofsson, & Simonsson, 2014; Lessing & Brege, 2015; McRobert, 2018). However, this brings many challenges. For example, Jansen et al. (2012) found that tighter integration between design and construction requires complementing the downstream flow of design-to-manufacturing information with an upstream flow of constraints from manufacturing to design. Many practitioners poorly understand it, leading to reluctance and mismanagement (Pasquire & Gibb, 2002). As mentioned, professionals along the value chain often use different expressions to describe the same. Therefore, IHB needs a system integrator, an organisation that brings together component subsystems into a whole and ensures that those subsystems function together (Larsson, Eriksson, Olofsson, & Simonsson, 2014).

The shift from traditional to industrialised house-building also changes strategic roles. In traditional (design-bid-build) construction, the client often controls, manages, and integrates. Despite all its imperfections, this role is put into the hand of a developer in IHB. The real estate developer is the one who integrates certain aspects of product platform development (Lessing & Brege, 2015). Lessing et al. (2015) display developers as platform integrators. This role requires strategy formulation and control over companies involved in the development process, thus integrating them into a team.

2.2.5 Integration Strategies

Integration of business is not a new concept. Many strategic management thinkers have explored ideas of integration across the value chain. In a simplified view, integration is the act or process of combining two or more things to work together. Companies can opt for internal integration, which results in better use of their resources. On the other hand, they can choose a supplier integration. This approach would leverage the supplier's resources and networks and enhance customer satisfaction.

In Porter's five forces model, such a move can lead to considerable profit potential, simplify knowledge flow and gain a competitive advantage (Porter, 1980). However, integration also carries certain risks. Expanding into a different part of the value chain can take the firm into a very different business that requires distinct approaches than the firm usually practices. Adapting a business to new conditions can be lengthy and costly, giving a significant competitive advantage. In the case of vertical upstream integration, it can lead to complacency. Newly acquired comfort and loss of connection with the market environment can lead to little innovation and thus loss of competitiveness (Grant, 2018). It can also bring less variability. Companies prioritise their resources and solutions over external options, which might be better for a specific product.

There are several other challenges to integrating supplier networks. The construction industry is strongly disintegrated with low vertical and long-term connections (Dubois & Gadde, 2000). In their research, Dubois & Gadde (2000) studied network connections in the construction industry and which relationships create. Furthermore, Popovic et al. (2021) research argues that IHB promotes vertical integration over time as IHB product platform owners strive to gain greater control over the value chain. Interestingly, both pieces of research were

conducted in Sweden, assessing several case studies. The results of those studies suggest a significant difference between traditional construction and IHB. It might also suggest the evolving trend across the industry that leads to increasing collaboration.

Kim (2013) showed that leading companies collaborate with their value chain partners at multiple levels to develop synergies and thus benefit from integration activities. In this line, integrated suppliers become strategic collaborators or partners. In manufacturing, this integration can occur in two ways. Firstly, product integration is promoted by gaining the authority to design, develop or assemble parts. Subsequently, with deep involvement in product development, suppliers can be involved in internal processes resulting in process integration. Many studies further emphasised that an early integration in the product development process brought more benefits to the platform owner (Koufteros, Vonderembse, & Jayaram, 2005).

Integration tendencies can be found at all strategic levels of the organisation but with different implementation processes. The organisational level often decides on strategic acquisition within the supply chain, which promotes primarily vertical or horizontal integration. Within the platform strategy, the product level is mainly concerned with forming close or loose relationships with suppliers. Also, it involves standardisation. While some processes in product development appear more beneficial to standardise, for others, it would lead to undesirable constraints (Kim D.-Y., 2013). Organisations can decide how to utilise their resources at the production level leading to in-house production or outsourcing (Ford & Farmer, 1986). In principle, when developing and manufacturing products, companies can choose to develop and manufacture parts in-house and purchase development and manufacturing capacity on the market (Karlsson, Nellore, & Soderquist, 1998).

According to Ulrich & Ellison (2005), in non-integrated or specialized supply chain structures, the system architect (developer or platform owner) determines whether to outsource only development or production tasks. Most development and production tasks are outsourced to external partners in such formations. Changing design rules can be a motive for outsourcing or internalizing activities. Utilising strategic integration options helps overcome some of the barriers they face. For example, outsourcing the technical system development allows leading companies to take advantage of the external partners' expertise as they have significant internal resources in production or logistics. On the other hand, in-house development and production might reduce transactional costs.

2.2.6 Synthesis of Integration Strategies

This section has shown how the IHB is inscribed in the organisation's strategies and the impact on the organisation's resource allocation. Similarly, the implementation of the product platform and its impact on forming supplier networks is evident. Based on the analysis of the theory on strategies, IHB and PP strategies were organised into three strategic levels. Figure 10 shows those levels concerning concepts of the product platform and IHB introduced in section 2.1. Furthermore, Figure 10 demonstrates some of the identified barriers to adopting strategies.

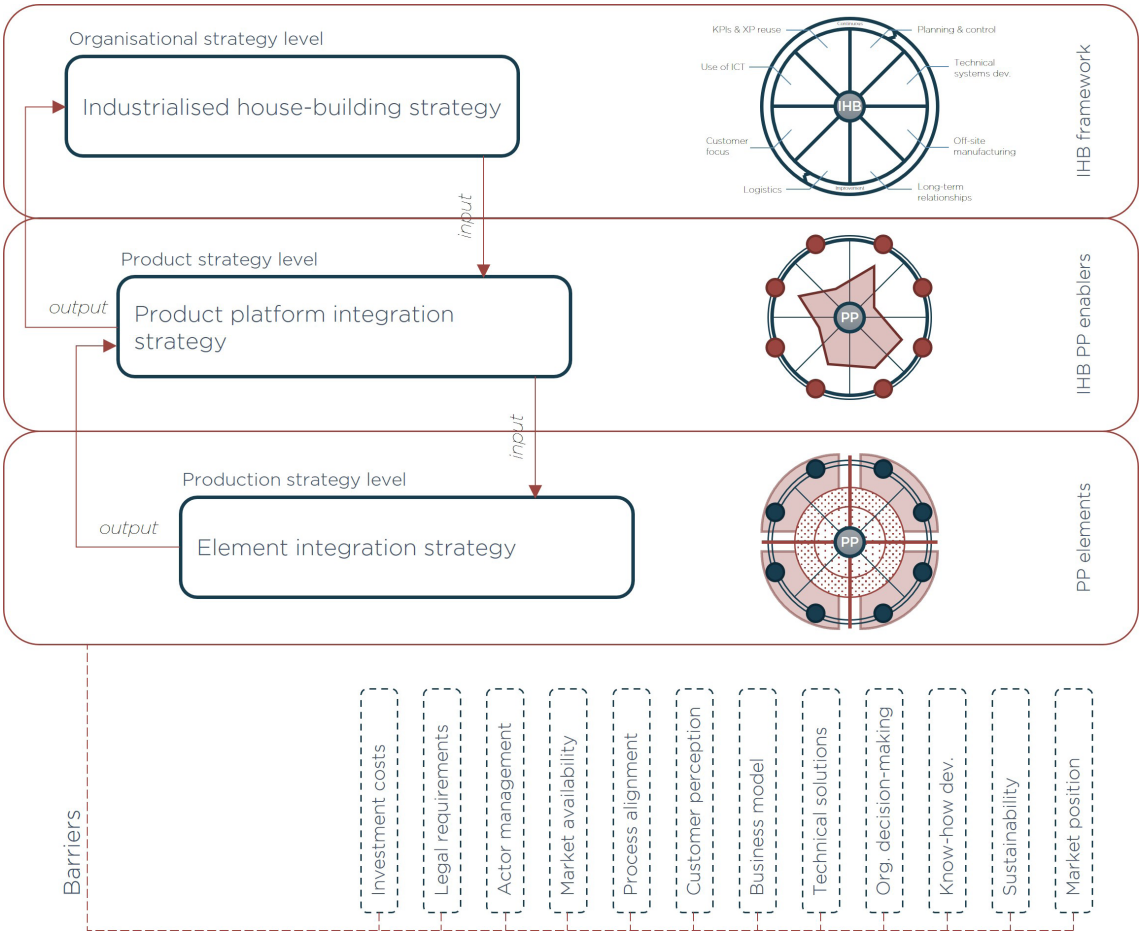


Figure 10

Industrialised house-building product platform integration strategic levels (Source: author)

In addition to the strategic investigation, this section explored supplier relationships and the formation of networks. Based on the findings, it can be concluded that platform owners aim to create long-term relationships that bring several benefits. Furthermore, relationships across the industry form networks that stimulate network effects through long-term interactions.

As shown in Figure 11, two concepts of supply networks have been identified in the literature. The first one evaluates networks based on clustering around a leading actor or platform. Centralized clusters have a direct relationship with an organizer who creates design rules. In contrast, decentralized suppliers have equivalent relationships with multiple customers and create rules across the sector. The second concept organizes networks according to their integration into integrated, non-integrated, and quasi-integrated. The red dots in Figure 11 represent the differently integrated suppliers for platforms.

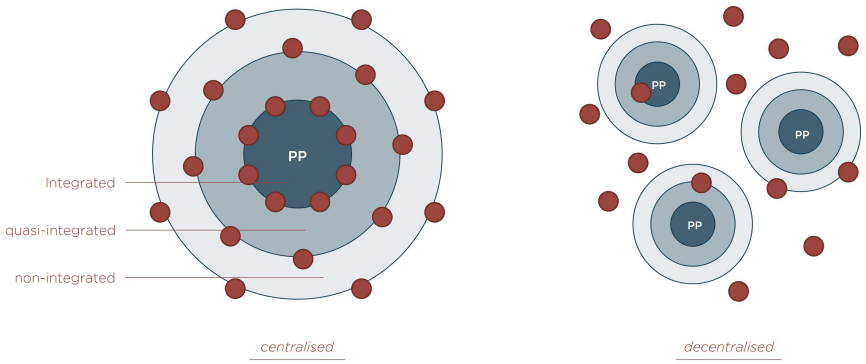


Figure 11

Supplier network formations
(Source: author)

2.3 Synthesis of Theoretical Framework

Product platforms in industrialised house-building are currently a developing topic. The focus is increasing among both practitioners and academics. Digital technologies enabled dynamic changes in this field and might bring start-ups disrupting the construction industry. However, in the meantime, many aspects need to be unified in the debate about IHB product platforms.

Product platform development faces several barriers. The theoretical study showed that platform owners and the industry must deal with limitations that undermine the adaptation of IHB in terms of strategic management and product platform development. The identified barriers are recorded in a table, see Appendix E, and are further organized by general themes. Furthermore, those barriers can be organised along the four platform elements recognised in this chapter. Table 1 shows product platform elements and generalised barriers. They are generated from literature (i.e., Goulding et al., 2015; Hall et al., 2022; Shibani et al., 2021), grouped into twelve categories and linked to platform elements. This link is essential because it influences strategies that platform owners utilise.

Platform Elements	Barriers	Literature
Knowledge	Know-how dev. & protection	(Goulding et al., 2014)
	Business model development	(Goulding et al., 2014; Lessing & Brege, 2015; Hall et al., 2022)
	Sustainability adaptation	(Goulding et al., 2014; Silva, 2020)
Relationships	Integrative decision-making	(Goulding et al., 2014)
	Actors management	(Abu Bakar et al., 2011; Goulding et al., 2014; Hall et al, 2022)
	Legislative limitations	(Larsson et al., 2014; Lessing et al., 2015; Shibani et al., 2021)
Components	Technical solutions	(Goulding et al., 2014; Hall et al., 2022)
	Market availability	(Goulding et al., 2014; Hall et al., 2022)
	Investment calculations & return	(Goulding et al., 2014; Lessing & Brege, 2015; Shibani et at., 2021)
Process	Software/process misalignment	(Goulding et al., 2014; Larsson et al., 2014; Hall et al., 2022)
	Customer perception	(Goulding et al., 2014; Lessing & Brege, 2015)
	Market position	(Goulding et al., 2014; Lessing & Brege, 2015)

Table 1

Product platform barriers (Source: author)

When synthesising product platform thinking, one might conclude that Robertson's & Ulrich's (1998) four constituting elements need to be harmonised among the platform owner organisation and its suppliers. The eight aspects of the product platform defined by Lessing (2006) act as enablers in adapting IHB and the product platform. Table 2 summarises the link between elements and IHB aspects. Each enabler corresponds to a platform element to complement its purpose. Notably, there are two enablers for each element. Despite their position referencing a specific element, it is critical to emphasise that they might have an indispensable role in other elements. Enablers interact with each other to complement product platform development. Additionally, it strongly influences strategy formulation and supplier network integration at all levels.

Platform Elements	Enablers
Knowledge	- KPI's & Experience reuse - Technical systems development
Relationships	- Long-term relationships - Planning & control
Components	- Logistics - Off-site manufacturing
Process	- Use of ICT - Customer focus

Table 2

Product platform enablers
(Adapted from Lessing, 2006)

The interaction and belonging between elements can be seen, for example, in the process element. Academics have recognised the digital (use of ICT) aspect as essential for modern IHB. Many emerging companies use modern technologies to disrupt the industry (Hall, Lessing, & Whyte, 2022; Mosca, Jones, Davies, Whyte, & Glass, 2020). This enabler is critical, especially for mitigating increasing labour costs and improving efficiency (Shibani, Agha, Alharasi, & Hassan, 2021). However, the more advanced use of modern technology and data collection tools is one of the hurdles that IHB companies must overcome. Suppliers from different construction sectors and technologies use different software, leading to inconsistencies in developing standard processes. Therefore, the integration of such suppliers is based on long-term relationships and is dependent on technical system development.

Networks are not composed of only one type. Suppliers are formed in distinctive networks depending on the component and its level. As Lessing (2006) described, platforms facilitate the reoccurring process of product development in a project-based industry. Different component types come variability across supplier networks and different

levels of integration. The platform owner can develop a centralised or decentralised network of suppliers. It can also relate to the openness of such a platform. Decentralised platforms tend to be semi-open or open, while centralised are often closed. In addition, suppliers are further classified according to their level of integration into integrated, quasi-integrated and non-integrated. The most integrated suppliers often participate in development, manufacturing, assembly and rarely in construction. Suppliers with a looser connection to the platform usually interact less with the entire process. The construction of finished modules is often outsourced to a general contractor with a network of sub-contractors but does not interfere with the actual development of the product (Lessing & Brege, 2015).

For the purposes of this thesis, the levels of integration are divided into two extremes related to each element of the product platform. Table 3 shows integration strategies linked to a particular platform element. Platform owners are not limited by one extreme option. Each strategy might variate depending on the specific supplier and their properties (Kim D.-Y., 2013).

Platform Elements	Integration strategic options
Knowledge	- In-house - Outsource
Relationships	- Tight - Loose
Components	- Make - Buy
Process	- Standardised - Non-standardised

Table 3

Platform elements integration strategies (Source: author)

Figure 12 describes the integration options and the networks related to product platform elements and types. The division is related to the strategic levels identified in the previous section. Figure 12 provides a tool to identify the supply networks in the empirical research and evaluate each case study.

The synthesised knowledge of existing theory is a base for theoretical framework development. Figure 13 is established based on the knowledge introduced in this chapter. It provides an overview of aspects that influence a strategy formulation on all levels. Furthermore, Figure 13 captures barriers, enablers and platform elements in a comprehensive framework that operationalises links between different parts of the integration strategy. Moreover, the central point is the output; in the case of this thesis, it is a product platform.

In Figure 13, the red-dotted area around the output highlights the strategic options and is further divided into five integration degrees. Four gamepad symbols mark each element section. Additionally, Figure 13 captures the eight enablers by the ninth called continuous improvement. The outer ring connects the barriers to the enablers. Although their location corresponds to certain elements, their influence on other parts cannot be ignored.

Barriers to product platforms are not just on the firm level. Many barriers come from the external environment, which could be impossible to influence by partners involved in product development. It could be, for example, a building code or other legal requirements. Furthermore, the municipality has a vital role when deciding whether to issue a consent or building permit (Shibani, Agha, Alharasi, & Hassan, 2021). Nevertheless, these external forces are also one aspect of the product platforms or their development, thus considering when formulating a strategy.

The theoretical background presented in this section helped explain and define thesis concepts. This insight is crucial, especially concerning the focus of this thesis. It has also provided the basis for the development of a theoretical framework. This section has created the theoretical framework introduced in Figure 13. It serves as a base for the empirical research in the following chapter.

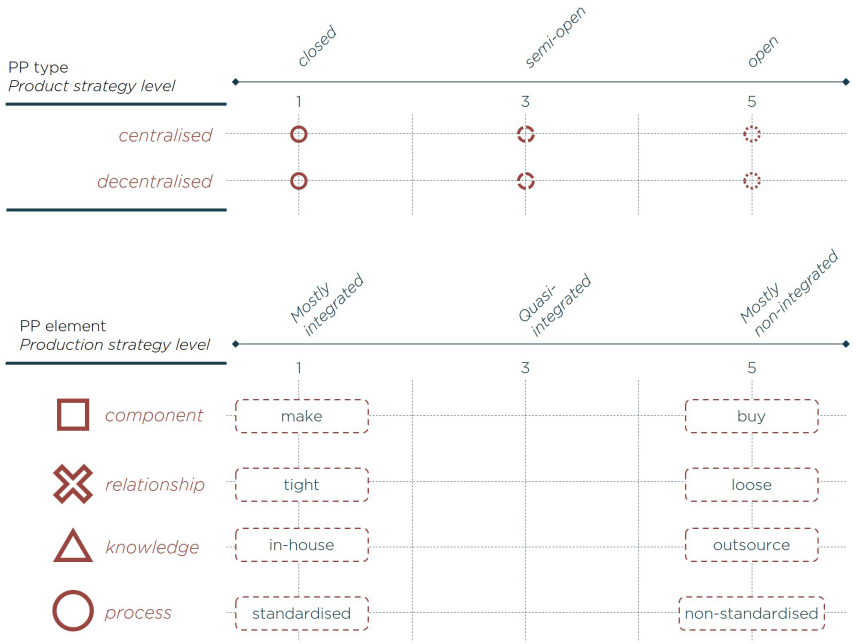


Figure 12

Supplier network integration types (Source: author)

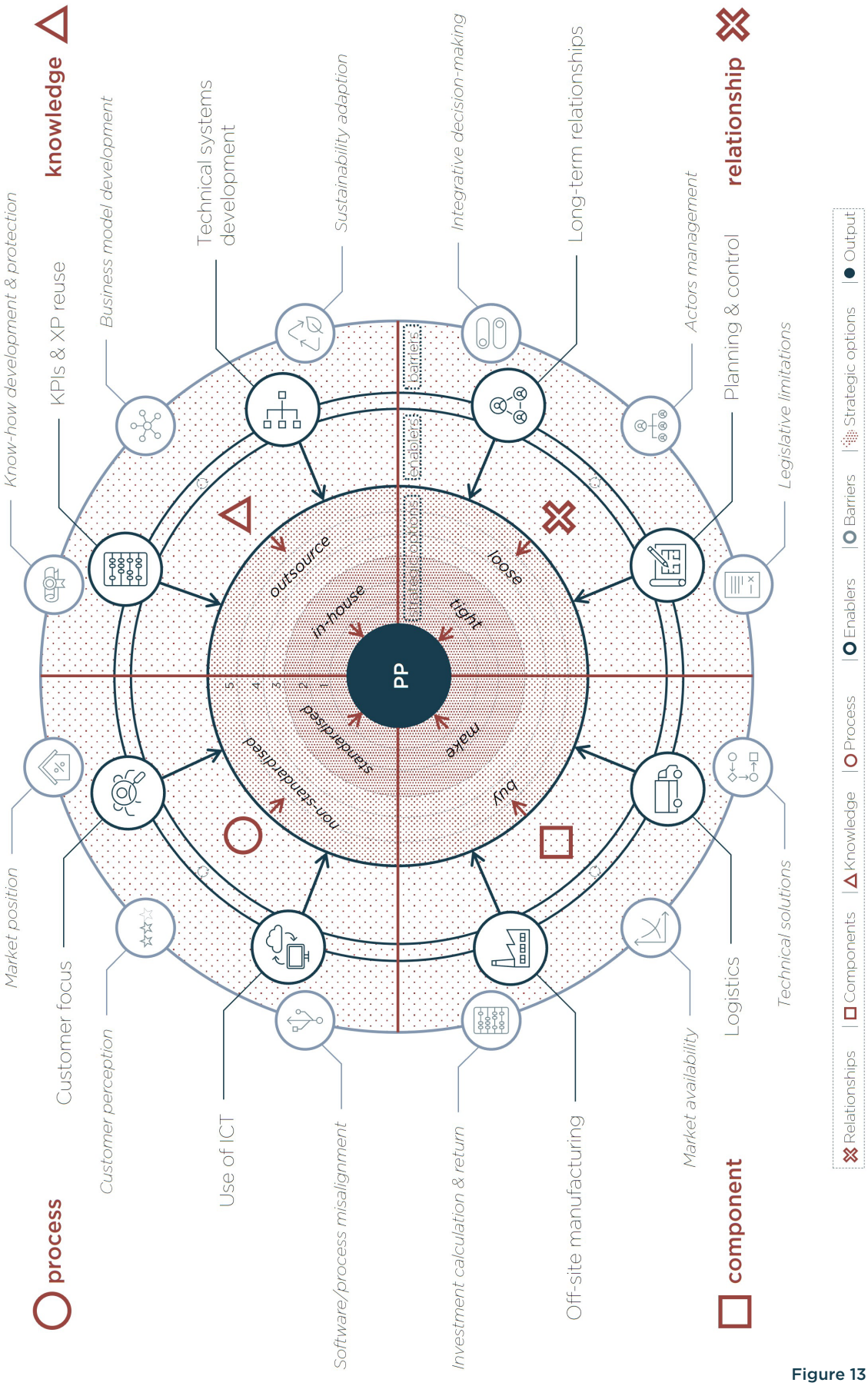
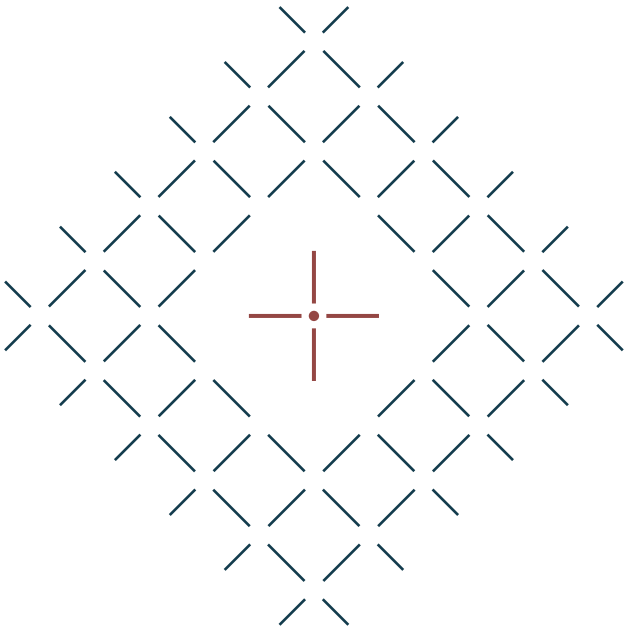


Figure 13

Product platform integration strategy framework (Source: author)



– 3 –
RESEARCH METHODS

3 – Research Methods

The research method chapter describes methods used in various stages of the research. Additionally, the ethical consideration of those methods is presented. The following sub-sections will discuss the research approach, design of data collection, and data analysis.

3.1 Research Objectives & Deliverables

This thesis focused on analysing product platforms that distinctively integrate supplier networks. Subsequently, it aimed to create a strategic framework for construction and development companies to create or re-work their product platform. Insights gained by this research should facilitate more knowledge in supplier network types in industrialised house-building. Furthermore, companies could utilise the framework to expand or create new product platforms and relationships. The framework is based on practical and theoretical knowledge obtained from several companies and information from the scientific literature.

The main research question and its sub-questions met the following objectives. The first objective was to explore critical elements of product platforms. Next was to investigate what relationships between suppliers and product platforms exist. Additionally, the third objective was to describe supplier networks and their types. Lastly, the fourth objective was to formulate the integration strategies for supplier networks and product platforms. In addition to the strategy framework's main objective, this thesis aimed to deliver several other deliverables based on the objectives above. First was the background knowledge development. The latter was essential to create a comprehensive strategic framework for the following discussion.

Two case studies from distinct markets were analysed. The preview of firms from different countries aimed to understand the challenges firms generally face. Comparing firms in a single state was desirable since it provided a more extensive description of relationships within the industry. Those relationships could be influenced by socio-economic aspects or the market position of a specific company. Broader knowledge of the market gave a better overview of the supplier network and the market availability.

3.2 Research Approach

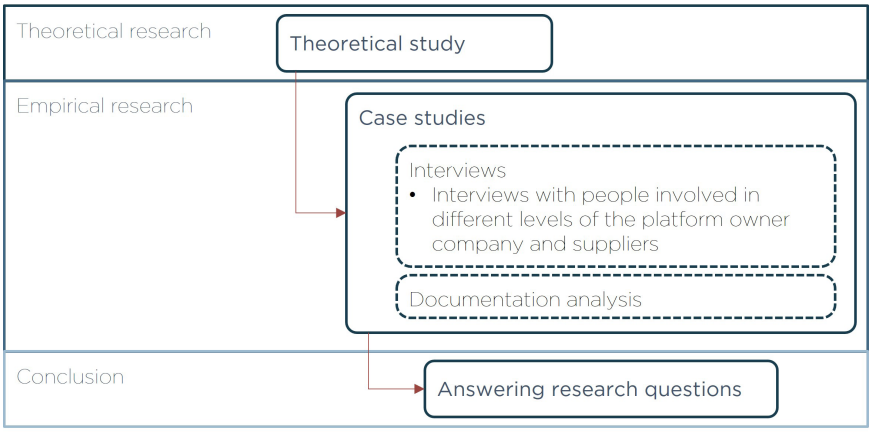


Figure 14

Research methods framework
(Source: author)

The research aimed to gain knowledge by exploring supplier network types and what strategies platform owners utilise in their integration. This thesis resulted in a comprehensive strategy framework that firms can adapt to their organisational, product and production strategies. Therefore, the nature of the research could be defined as empirical. However, a thorough theoretical study supported or gained a particular part of the obtained knowledge. The main objective of empirical research was to gain knowledge and generate explanations using a descriptive methodology to understand the research problem (Barendse, Binnekamp, de Graaf, van Gunsteren, & van Loon, 2012).

This study was conducted using an inductive approach. According to Bryman (2012), the link between theory and research is defined by drawing generalisable conclusions from observations that define the theoretical position. The inductive approach develops generalise findings based on observation and patterns. The research investigated and described a relatively new topic that has not received much attention in academic research by following an exploratory research method. Product platforms in industrialised house-building are a term evolving in recent years. In addition, challenges in the construction industry nowadays are the basis for the search for practical alternative solutions.

3.2.1 Research Design

Research design creates a framework for data collection and analysis (Bryman, 2012). Figure 14 represents the research methods design consisting of three main parts: theoretical research; second, empirical research, and lastly, conclusion. Additionally, the theoretical research defined the niche and provided a knowledge background for researched concepts. Next, empirical research analysed two case studies. In conclusion, those case studies provided data from practice that were later generalised to answer research questions.

In Figure 15, the research methodology framework is introduced and organised chronologically according to P terms. Each stage of research is highlighted with a distinct shade of blue. Every part shows the essential activity that was conducted. Furthermore, it shows a relation between research methods and sub-questions with the thesis output.

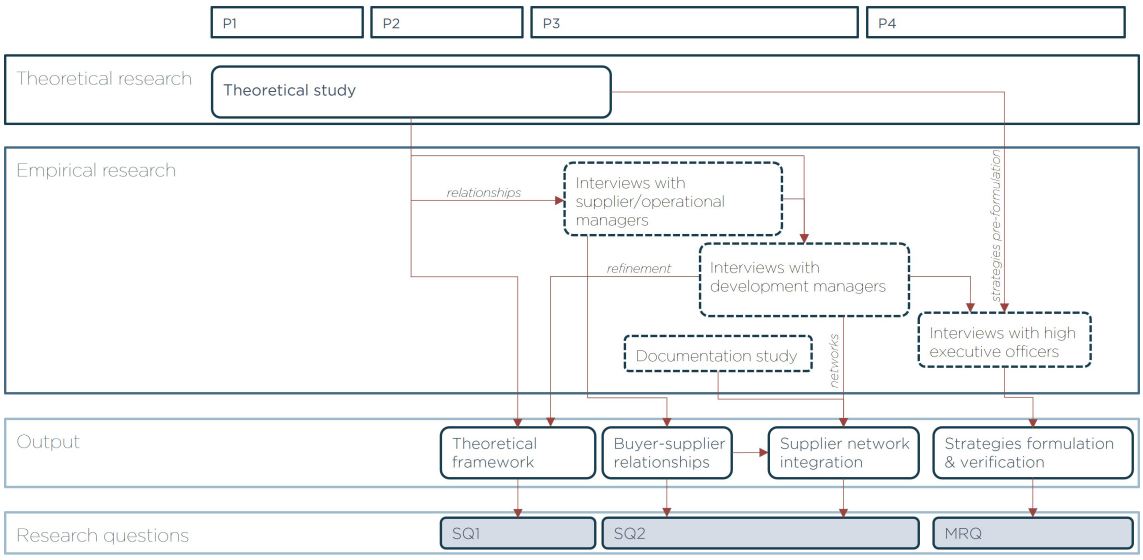


Figure 15

Research methodology framework
(Source: author)

Case study A – Swedish PP

Interview	Role
A.1	High-level executive officer
A.2	Platform development manager
A.3	Supply-chain manager
A.4	Business development manager
A.5	Product development manager

Documentation analysis

Case study B – Czech PP

Interview	Role
B.1	High-level executive officer
B.2	Platform development director
B.3	Product development manager
B.4	Supplier 1 (off-site production)
B.5	Supplier 2 (off-site production)
B.6	Supplier 3 (designer)

Documentation analysis

Different integration approach

Figure 16

Case study methods diagram
(Source: author)

In the first part, the theoretical study established a theoretical framework. This form is quite broad and allows for a thorough field exploration (Bryman, 2012). However, the information gathered was essential to develop a comprehensive understanding of what is already known from previous research and to develop a basis for subsequent empirical research. Additionally, it established a research gap that was filled with this thesis. This part of the research was used to formulate the research questions. Furthermore, based on this section, the first sub-question could be answered through a thorough theoretical study.

Academic search engines such as Scopus, Google Scholar, and the digital platform of the TU Delft Library were used for theoretical review data collection. Books and commercial publications also partially shaped the theoretical background. Profound academic papers with a higher number of citations are prioritised in the theoretical background. However, given the novelty of this topic in the construction industry, less cited studies were also used.

The empirical research in the second part strived to adjust and complement the theoretical framework of the last part. It is based on a qualitative study. Firstly, market research was conducted to explore the market practice. Next, Figure 16 shows that two case studies were analysed, mainly by interviews. Those case studies provided a distinctive integrative approach based on their nature. A detailed description of the selection criteria can be found below. The assessment framework of case studies remained identical to obtain the most comprehensive data.

In the third section, the study's conclusion links all the theoretical and empirical research findings. Furthermore, it proposes a strategic framework for product platform owners to utilise during product platform development. The chain of answers to sub-question and synthesis of empirical data will answer the main research question.

Case study design

The empirical research was designed as a multiple-case design to ensure the quality of this thesis, including construct validity, internal and external validity, and reliability (Yin, 2009). The study was based on two cases of product platforms that have integrated their supplier network. The analysis included interviews with managers involved in platform development and critical suppliers. Additionally, case materials were assessed. The research was replicated across cases to explore patterns related to the aforementioned theoretical framework. According to Yin (2009), it strengthened the sensitivity of research and improved the insights of the empirical study. Finally, the multiple-case approach enhanced theory building and results while minimizing biases and errors in a study (Bryman, 2012; Yin, 2009).

Figure 17 illustrates this thesis's multiple-case study procedure, as Yin (2009, p. 57) suggested. First, the theoretical proposition was developed concerning the theoretical framework of industrialised house-building product platforms and supplier network integration strategies. Second, the data were collected by interviewing managers from different levels and with a distinct relation to the product platform case. There, cases were analysed individually. Third, the collected data were analysed to explore common patterns across the cases. Finally, it led to defining general conclusions that either collaborate, modify or supplement the theory defined from the theoretical study.

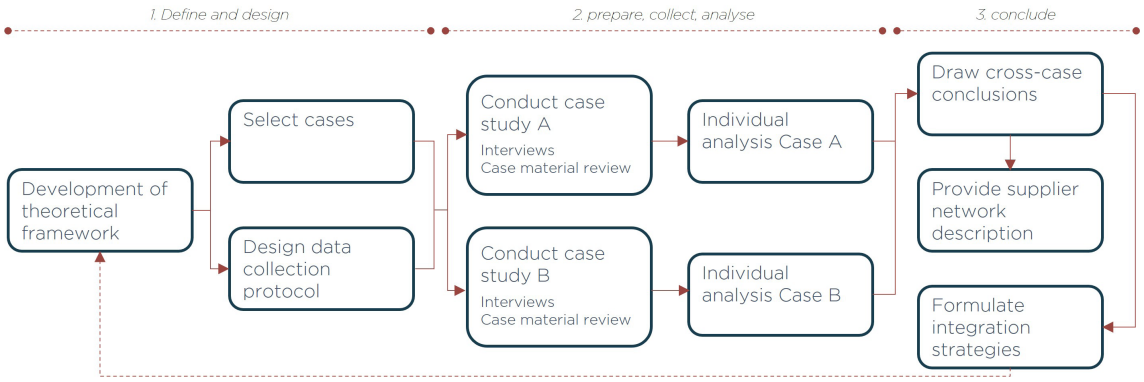


Figure 17

Multiple-case study procedure
(Adopted from Yin, 2009)

Case study selection criteria

Defining the criteria for selecting specific cases is essential for adequately executing case studies. Based on the concepts defined in the theoretical framework, the selection criteria are divided into two parts: required, which means that all cases must meet, and desirable, which means that at least one of the cases must meet this criterion. Table 4 illustrates the six criteria defined and their relevance in selecting cases.

As seen in Table 4, selected companies for the case studies must fall under specified criteria. Firstly, the product platform's primary focus is on residential buildings and has adopted aspects of industrialised house-building. Next, those platforms are situated in distinct markets, which resulted in the selection of Sweden and the Czech Republic. Carefully chosen cases provide a different approach to integration strategies. Simultaneously, each platform is in a different stage of development.

	Criteria	Reason
Knowledge	1. The product platform is related to residential development	For the thesis purpose, it is necessary to narrow the scope of the product platform so that individual cases can be compared.
	2. The product platform has adopted aspects of industrialised house-building (IHB)	The product platform must meet the aspects of IHB defined by Lessing (2006).
	3. The product platform has diverse supplier network integration strategies	To compare different product platforms, they must have different approaches to supplier network integration.
	4. Product platforms are located in distinct markets	Variation in the location and operation of the product platform should ensure variability in supplier networks and barriers they face.
Relationships	5. The platform already delivers existing buildings	Successful product implementations of the resulting product platforms should demonstrate the suitability of the integration strategy.
	6. The outlook of product platforms is long-term	It should not be a short-term project with a temporary organisation. It would affect the eventual approach to the integration of individual partners.

Table 4

Case study selection criteria
(Source: author)

Case studies introduction

Based on the selection criterion in Table 4, two product platforms have been selected as case studies for this thesis. Next, the introduction to those case studies is presented. However, the full case description can be found in chapter 4.1 Individual Case Analysis.

Case A – Swedish IHB Product Platform

Case A operates in multiple markets, but its original place is in Sweden. It is a well-established product platform with over a thousand housing units produced yearly. The platform owner's approach is strongly integrative. This trend has further deepened with the development of a digital platform for sharing the learning aspects of the product platform. The platform owner groups and controls a significant part of the value chain in-house. It utilises internal resources, including product development, production facilities and business operations. The overall control is an essential part of their business. Partners and suppliers related to Case A maintain long-term relationships. It enables a stable production system with predictable prices and quality.

Case B – Czech IHB Product Platform

Case B is a developing product platform located in the Czech Republic. The motivation to deliver affordable housing played a significant role in shaping a supplier network and a product design. Case B represents the product platform that utilises broader cooperation between multiple critical suppliers. The platform owner controls the development, but many tasks are outsourced. The Case B product platform can be considered a semi-opened platform with a more supply-chain organisation. The platform owner governs the know-how and other protected product parts developed by platform partners.

3.2.2 Data Collection

The data were collected through a qualitative research methodology. This approach enabled addressing complicated research questions and collecting a wide array of evidence (Yin, 2009). Firstly, semi-structured interviews were conducted with managers and other representatives of product platform participants to gather information about their approach to product platforms and integration strategies to the platform. Participants' motivations, enablers, barriers, and outputs of those strategies were also observed. According to Bryman (2012), semi-structured interviews allow concepts and theories to emerge from the collected data. Secondly, written materials about the cases and product drawings were reviewed to complement the interview information collected.

Semi-structured interviews

Within the case studies, several semi-structured interviews were conducted. Interviews were designed to obtain insights from different levels within the platform owner's company and by the product platform suppliers. First, the interview protocol was developed. The structure followed suggestions by Bryman (2012). It contained a set of core questions that were replicated interview by interview and a few questions that vary based on the specific case. The protocol was structured in five parts; first, the general introduction; next, it was followed by four product platform elements, each investigating specific approaches and other aspects. The protocol can be found in Appendix B.

Interviews were conducted in English and Czech – it depended on the interviewee's preference. A consent letter with a brief description (see Appendix A) was sent to the participants before the interview. Audio

recordings were transcribed to facilitate the comparability of obtained information and ensure transparency with the interpretation of the finding. However, the results were anonymised to protect the confidentiality of the information.

The participants have been selected based on their experience with the product platform and their relation to its development. Those are essential to obtain insights into the platform's working and development and the supplier network structure. The participants were contacted by email, and after confirmation, all interviews were conducted through a video call. Table 5 provides a detailed overview of the interviews. As can be seen, three levels of managers were interviewed. The first two levels helped to establish the operational aspects of the product platform and supplier network and gave an overview of platform functionality and structure. They provided the bases for integration strategy formulation. Interviews with high-level executive officers provided general insights into the organisation's strategic thinking. Moreover, in those interviews, proposed strategies were discussed.

Case material review

The individual case studies were complemented with additional materials such as written materials or product drawings. It provided background information about involved organisations, historical development and product aspect. Those were used to reflect information from interviews.

Case	Interviewee no.	Description
Case A – Swedish product platform	A.1	High-level executive officer
	A.2	Platform development manager
	A.3	Operation supply-chain manager
	A.4	Business development manager
	A.5	Product development manager
Case B – Czech product platform	B.1	High-level executive officer
	B.2	Platform development director
	B.3	Product development manager
	B.4	Critical supplier manager 1
	B.5	Critical supplier manager 2
	B.6	Critical supplier manager 3

Table 5

List of interviews
(Source: author)

3.2.3 Data Analysis

This section explains the steps to analyse collected data from theoretical and empirical research. First, the theoretical review was used to find the concepts and explore the background information to refine the interview questions in the following step. The established theoretical framework provided clear guidance for the interviews and subsequent analysis of the information gathered. Furthermore, it formed the basis for the formulation of the analyses in the conclusion of this thesis.

The collected data from the eleven interviews were recorded and transcribed to be further coded and analysed. For that purpose, the ATLAS.ti programme was used. This computer programme provides various tools for analysing textual and graphical materials. It was designed to analyse quantitative research content. The coding of interviews in qualitative research is a data sorting process into parts that seem to have a potential theoretical significance and are labelled with concepts and categories (Bryman, 2012). Codes are defined by the researcher. Figure 18 presents Saldana's (2021) code-to-theory model for qualitative inquiry. The coding process includes reading reports and create codes using semi-open coding method. There words or short phrases capture the essence of the data. Next, codes are categorised into larger groups. After this, categories become themes and later assertions. If no additional themes are discovered within a substantial number of transcribed interviews, it can be concluded that the research reached data saturation (Saldana, 2021).

In this thesis, several concepts and categories were identified in the literature and became a part of the theoretical framework, such as product platform elements (i.e., "knowledge component"), IHB aspects (i.e., "customer focus"), or strategic options (i.e., "outsource" or "in-house"). The obtained results were cross-checked with documents from those companies and compared with existing academic literature to secure triangulation of the research (Shenton, 2004).

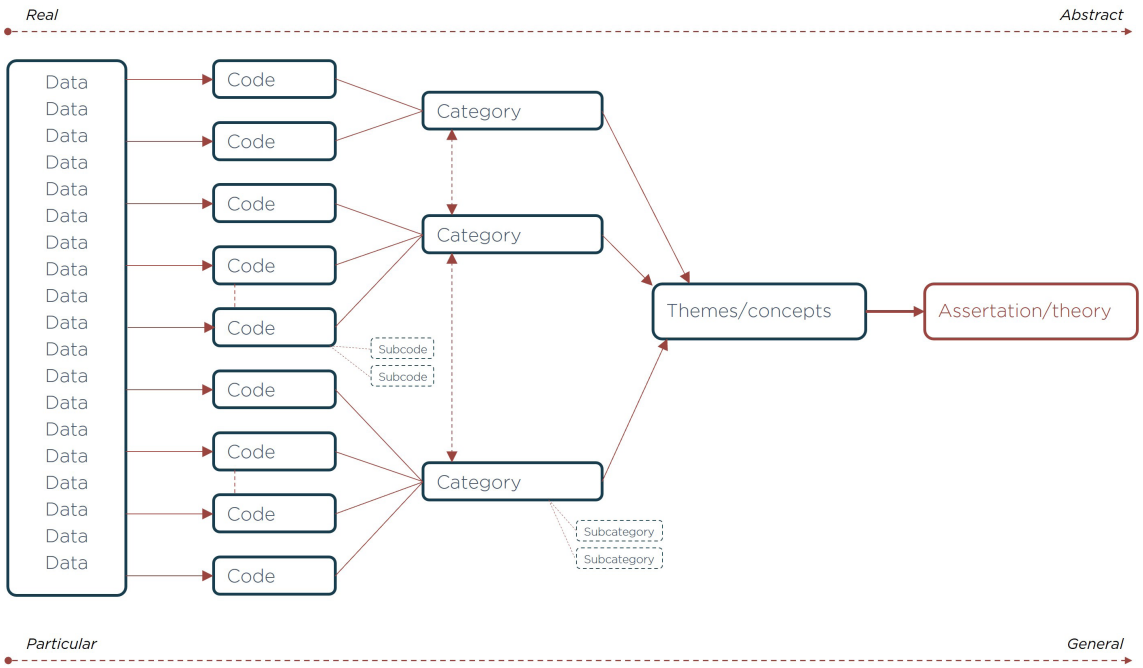


Figure 18

Codes-to-theory model for qualitative inquiry (Saldana, 2021)

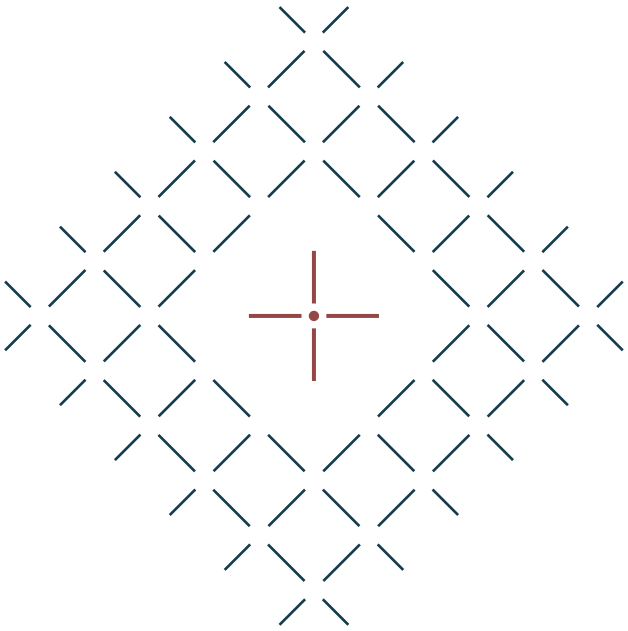
Subsequently, the coding process in the software helped to organize the data according to the defined themes of the theoretical framework and facilitated the comparability of information across cases. Each interview was coded and analysed individually, and then the codes were analysed concerning the different integration strategies and product platform components. It can be described as follows: in the raw data (transcribed interview), the intentions, methods and goals associated with the integration of the product platform were found. It can be named as the first order of data. Subsequently, the information was linked to the second-order, reflecting strategic options (i.e., buy/make). The third order links strategic options to the elements of product platforms. Refer to Appendix C for a more detailed example of data analysis.

3.3 Data Plan & Ethical Consideration

This thesis follows the FAIR Data Principles. FAIR data meets the four principles of Findability, Accessibility, Interoperability, and Reusability. First, the final research thesis can be found in the Delft University of Technology repository under the following link: https://repository.tudelft.nl/. The thesis is written in the English language to secure the interoperability principle. Lastly, the reusability is achieved by thoroughly explaining each research step. Moreover, all citations (i.e., academic journals, books, commercial reports) use the APA 6th referencing style with the List of references placed at the end of the thesis.

This thesis follows the "Code of Ethics of the Delft University of Technology". The concept of ethical considerations is most thoroughly focused on collecting, storing, using and disposing of data from human beings (Fellows & Liu, 2015). It is also necessary to consider the legal aspect of intellectual property, confidentiality, and integrity in data collection. Interviews and discussions are only conducted with informed personal and corporate consent. There is no pressure on interviewees, despite unanswered questions that might lead to knowledge gaps or secondary data analysis. For this purpose, interviewees first received a consent letter with a form and an interview protocol if agreed. Both documents can be found attached in appendices A and B. The interviewees acknowledge by their signature that they have been informed of the research content and interview topics and agreed to be interviewed. Furthermore, he/she has been informed of the possibility of withdrawing from the interview, not answering the selected questions, or requesting to be excluded from the metrics used for this thesis. Signed consent letters can be provided on request by the researcher.

All materials related to data analysis, including recordings, transcripts, and other confidential documents, are stored offline and deleted after the graduation date. Personal information, including interviewees' names, email addresses, and phone numbers, is kept confidential. Moreover, inclusive and non-offensive language is used throughout this text. Data that the participant wishes to remain anonymous is anonymised and not associated with that person. These principles align with the Ethical Considerations for Research of TU Delft. It means that this research is intended to have integrity and quality assured. In addition, staff and subjects are informed about this research's purpose, methods, and possible applications. All interviews were followed by debriefing before informed consent. In addition, confidentiality is assured if participants wish to be anonymised. Privacy is also assured, and participation in this research was always voluntary and without harm.



– 4 –
FINDINGS

4 – Findings

This chapter is structured in four parts. First, the brief market analysis that preceded the empirical research is presented. Next, the individual case studies are analysed, followed by the cross-case analysis presented in the next section. Lastly, the conclusions of the empirical research are stated.

Market analysis

The market analysis assessed the wide variety of companies that implemented certain aspects of industrialised house-building. It served as a basis for the upcoming empirical research and defined case study selection criteria. Furthermore, this analysis has expanded awareness of possible product platforms or other approaches to industrialized construction. The analysis focused on companies from different countries and construction segments.

In the analysis, multiple companies across the industrialised construction were analysed. The only criteria imposed were those companies involved in product development and are situated in the housing sector. They can be called product platform owners or developers who attempt to establish product offerings. Some of the selected companies did not successfully implement their product portfolio in the market and stopped their programmes. In addition, four companies differ in what level of integration they operate. The description of the assessed companies can be found in Appendix C.

The analyses described aspects of each company while observing their offering, development, and production processes. A thorough examination of the supplier network was made to gain more insights into how it affects the platform development. Certain similarities can be seen between those businesses, such as striving for a high standardisation of vital parts. None of the observed companies scaled their production over a lower number of hundreds of housing units per year. Regardless of their location, many companies struggle to make the business viable.

The result of this analysis is as follows. For successful companies, the degree of vertical integration increased as their product production level increased. Those that offer homes made of volumetric modules are typically more integrated. The same is observed in the opposite direction. The example of Kärnhem shows how the need for integration to ensure control over the product offering raises as the level of knowledge increases. Based on these findings, it can be assumed that one of the strategies to integrate supplier networks in product platform development and production is vertical integration. However, this is not the only strategy used by companies. Despite much attention to vertical integration, examples from other companies show that other strategies have not been adequately researched and described. Figure 19 visualises a simplified structure of the market analysis findings.

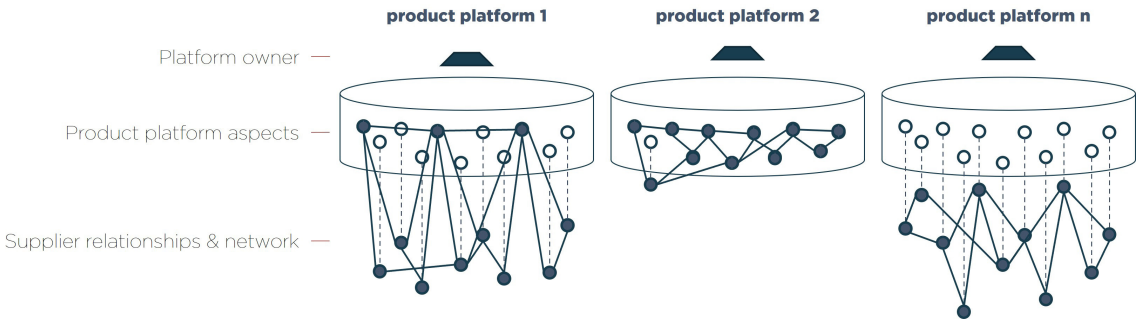


Figure 19

Platform network types visualisation (Source: author)

4.1 Individual Case Analysis

The following section investigates each case study. Firstly, the product platform and the platform owner are introduced. Secondly, the analysis focuses on each platform element. This part includes barriers and enablers of each element. Lastly, the supplier network integration strategies subsection includes a summary of the findings of each case and connections with the overall theoretical framework.

4.1.1 Case A – Swedish IHB Product Platform

Case A is a product platform that has been developing for over 25 years, mainly in Sweden, but the products developed under the platform owner's supervision can be found in other Scandinavian countries. Currently, the platform consists of several products – the typology ranges from semi-detached, terraced to multifamily houses. Multifamily housing can be considered the most advanced, with increased flat-mix variability. The annual production reaches approximately 1200 housing units, primarily located in Sweden. A significant part of the production occurs in a factory owned and operated by Case A platform owner. The platform is represented by nearly three hundred people who are directly involved in its development and operation.

The platform owner is a multinational company with a headquarters in Sweden that develops the housing concept. The company benefits from its ownership structure. Cooperation and sharing of know-how between shareholders have been and continue to be essential factors for successful development. Case A platform owner employs over two hundred people, around seventy work in business, project and product development, while the rest work in production.

Case A represents a largely integrated approach. The platform owner groups and controls a significant part of the value chain in-house. It utilises internal resources, including product development, production facilities and business operations. The overall control is an essential part of their business. Partners and suppliers related to Case A maintain long-term relationships. It enables a stable production system with predictable prices and quality.

The platform thus consists of a unique structural system of volumetric (3D) modules that create affordable housing. The physical manifestation of the platform is not only the people and processes behind it but quality prefabricated buildings at an affordable price.

Component element

Case A delivers a limited variety of products to the Swedish market, from (semi-)detached houses to multifamily houses. Unlike conventional competitors, Case A focuses on developing volumetric (3D) modules produced in the factory from which it assembles the final building. Most of the construction process thus occurs off-site. However, the chosen prefabrication method affects the complexity of the development and manufacturing process, which in turn affects many other aspects of the product platform. Additionally, it implies the reuse of standardised components. The increasing role of using commonalities between products during development can be seen in product development. The effort to use as many standard components is limited by national regulations and local planning permit demands for products for multiple markets. For example, each country requires a different thickness of the structural timber walls. Therefore, only a small number of house components can be used across borders unmodified.

A factory capacity further constrains the product offering. Not every manufacturer can participate in product manufacturing due to location or technological advancements. These barriers significantly impact the price and thus the overall development. Location constraints, time slots, and materials can collectively be referred to as market availability for the product platform. If a factory is located in another country, the price advantages of such a factory, i.e., lower wages, may be offset by currency fluctuations or transport costs. Expansion into new markets is significantly more challenging and lengthier, mainly due to the market availability of certain component suppliers.

Case A platform owner has its factory. This approach allows the platform owner to focus on improving production and improving the design of individual components. The knowledge gained is then applied in communication with external suppliers, which should improve the quality of the final product. Additionally, the deeper integration enables more significant factory automation investments. However, the complex technical system implied by 3D modules influences the number of off-site manufacturers that could participate in the product platform.

The logistics of the finished modules on-site are affected by the factory's location and local transport rules. It affects the product design. Manufacturing in the facility itself also affects the overall control over the volume and quality of raw materials. However, from the interviews, it does not appear to be a primary reason for more or less integration in this area.

Relationship element

For over two decades, the Case A platform owner has been present in the IHB housing market. Such a long presence impacts the development of relationships and requirements when selecting a supplier with whom the platform owner wants to work in the long term. All interviewed actors from this case study mentioned long-term relationships as essential to successful development. However, the length of individual long-term relationships can vary. The integration of some suppliers, especially designers, such as electrical or plumbing engineering, may be on a loose relationship basis, as knowledge in these areas may vary at the level of individual projects.

The platform owner has most of the control and planning power. Business planning and strategic decision-making concerning the next project's location and composition is entirely the platform owner's responsibility. After a market demand recognition from a local unit, the central development group (platform owner company) follows a brief from a company board. Afterwards, the product development starts with engaging external designers and experts on, for example, plumbing or fire safety. Development is preferably carried out with long-term partners with whom the platform owner has worked for several products and projects. However, one of the barriers to be overcome is finding suitable partners, as not all of them

can meet the production requirements or lack the necessary expertise. Case A components are designed in great detail (e.g. production documentation) before building permits and production starts, which is different from traditional construction. This different way of design is unusual for established studios.

"In a traditional project, it would not take much effort for architects, structural engineers and other consultants to develop a design. However, in our case, we need to dig deeply into the details. We need to figure out how it affects our factory or supply chain and how it will be transported. We optimise and see different solutions or how modules can be transported so that it is fast and safe to assemble. So, we have to deal with more details than a traditional building project" (Interviewee A.1, March 2022).

Off-site manufacturers need a steady supply of orders to progress to greater robotization of production. It requires adapting manufacturing know-how that cannot be adopted with low order volumes. Low volume leads to looser relationships more similar to traditional construction ones. However, the product platform also depends on transparent production and operational data exchanges. Therefore, there is a contractual relationship between the platform owner and the suppliers to exchange crucial information.

One of the most often mentioned barriers is a legal limitation. This limit adds complexity to an industrialised approach to lower such a complex process. One interviewed manager emphasised that different building codes across regions limit the standardisation of components and processes. For example, minimum bathroom size requirements vary from region to region, leading to the use of the largest ones in the final product, which is then built in all regions. Additionally, it leads to increased costs and longer development time. Other regulations have an impact on a module design due to logistics constraints. Some areas limit the size of one module that can be transported without a police escort.

External partners participate in this network too. Such partners come to the platform during the whole life cycle, including plot assessment, product design, manufacturing, and logistics. Despite a relatively broad network, suppliers are encouraged to standardise processes on a long-term basis. For that reason, architects and other designers share principles and know-how on the platform while maintaining independence and working on other projects. However, external suppliers play a critical part in the development; thus, the platform owner strives to keep them participating in the platform.

"In the best-case scenario, you have a supplier, a preferred supplier that is ready to be a partner, or they are already our partner. (...) Their knowledge and input are really, really important, and it develops the longer we collaborate" (Interviewee A.1, March 2022).

It can be concluded that the Case A product platform has various aspects that vary with a specific product. The supplier network varies according to the needs of the product and the region. Location is generally essential for the development and production, thus network formation. Additionally, it is clear that some suppliers are closer to the platform owner, and some have only a loose relationship with the platform. However, the essential part of the network is created and maintained with a long-term perspective.

Process element

Customer focus is essential for every product development. The Case A product platform has set its target group as lower-income people, generally articulated as people working in public services such as health care or education. Setting such a target group requires product development adjustments accompanied by certain customisation limitations, resulting in constraint options of, for example, interior finishes. The customer can thus choose practically only the apartment size or the orientation. The house's external appearance results from architectural design and local building regulations. This customer

focus impacts the technical aspects of the building as well as the requirements of the suppliers. At the same time, this approach is evidence of a strongly supplier-oriented product platform.

Nevertheless, Case A product platform benefits from a strong customer focus. It is manifested by consistently positive customer perception and high satisfaction levels. Positive recognition among customers is one of the critical indicators for future platform development. The platform owner collects user experience data and uses them in feedback loops in discussions with suppliers to improve products. Continuous improvement is secured by a large customer base and data provided by users and off-site manufacturers.

One of the critical enablers in the current Case A product platform development is the use of ICT. This area ranges from advanced automation to a common software platform utilisation. The standardised software environment requires a tighter integration due to higher investment costs. The current goal is to build a standard BIM solution to provide a digital platform for all markets. Digital technologies are not a significant limitation for this product platform. Despite a goal to have the entire process covered by the BIM solution, the software part seems to be of lower concern. If a supplier utilises a different software solution, it is not considered an issue in the short term, but the platform owner strives to unify it in the long run. Additionally, it demonstrates that relationships in IHB are built with a long-term perspective which also influences the adaptation of certain aspects within the product platform.

"You have to listen to them, but our goal is to use one programme in the long term" (Interviewee A.3, March 2022).

Developing a common digital platform must overcome many barriers. For example, there are differences in local legal requirements. The components that will reside on the digital platform may vary concerning the local environment, which increases the complexity of the overall platform solution. However, the digital platform does not only involve 3D models of components. The experience gathered during production is essential too. Therefore, the priority is to work in a unified software environment and standardise processes. Suppliers share a shared digital space where they store data or, for example, file issues discovered during production and assembly.

Furthermore, the motivation for a digital platform is to capture knowledge. The supplier network integration varies depending on the product or part in which the supplier is involved. Namely, an off-site manufacturer often handles logistics and transportation. Those activities have a low influence on the final output, but the experience and knowledge gathered by those suppliers are valuable for optimisation and future improvements.

"Something is changing every day. It may not be obvious on a daily basis to the worker, but in the long run there is a significant improvement" (Interviewee A.1, March 2022).

Knowledge element

Case A product platform is a closed platform governed by the platform owner. Therefore, the knowledge produced during the development and the production is retained within the platform. Keeping individual suppliers within the platform is vital as it reduces the cost of developing new knowledge. To this end, the platform owner maintains selected capacities in-house. Similarly, it handles the experience generated during development and production. These are also primarily maintained within the platform.

The product offering is developed concerning the so-called housing career. It involves different housing types, which provides a person with an option to move from an apartment to more independent housing such as a terraced house. However,

all products offered are unified by common design principles. Houses share many components and technical system solutions that enable standardised production. Much of the development of technical systems is done in-house to maintain this construction method while allowing for a generational renewal of products and retaining as many components as possible. Development capabilities are concentrated with the platform owner, and only selected capabilities primarily related to product design are outsourced.

Suppliers are a critical part of the Case A product platform. Platform owner utilises the knowledge of each of them across the product development process. However, the network differs depending on which product is under development. The core of this network is created by the internal resources of the platform owner. Those cover most of the product life cycle, including plot acquisition, detailed building drawings, and sales department. The platform owner operates a factory that manufactures products solely from this platform for some product types. Additionally, from a long-term perspective, the trend of greater integration is supposed to continue to centre more activities under one roof.

One of the motivations for having capacities in-house is that searching for new suppliers is a timely process. Construction industrialisation requires adapting specific standards that are unusual in traditional construction. Therefore, not every consultant or supplier can participate in the product platform. The suppliers participating in the platform are seen as partners who exchange information and equally participate not only in developing the product. Unlike traditional construction, suppliers stay in the product life cycle and continuously update their know-how. It refers to product development which is updated on a project cycle.

Product platform integration strategies

Case A product platform can be considered highly integrated. The platform can be deemed a closed platform with solid governance of the platform owner. Nevertheless, it provides some room for openness too. Local units operate in a way that could be described as franchising. This approach provides more flexibility in the regional environment and better orientation to the market's requirements. Insights obtained by local units serve as a base for new product development. However, product development is controlled by a central unit, which invites external suppliers to share their expertise and possible constraints for a product.

"So our way of working is a vertically integrated model. So we have our land acquisition team, product or customer offering team, and product development team. We produce in our factory, and then we control the construction sites with a site manager" (Interviewee A.1, March 2022)

The importance of manufacturing capacities integration appears to be beneficial. Platform owner owns one factory that has been recently reorganised to be equipped with modern technologies. The significant integration of the manufacturing facility enables an increased learning process and mastering of the production process. Additionally, it decreases the time between discovering an issue and handling it by the development department. The platform owner reuses obtained experience in a search for new partners. It can be said that component integration also influences knowledge element integration.

"It is an advantage to have our factory because we want to be good in understanding what to do within the factory. We think we will be a better buyer from an external factory because we know their possibilities, struggles, and challenges. Additionally, we know how much it should cost" (Interviewee A.2, March 2022).

Despite ownership of the production facility, making everything in-house is not always beneficial. The integration strategy for component elements is to buy from external partners primarily. This approach gives the platform owner more market expansion flexibility and mitigates factory operation risks. However, because the platform is closed, external partners are selected based on strict criteria that limit the number of suppliers who can participate. It indicates that the component element is related to the relationship element of the product platform, even though specific strategy contradicts. Using the capacities of external partners helps to reduce investment costs while at the same time making it possible to reduce expenses with lower production volumes.

Process element integration seems to be the most integrated. Platform owner strives for robust standardisation of processes related to, for example, product development and data handling. This approach includes a digital environment that can be used across business units and thus promote the learning process. Data are also used to understand user demands and priorities better. To ensure that data is wholly shared, suppliers must participate fully in the system, which is done by process standardisation. At the same time, with the future expansion of the digital product platform, where the building components will be stored and shared, this standardisation will be further deepened.

Knowledge and relationship elements are closely interrelated. Even though the network of participating suppliers is broad, the strategy is to maintain long-term relationships and tight cooperation. Knowledge is developed in several distinct ways. However, the strategy is to integrate it as much as possible into the product platform by employing digital technologies. Expertise and know-how are created by merging the existing knowledge of suppliers and the platform owner. External partners often bring their best practice. Nevertheless, it is adjusted to the product and platform requirements during product development.

The integration strategy is oriented to keep most processes in-house regarding technical system development. The platform owner has a development team that handles a significant part of the development. However, partners are brought in to provide their expertise. The platform owner owns the technical solution or design created and then uses it for production with the partners who participated in the development. The central unit owns the technical know-how and consults or provides it to local units, which participate in the development mainly by providing knowledge of local conditions. Monitoring key performance indicators and collecting feedback work on a similar principle. Everything is generated and stored in-house to distribute the necessary outputs to a specific unit or partner.

The integration diagram in Figure 20 summarises the Case A analysis. It can be seen how the platform owner accentuates tight relationships and standardised processes. The interviews revealed that long-term thinking is critical for such an integrative approach. It influences how the platform deals with barriers and limitations, especially when developing a product for various regions. Figure 20 shows a strongly integrated approach that aims to execute as many tasks as possible in-house or in cooperation with external partners but with aligned processes and a thorough selection.

This platform can be labelled: **Platform of Internal Improvement**. It shows how the platform approaches processes that are mostly internalised. There is a strong emphasis on optimising production, processes and the creation and preservation of know-how. The platform aims to integrate or have a strategic alignment of critical suppliers. The main driver of activity is continuous improvement, which dictates most decisions and the direction of supplier relationships.

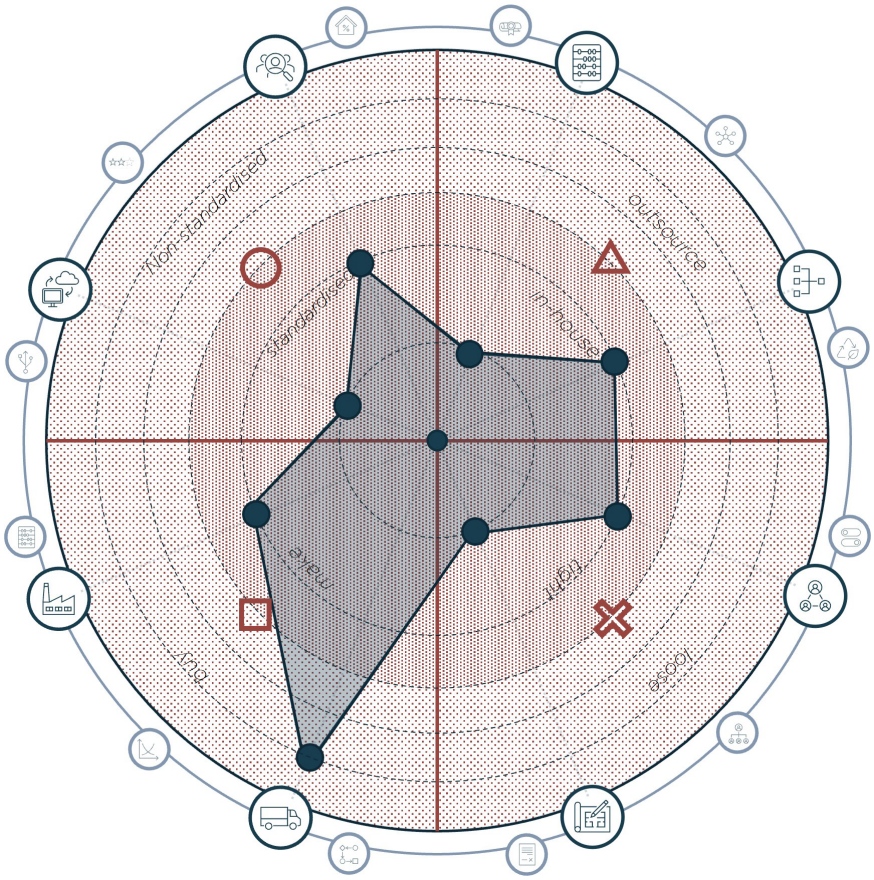


Figure 20

Case A product platform integration diagram (Source: author)

4.1.2 Case B – Czech IHB Product Platform

The development of the Case B product platform started in late 2018. However, the initial contact between the future platform owner and some critical suppliers occurred a few years ago. This long-term relationship development is vital for the development of the platform. The product platform supports two main products – row houses and multifamily houses – each with several versions. Despite thorough two years-long product development, there is no realised project as of the first half of 2022.

The platform owner is a well-established housing developer. Their primary focus is on traditional construction, but with increasing construction costs, the industrialised house-building and product platform development provided a new business opportunity. The motivation to deliver affordable housing played a significant role in shaping a supplier network and a product design. In response to this, the technical solution is a hybrid prefabricated construction made of 2D element modules, the so-called flat-pack. Similarly to Case A, the Case B platform owner benefits from its ownership structure. It influenced the platform formation and provided essential capital at the beginning.

Case B represents the product platform that utilises broader cooperation between multiple critical suppliers. The platform owner controls the development, but many tasks are outsourced. External partners provide their expertise. Unlike in Case A, suppliers are partners with an equal say in the development process. The Case B product platform can be considered a semi-opened platform with a more supply-chain organisation. Nevertheless, the product's know-how and other protected parts remain in the platform owner's possession.

Overall, this platform is represented by its technical approach, which is materialised by the hybrid design. However, the relational part of the platform is significant, creating deep partnerships while allowing for the participation of multiple suppliers.

Component element

Case B provides a different approach to components. Case B has developed a unique technical solution that combines a concrete skeleton system and a timber panelised envelope. Combining two construction systems requires multiple suppliers and limits the capabilities to integrate them under one roof for several reasons, such as high investment costs or lack of know-how. Two leading suppliers participating in the design process also provide off-site manufacturing capacities. Additionally, the wooden and concrete technical system requires broader collaboration within the supplier network because of considerable coordination on-site and the development of a standardised interface.

While participants work closely together to create a standard interface, the core assets remain in the possession of each supplier. The standardised interface developed jointly by partners, including architects, becomes the know-how of the platform owner. This approach secures the platform open to possible future-coming suppliers to connect with their product parts. However, the degree of off-site prefabrication is reduced to a so-called flat-pack solution. Prefabricated components are delivered to a construction site where the component supplier and on-site contractor assemble them.

The approach to having partially preassembled off-site manufactured components enables more products to be composed with the same components. Additionally, the wide variety of products increases flexibility for the platform owner to alter the urbanism of individual projects according to local specifics. There are three multifamily house types. Each response to different legal requirements, for example, underground parking. The component system allows changing the flat-mix within each building based on a specific module system. However, this change requires a new assessment from fire specialists or minor adjustments to the plumbing design. On the other hand, it allows the ability to adjust the product to the project site, thus not significantly limiting the location.

Off-site manufacturing is designed to occur in suppliers' factories. Based on information from interviews, the distance between the factory and a site does not play a significant role. The suppliers' further distance from future project locations is mitigated by other aspects such as labour costs and proximity to other sub-suppliers. Logistics of materials and components are secured mainly through suppliers. The platform owner leverages the internal resources and participates in an on-site organisation.

Relationship element

Participation of suppliers in the product platform development is essential for Case B. Although the actual development of the platform began later in 2018, some relationships were already forming before then. It also applies to the leading suppliers' motivation, who have been considering a similar approach for a long time. Despite the product platform nature that enables various suppliers of the same component to participate, the original suppliers expect to continue in the production of components in the future. However, this is uncertain due to the slow progress of project execution.

A critical aspect of the relationship element is that suppliers participating in product development are equal. This approach creates a transparent partnership where each partner's word has the same value. It is reflected in this element's aspect of integrated decision-making and actors management. Suppliers are in a position of partners, which several interviewees emphasised. Therefore, the platform owner is a moderator that steers the conversation between suppliers and controls the strategic direction of the product platform. One of the interviewees appointed that it enabled better collaboration and accelerated development.

With the semi-open platform, suppliers create a complex network. As product development requires unique solutions, suppliers employ internal and external resources to be able to deliver the optimal solutions. This approach leads to several results. Suppliers

tend to share some of their labour capacities mainly to exchange expertise and intensively cooperate with sub-suppliers for component optimization. One of the suppliers highlighted the importance of communication and transparency, which would be only possible if suppliers were partners. However, this cooperation also encountered problems related to different attitudes to certain aspects of the work, such as the level of detail or the quality of documentation exchanged between the different partners. Architects might have a different workflow compared to engineers in the timber industry.

Long-term relationships play a vital role in a product platform. Interviewees agreed that this is one of the most important motivations to participate in a product platform. However, not every partner is involved throughout the product lifecycle. It presents one of the challenges for a loosely integrated platform organisation. Consequently, feedback problems can arise. It was evident in Case B on the project level that the feedback between the project team and designers was limited and caused documentation issues.

Legislative limitations are a severe barrier to the formation of relationships that has a significant impact on other elements of the product platform. Similarly to Case A, the municipality's role and regulative power influence the design. Additionally, those demands push more substantial product variability and thus flexibility of the product platform. It also influences the possible material and technical solutions of the product platform. Consequently, it increases costs and extends the number of platform suppliers, especially in the product design phase.

"Legislation prevents the use of wooden posts as a support system. It simply has to be non-combustible, meaning a steel profile or concrete is adequate, complicating the construction. (...) it forces us to think about how to protect the structures with different profiles, such as plasterboard, which complicates the prefabrication in our factory" (Interviewee B.4, March 2022).

Process element

Essential aspects of the product platform include customer focus. This aspect influences almost every platform element and affects suppliers' selection. The interviews revealed that all actors are fully aware of clearly defined customer and general target group, which was reflected in the objectives of each supplier. It can be concluded that a standardised customer focus is a key to the Case B product platform. However, one of the interviews indicated that, for example, pressure for a low price could affect customer perception of the industrialised house-building concept. Those concerns are common to the industry in general.

Case B platform owner is known for its strict policies and standardised processes. In interviews, the owner's representatives mentioned that these principles are also essential to collaboration within the platform. Although suppliers respect these principles, none of the interviewees saw a reason for standardisation within the product platform. Contractors have indicated that standardisation of some processes will be necessary for on-site implementation. Nevertheless, they added that more experience from construction would be required to support this claim, which has not yet occurred.

Digital technologies are not a significant part of the product platform development. It results from the chosen technical system, which combines two different sectors. The interviewees unanimously indicated that they see the possibility of more standardisation within the BIM environment in the future, but they do not see the reason for this, nor the readiness of the whole industry. A less standardised digital environment enables more actors to enter the product platform. On the other hand, it does increase some transactional costs due to software and process misalignment.

"I do not know why people resist [using a standardized environment; author's note], and working with external partners is even harder. Because even our very professional partners get most of our documents redrawn" (Interviewee B.6, March 2022).

Knowledge element

Actors in the interviews unanimously mentioned knowledge acquisition as a crucial element for participation in the product platform. While knowledge about the components is critical for the platform owner, the suppliers can develop their own solutions or apply only theoretical considerations about alternative construction methods. The idea of industrialised house-building has fundamentally shaped the organisation of the platform. For example, the experience of designers significantly influenced the technical system development.

Case B product platform takes a relatively integrated approach to create shared know-how. It means that the knowledge created by the partners' joint efforts remains part of the product platform and is held or managed by the platform owner. One of the barriers to multi-vendor involvement often mentioned in the literature is the development and protection of know-how. Case B suppliers mentioned in interviews that the chosen intellectual property protection model was not a barrier primarily because participation in the platform allows many opportunities to learn and experiment.

The advantage of industrialised house-building is minimising waste and optimising energy resources during the manufacturing and assembly process. Sustainability is an aspect that is a shared value within Case B. However, suppliers and platform owner approach this topic differently, and there is not much integration between the partners and the platform. Moreover, it should be mentioned that the sustainability topic was behind the development direction of the technical system.

The business model of the Case B product platform is strongly oriented towards outsourcing. The novelty of the industrialised house-building approach in the Czech construction industry influences the decision of such a platform strategy. The product platform and the joint participation of several partners reduce the risks associated with developing such an unknown product on the market. The longevity of the relationship between suppliers and the platform plays a vital role in establishing business ties. On the other hand, it may contrast with the development of a semi-open platform as in the case of Case B.

Product platform integration strategies

Based on the case study analysis, the Case B product platform can be considered a semi-open with some integrated aspects and elements. On the other hand, the general approach enables external partners to participate in the product platform. It influences, for example, design choices, component interface standardisation, and process alignment. However, these strategies are mainly influenced by the immaturity of the Czech industrialised construction industry. Market availability poses a challenge for developing a product platform focusing on residential development.

For the platform owner, the lack of internal resources for off-site manufacturing results in a strategic option of buying. External suppliers provide the necessary expertise and capacities in the prefabrication of components. Additionally, this network of suppliers secures most logistics tasks related to product delivery on-site. Due to the chosen technical system, the platform owner can use some of its internal resources for site preparation and partly for the final assembly of the prefabricated product. In the future, as admitted by a large part of the interviewees, it is possible that there would be more integration and that some of the capabilities would move under the product platform.

While manufacturing suppliers are less integrated within the component element, this approach is different in the case of relationships and knowledge.

Despite a relatively open approach to the platform's future development, the product's actual development meant establishing tight relationships between critical suppliers. Some of the suppliers compete in a market with their products. However, they cooperate on the platform to deliver the better product together. Interviewees frequently mentioned openness and transparency in fulfilling the platform strategy. This strategic option of tight relationships allows for integrative decision-making, where all partners are involved in deciding key steps in product development. Thus, the platform owner primarily exercises control. At the project level, planning and control take place primarily on the part of the platform owner, and looser relationships with suppliers are created.

The relationship between suppliers and the platform owner is bi-directional and heavily influenced by market availability. Although interviews with platform owner representatives indicate that the intention is to maintain long-term relationships, supplier interviewees were more reticent. It may have implications for strategies at the production level. Another unmentioned platform participant appears to be the municipality. Although this may be a relatively short-term relationship, municipalities have a significant influence that can affect product development at the project level. However, the platform owner considers this external partner to be a very demanding partner, which may be, for example, due to inexperience with this type of construction.

The process element represents a challenge to the Case B product platform. While there is a strong focus on standardised customer focus, the use of ICT and process alignment are non-standardised. According to interviewees, this is symptomatic of a young product platform emphasising fast product development. However, it was mentioned that this is an area where the focus should be in later stages. For example, the BIM solution is something where the platform could develop further. Nevertheless, it will first require the implementation of first projects that will verify the feasibility and functionality of the current technical systems.

The integration strategy is tailored to ensure that knowledge is developed evenly across suppliers and the platform owner. By the nature of the current market, the development of technical systems needs to be outsourced. External partners bring the necessary expertise, experience, and knowledge to the platform. However, the Case B product platform aims to integrate the know-how generated so that it can be maintained and developed even if other suppliers are involved. In this respect, the actors work closely on technical systems, but each has several different KPIs and pursues different objectives within the product platform.

Figure 21 visualises the integration strategies specific to the Case B product platform based on the case study analysis. The interviews revealed that knowledge development is critical for all actors. It shaped the openness of the product platform and thus integration strategies towards external looking. It also influences how the platform deals with barriers and limitations, especially when developing a standard interface for interchangeable core assets. Figure 21 shows an external approach that aims to use different suppliers and their resources. However, this approach is primarily influenced by only recent developments, and interviews indicated that there could be more integration in the future.

This platform can be labelled as **Platform of Flexible Starter**. It shows how this young platform approaches its technical knowledge. Furthermore, it captures the fact that the technical solutions enable more component suppliers to connect their businesses and enhance the product variability. Also, it shows the desire to learn and capture knowledge from others.

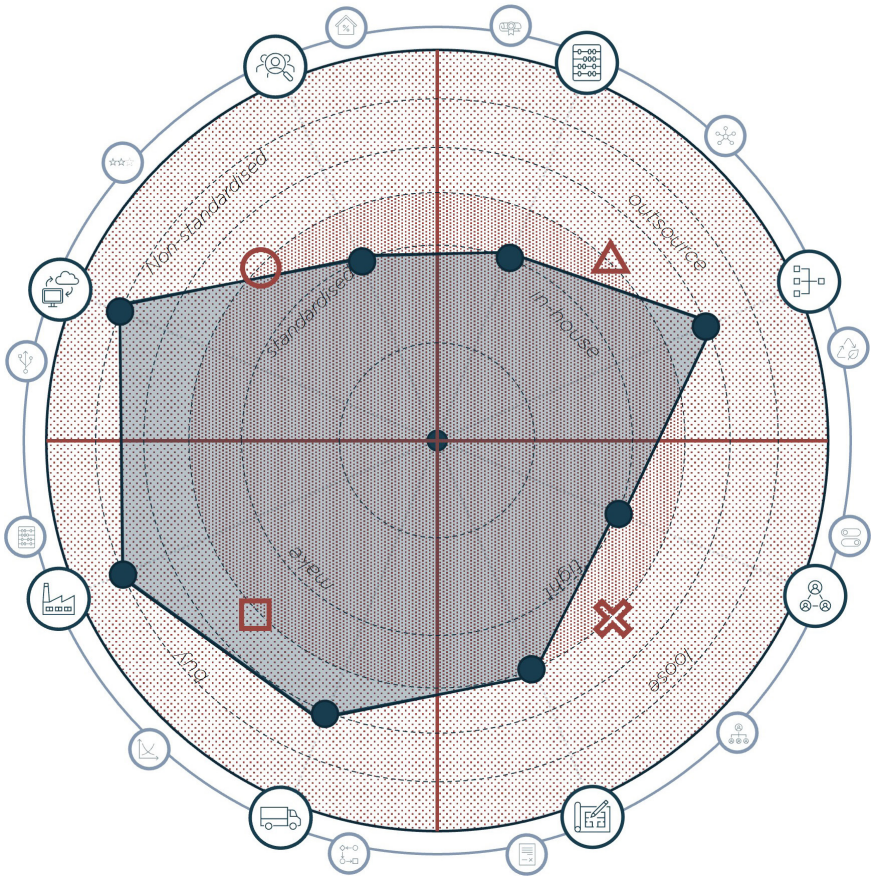


Figure 21

Case B product platform integration diagram (Source: author)

4.2 Cross-case Analysis

The cross-case analysis compares findings from multiple cases and assesses similarities and differences concerning the main themes delivered in the case studies. This section presents the findings from the cross-case study according to the four elements of product platforms (namely knowledge, components, relationships, processes), motivations, enablers, and barriers.

4.2.1 Product Platform Elements

The two case studies face different challenges in developing product platforms. It is reflected in their strategies at the organisational level and the production and product level. However, there are some areas of commonality between the two. It reflects supplier networks and their integration into the product platform development. The different elements of the product platforms are used for a comprehensive comparison of the case studies. Together with motivations and barriers, they form the basis for formulating general integration strategies.

Component element

The approach to components differs considerably in both cases. While Case A has moved towards sophisticated 3D module production throughout its existence, Case B takes a more flexible approach with 2D components. These different approaches also affect where the components are manufactured, how they are transported to a site, and how long it takes to assemble them on-site. It primarily influences the suppliers and production methods and, as the case studies show, also limits the choice of participants on the platform.

Case A's more complex approach leads to more significant production requirements in the factory. The 3D modules for the multifamily houses are produced in a factory belonging to the platform owner, while an external supplier supplies the smaller houses, but with the vision that these components can also be produced under one roof one day. However, this is mainly hampered by capacity and, to a large extent, the know-how of the production processes.

The complexity of this production process leads to several conclusions. Firstly, the variability of the components is minimal. Modules are finished products stacked in a predetermined order, and interchangeability is severely limited. It leads to positive effects such as streamlined production. On the other hand, it also leads to rather adverse effects, such as uniformity and minor appearance variation, which can negatively impact external partners, such as municipalities, when competing with another developer for a particular land.

Secondly, this method requires greater precision and quality control of production. The higher demands and, at the same time, more advanced production methods reduce the number of potential partners participating in developing the product platform. Technical solutions thus influence the decision whether or not to integrate a given supplier more closely. Thirdly, it affects the choice of the logistics provider. The transport of finished modules does not allow much flexibility and thus reduces the options for choosing this supplier. Although the platform owner with external suppliers addresses this, there is also a tendency to maintain close relationships.

Case B's approach is different concerning the components, with two main reasons influencing it. The first is the relative newness of the whole product platform. It leads to a certain lack of know-how from a manufacturing perspective, which is primarily addressed by external suppliers' participation in component development. Furthermore, the more significant variability of the resulting products also has an impact. In order to deliver different products to the top that are more in line with market and location requirements, there is a need to allow for component variability. It leads in particular to the development of standardised interfaces complemented by a set of core components. A significantly more considerable number can deliver peripheral components of external suppliers that may vary from project to project.

Although the product platform comprises several critical suppliers involved in developing the technical solution, off-site component manufacturing is not limited to them. This approach leads to several factors. Firstly, it enables a reduction of some costs for the platform owner. Building a factory, setting up processes and creating an entire supply chain is both financially and time-consuming. This approach is also associated with many risks, which the platform owner tries to eliminate by opening the platform to more participants.

Secondly, this strategy increases the number of manufacturers available in the market. As a result, the risk associated with a lack of production capacity or time can be reduced. Similarly, the logistics provided by the individual suppliers for the product platform are also addressed. The technical design of the 2D components allows for more accessible transportation due to the smaller size of the individual parts. On the other hand, this solution leads to greater demands on assembling the components at the construction site.

The cross-case analysis of the component element shows the diverse strategies of both cases. While Case A tend to integrate and thus make as much as possible, Case B relies on buying from suppliers of the product platform. However, the analysis shows that those strategic options are influenced by other factors such as know-how, market availability or investment costs.

Relationship element

While the component element was different for the two product platforms, the relationship approach is similar in many ways. One of the critical aspects of industrialised house-building is the longevity of relationships. In this respect, the integration strategy of both cases seeks to create the closest possible relationships with their key suppliers. However, the owners differ in their approach to control and planning. The difference between the Swedish approach, which is firmly integrated towards the platform owner, and the Czech one, which entails more involvement of other suppliers, becomes apparent.

Although the approach of the two product platforms seems to be similar in terms of long-term relationships, some aspects differ. It is primarily influenced by the length of the market presence, thus the experience and established position of the platform owner. The interviews revealed that novelty is a deterrent for some suppliers in Case B as they

do not see such potential for future activities. Conversely, in Case A, longevity in the market is an opportunity to be an experienced partner with new suppliers.

The two cases also differ in the way relationships are established. Case A usually seeks partners with whom it can establish a long-term contractual relationship. Although according to the interviews, these relationships are very balanced, the partners' position is subordinate within the platform. Case A platform owner maintains close relationships with suppliers, mainly in control and planning aspects. For example, production capacities are closely coordinated with manufacturers and designers, whom they repeatedly try to approach when developing or updating the product.

On the other hand, Case B is characterised by a more relaxed strategy towards suppliers. Their relationships are based primarily on mutual motivation to cooperate. At the same time, the platform owner primarily coordinates the participants and sets the impulses in the direction of development. It impacts the whole integrated decision-making, wherein in Case B, the suppliers are on a level playing field.

Both cases also encounter legislative limits, but each in a different way. While Case A is more proactive in its relationship with municipalities, which is linked, for example, to municipal competition for building on selected land, Case B faces constraints from municipalities and their lesser understanding of the industrialised way of building. The interviews show a need to include governmental authorities in the supplier network. Their input is vital to the product development and its placement on the site. Closer integration of municipalities into product platforms is an area of primary focus for Case A.

Process element

The approach to standardising processes differs in some aspects across the case studies. Notably, the Case A initiative aims to build a unified digital environment that will capture knowledge and experience within the company and across the platform. In contrast, Case B chooses a path of very low standardization beyond developing a standardized component interface. However, both case studies commonly focus on the customer and their identification across the platform.

In both cases, platform owner representatives mentioned that customer focus is crucial for the platform owners in the interviews. According to them, it is the part that influences to a large extent the development of the platform, products and relationships. The interviews also revealed that other platform partners share this sentiment. On the other hand, it was also mentioned that although this aspect is essential, it does not mean for Case B, something that limits the participation of platform partners. Similarly, one of the interviewees mentioned that it is essential for Case A but may influence the discussions with other stakeholders too much.

In connection with customer focus, it was mentioned several times in interviews that customer perception of the product can play a role in adapting specific processes. Industrialised house-building is a construction method that tends to limit customisation. Even though it does not mean it is terrible, production issues might lead to a damaged reputation. It is primarily a threat to suppliers of the Case B product platform since more participate in delivering one final product. Additionally, the built position influences the creation and willingness to adapt some standards by external partners and thus participation in the product platform.

The case studies differ entirely in their approach to digital technologies. Case A platform owner aims for maximum integration through the digital environment. Its approach to adopting a BIM solution that includes digital models and a single place to share documents, operational issues, and feedback should unify the software used by each vendor across the platform and markets. This integration is not a short-term

goal; however, it is an issue for the medium term when coupled with long-term vendor relationships. The result should then be a standardised product platform environment in digital form.

In contrast, Case B is heading in the opposite direction, although some interviewees mentioned the possibility of greater standardisation in the long term. Suppliers currently utilise various software related to their profession with low direct compatibility with others. However, it emerged from the interviews that standardisation of the product platform digital environment is not presently a consideration. Moreover, interviewees believed it would not significantly impact product development and production.

Knowledge element

The knowledge element is essential for product platforms. Both are taking a more integrative approach, which includes more in-house activities. However, they diverge on more integrated aspects concerning all product platform partners. At the same time, however, the closed nature of the Case A platform can be seen. While the experience replication and KPIs aspects of Case B are primarily outsourced, Case A benefits from a long-standing presence in the market.

Therefore, long-term development and more experience allow the platform owner to leverage more of its knowledge. Thus, the platform owner can rely on internal resources when communicating with external partners. It is also related to the greater standardization of manuals and the like for platform participants. In contrast, the Case B platform owner lacks this long-term knowledge, and its knowledge base consists of experience from traditional construction. Therefore, experience and some KPIs are outsourced to other product platform partners. The product platform also benefits from greater openness, allowing more participants to share knowledge in product development.

The same is valid for developing the technical solution, where the knowledge element is essential. However, in this case, the Case B platform owner chooses an integrative strategy, whereby all the know-how and technical solutions developed remain its property. The aim here is to keep this knowledge within the platform in case new suppliers participate. Case A suppliers, mainly component manufacturers, keep their manufacturing know-how but share it with the platform owner in case of new product development.

One of the motivations and barriers to participation in the platform is the environmental benefits of this delivery method. It significantly influences the development of the technical solution and thus its complexity. In this case, suppliers who have knowledge of the methods enter the product platform and share it within the platform. Both case studies deal similarly with this aspect and try integrating as much knowledge in this area as possible. Criticism of business models was mentioned during the interviews. The development of product platforms takes place at the levels of product development and production, making them not very different from traditional delivery models.

One interviewee mentioned the possibility of using internal resources for longer-term control of components and building user experience. Additionally, industrialised house-building requires a different approach to knowledge capturing about user experience and building operation. Case A employs more digital technologies to harvest those precious data. Moreover, it relates to experience from the on-site assembly, which Case B lacks. Integrating more experience in the future with a more diverse group of suppliers might be a challenge.

4.2.2 Motivations and Enablers

Integrating within a product platform needs to have specific motivations or intentions. It also influences the participants who join the platform through the enablers. Different motivations influence the two case studies, and so are the suppliers' motivations. For Case A, the most prominent motivation at the moment, according to the interviews, is to capture as much knowledge as possible using the digital platform, which will lead to more significant software standardisation. For Case B, the primary motivation is technical solution development and acquiring technical knowledge.

Additionally, there are eight enablers identified by the theoretical background. Those drivers are associated with product platform elements and refer to certain aspects. Strategic enablers are elements that must be in place and whose implementation to some degree must be competent for a strategy to be successful. Enablers tend to be skills and capabilities rather than strategies. It can be considered a required core area. They work with motivations as a means of fulfilling a set integration strategy. Exploring IHB enablers is essential to describe vital aspects of the product platform. Those provide different fields of participation for various suppliers. IHB enablers cover eight general topics and provide more insights into the platform aspects.

In Case A's interviews, the importance of a digital platform for product development and overall business was mentioned several times. This direction is essential to Case A concerning greater transparency and sharing of development and operational information. Typically, one person is responsible for a specific area which also takes away a significant amount of knowledge that is important to the platform's operation when they leave the company. A digital environment to store most of this knowledge will enable, for example, informed communication with external partners or better data-driven planning.

The platform needs to focus on some of the enablers identified in the desk study to achieve such goals. For Case A, the emphasis on digital technology was frequently mentioned in interviews, not only in building a digital platform. As an off-site manufacturer, one of the key elements for Case A, the platform owner, is to increase capacity through automation and robotization of production. Thus, the motivation in these areas is integration into the product platform and closer to the owner's platform.

Case B focuses on building know-how. Both the platform owner's representatives and the suppliers mentioned that the primary motivation for integration into the product platform is the extension of knowledge. The secondary is the possibility of trying new technical solutions that can be capitalised on in as many follow-up projects as possible. Motivation in the knowledge domain is also related to the enablers of the knowledge element. Technical system development is a driver of deeper integration, where individual partners share their experience and knowledge to develop a new solution that best fulfils their product platform goal.

The motivation within product platforms is to establish long-term relationships. It can be different for each supplier. However, the aim is to create an environment on the platform where individual suppliers exchange information, act transparently and ensure the quality of the platform development. Related to this is creating an environment that ensures a larger volume of components or product sales. Long-term relationships also reduce transaction costs, which can be seen, for example, in the incentive to retain selected designers over the long term.

In summary, there are many motivations for integration into a product platform. Product platform owners should focus on the enablers that will help them meet their chosen objectives and use the means to ensure that they do so. Additionally, as suppliers have their motivations, it is necessary to align those with the directions of the product platform.

4.2.3 Barriers

Twelve general barriers were identified in the theoretical study. These were analysed along with the motivations and enablers of the respondents to obtain specific strategies. The defined barriers or challenges are associated with specific elements of the product platforms and are related to aspects of IHB. For example, the enabler Customer Focus is influenced by barriers to customer adoption and market position.

Several critical barriers emerged from the interviews that affect integration strategies. Consistently, interviewees mentioned legislative barriers. These included primarily municipal participation and local regulation. According to Case A, the municipality plays a crucial role in acquiring suitable land for development. Swedish municipalities launch developer competitions to develop a given plot of land with strict conditions. This influences, for example, the technical design of the product, which can be extended by several floors or, for example, to allow more variability in the facade design. The municipality's role thus influences integration within the element of relationships and encourages closer relationships.

In contrast, Case B addresses the strict regulatory constraints that affect the structural design of the products. Technical constraints based on strict building standards lead to a less integrated solution that can be seen in Case A. Furthermore, it leads to a more open platform, involving multiple suppliers from different construction areas and experts in a given technical construction solution. Additionally, it encourages looser relationships in the supplier network. In summary, this barrier also affects other, e.g., technical solutions or actor management barriers and their impact on integration strategies.

The cross-case analysis showed that different product platforms are affected differently by barriers. Their influence is more likely to determine the chosen strategy and the formation of the supplier network. However, barriers are not necessarily just obstacles. For example, the adaptation of sustainability appears as a possible motivation that, while influencing the technical solution and thus the element of knowledge and relationships, can also attract more participants to the product platform. The interviews revealed that this is an important area for all platform participants. However, it is still a new area, and its adaptation requires know-how development.

It can be concluded that barriers help define integration strategies. The interviews identified some key barriers that affect the creation of a supplier network and their integration into a product platform from the owner's perspective. While some are not so significant, their influence cannot be neglected, as identified from the theoretical study. On the other hand, integration strategies must be considered at all three levels (organisational, production and product). At the same time, it is necessary to identify those that are threats and those that are opportunities for the development of the product platform.

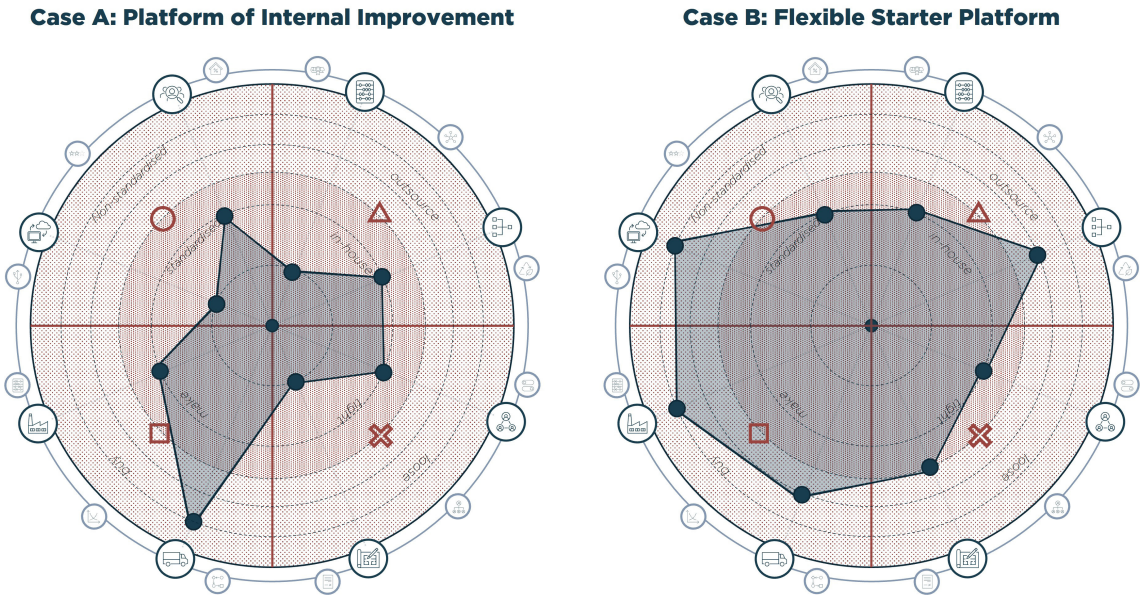


Figure 22

Cross-case product platform integration strategies (Source: author)

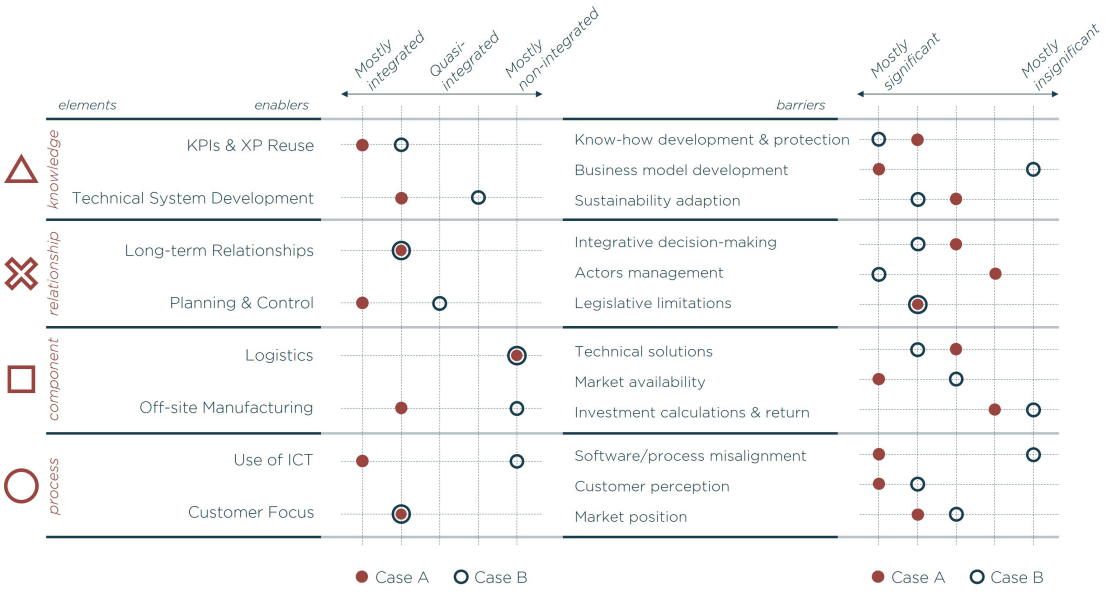


Figure 23

Cross-case element integration strategies (Source: author)

4.3 Findings Conclusion

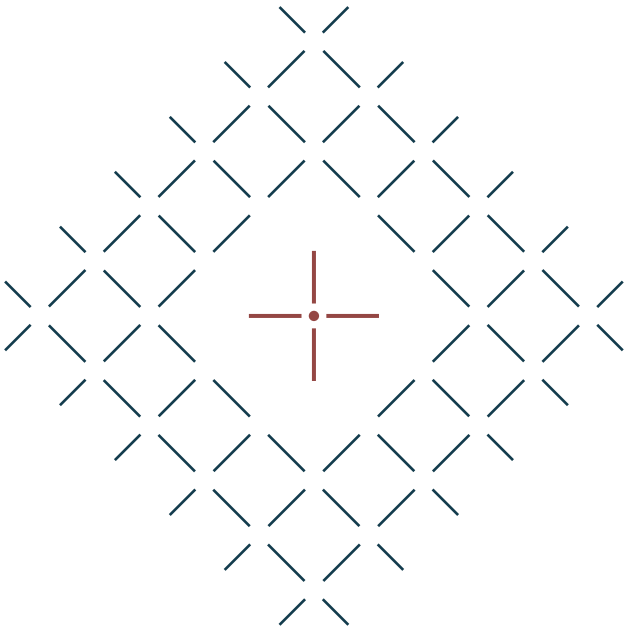
Based on the empirical research, Figure 22 and Figure 23 illustrates the critical findings of the individual and cross-case analysis. The graphical representation of Figure 23 demonstrates the areas of integration between elements and enablers, the approach of platform owners and the identified barriers depending on the case study. On the other hand, Figure 22 compares product platform integration strategies in both cases.

Consequently, it can be seen from Figure 23 that areas of integration can be identified, which is the aim of this study. Although specific strategies were not explicitly mentioned in all interviews, the executive managers acknowledged these approaches. At the same time, areas of deeper collaboration between suppliers and platform owners were identified in the interviews.

Simultaneously, key barriers or challenges to these strategies were revealed. Interviewees highlighted several key areas that impact the formulation of integration strategies. From Figure 23, it can be seen that the barriers are directly related to the area of integration. These findings can be generalised for future strategies based on the diversity of the two case studies.

Concerning the development of product platforms and the idea of industrialised house-building, it should be mentioned that this is still an area with strict regulation and fragmented relationships. Therefore, it could be concluded that this approach to constructing residential buildings still faces obstacles that are common to traditional construction. On the other hand, the empirical study results show that deeper collaboration in the construction industry works and can be beneficial for delivering quality and affordable housing to the market. At the same time, however, regionality and heavy regulation do not allow for faster implementation or more streamlined production processes.

Finally, these case study results confirm the different sources of integration within the product platform. They support the idea that many areas and approaches to integration may lead to supplier network integration. Additionally, it shows that such integration allows for broader collaboration between firms that compete in traditional construction.



– 5 –
DISCUSSION & RECOMMENDATIONS

5 – Discussion & Recommendations

This chapter presents discussion of findings. It is followed by the strategies that emerged from the empirical research in the previous chapter. Each strategy is described in more detail below. This chapter concludes with a Recommendations section that summarises the main features of the strategies and recommendations for their implementation at all strategic levels.

5.1 General Findings Discussion

Some general findings were identified during the study concerning the development of product platforms. The integration scheme presented in Chapter 2 (see Figure 13), adapted from the empirical research findings, shows that many aspects influence the development of platforms in the industrialised house-building industry. However, not all of them significantly influence supplier network integration or shape it.

All three identified levels influence the development of product platforms from the platform owner's perspective. From the top, the organisational strategy determines the allocation of internal resources and works with already existing internal know-how. It mainly reflects the resource-based strategy described by Mintzberg (1987). However, platform thinking moves away from a single company's focus on strategies and instead seeks to enable multiple companies to work together to achieve a competitive advantage (Choudary, 2021), which is supported on the platform element strategic level.

Cross-case analysis revealed that platforms use different prefabrication modules. This finding would not be surprising if Case A used only volumetric and Case B panelised modules. Nevertheless, in the past, Case A used the 2D modules too. In line with research by Popovic et al. (2021), it might suggest two things. First, deeper integration is bound to the prefabrication method. Second, integration is more significant for more mature platforms. A similar evolution can be observed in other industries. For example, Microsoft's gaming platform is gradually integrating some game development studios, and in the automotive industry, car companies are starting to integrate battery or chip manufacturers.

Supply-side orientation

It can be concluded that the construction sector is mainly supply-side oriented. This fundamental distinction separates it from other emerging sectors, such as digital services, which bridge the supply and demand sides. While these projects make customers participants interact with each other. These platforms aim to keep participants from both sides on the platform for as long as possible. Thus, they can promote

the network effect. For example, Uber, which has made its mark on people's subconscious as a ride-sharing provider, is supplementing its offering with additional services such as Uber Eats (Chan, 2020).

The observed case studies seek to create similar network effects but different means. The size or volume of production is what matters in attracting new entrants. It has emerged as a factor for the Case A platform. The guarantee of a specific buy volume or stability of subscription is an attraction for product platform suppliers. When demand is high, the primary concern of platform owners is to attract and retain suppliers. Guaranteed volume is something that traditional construction typically cannot guarantee due to variable design. On the other hand, their pool of users must grow for platforms to thrive. The literature here is complemented by the interviewees' insights, as this is a challenge that platform owners need to consider and what drives them to continue to innovate (see Chan, 2020).

The second approach to attract and retain product platform participants was demonstrated by Case B. The openness and sufficient flexibility of the platform and the product architect allow for the entry of more participants from the supplier side. Although Case B does not represent an eco-system platform, it adopts some elements (see Gawer, 2014). An example is a multi-stakeholder ecosystem, which enables the development of standardised component interfaces.

Another finding is that the customer, who buys the built apartment or house, is essential for product platforms. However, the primary competitors are developers coming from the traditional construction industry. The latter has significantly more flexibility, which they can use to build in various land conditions (i.e., a narrow street gap in the historical city centre) or municipal requirements (i.e., gable roof or brick façade). A similar challenge for platforms is posed by designers, for whom the industrialised way of building is relatively niche and with whom they lack enough experience. It poses a challenge, especially in the future, when there will be a need to ensure greater customisability for the client and adaptation to different local conditions.

Platform elements integration

The main question of this thesis is what to integrate within the product platform. Robertson and Ulrich (1998) defined four elements of product platforms concerning the manufacturing industry. These four platform elements (knowledge, process, relationship, and component) are used in this thesis to define the areas in which supplier network integration occurs. However, these areas were linked to the IHB framework developed by Lessing (2006) for further exploration. Aspects are linked according to how each one interacts with the four elements. This fusion of the two frameworks was used to explore the integration strategies used by platform owners in the IHB.

Of these four elements, each is important for current product platforms. However, it should be stressed that they reflect the situation described in the section above, namely that the primary focus of this platform is the supply side. The elements provide the platform owner an interface to navigate and target their resources more efficiently. These platform elements are essential for strategy formulation at the operational level of strategic management. This strategic level specifies how aspects interact to satisfy the implementation of the strategy at the business level, thus the overall integration of the product platform. The product platform's strategic level is to satisfy the IHB organisational strategy by setting platform boundaries. Moreover, it supports gaining a competitive advantage.

However, some critical findings regarding the elements are presented here. First, the importance of the element of relationships became apparent. This element poses a challenge for platform owners as it is essential for creating a network effect and maintaining long-term relationships. The relationship element represents primarily human resources – the teams of people and individuals involved in the platform's development. Their management, planning and control, and especially interaction, are essential aspects of a product platform's prosperity. However, the integration of this element is complex. As one interviewee noted, integrating the flow of information and setting specific standards is often challenging within one company, let alone across several.

Moreover, the case studies have shown that the closest suppliers, those most integrated into the platform's operation, are selected by the platform owners on a similar basis as in traditional construction. Tendering or a long selection process prevails over the free flow of suppliers as is expected on digital-based platforms such as Amazon or Uber. However, this might not be an issue as interviewees justified this approach with a long-term stable relationship. The thorough selection process might improve supplier relationships in lengthy product development.

Second, the element of knowledge is essential to get the new platform off the ground. Already the market research prior to the independent empirical study showed that there are many ways to develop a product platform. At the same time, there is interest in this way of creating value among new and established companies. However, the construction industry is a specific sector, and knowledge about technical solutions, business models or how to create the necessary know-how is a challenge for any new platform owner.

Third, Case B showed that the component element is not necessarily an area of deep integration as Case A approaches it. On the contrary, well-set product architecture standards, i.e., creating clear design rules, can present an opportunity for multiple suppliers to participate in off-site manufacturing or further product development. This finding may provide an opportunity for future orientation towards the demand side, which will require more customisation. It may also lead to greater flexibility in the event of less availability in the supplier market.

Finally, the process element is an area that presents a challenge for platform owners. In this respect, it appears that modern platforms that use digital technologies must create a sufficiently integrated digital platform. However, this increases the demand for standardisation of processes to ensure the operation of such an environment. It requires the alignment of software tools, which can be challenging in a fragmented AEC environment where stakeholders are not very familiar with each other.

Supplier networks

In product platforms, supplier networks are found in all four platform elements. However, their integration varies depending on the strategy chosen. At the same time, it depends on which the owner chooses the platform model. If it is an open platform, the supplier network will be different from a closed one. This realization is not significantly new and supports the thesis of Gawer (2014). However, this thesis shows that her concepts of managing (semi-)open platforms also work in the construction sector.

Another finding of this paper confirms several previous studies on platforms (Gawer, 2014; Mosca, Jones, Davies, Whyte, & Glass, 2020). Companies that participate in

product platforms would-be competitors in the traditional construction industry. The case studies have shown that platforms can offer an environment that attracts previously competing companies. It confirms a trend that can be seen, for example, with platforms such as Uber Eats, which provides space for several, for example, pizzerias in the same city. Additionally, product platforms must create an attractive environment for suppliers. However, once this is done and there is a motivation for further growth, it can encourage others to get involved. Suppliers who participate directly attract other subcontractors, creating a well-developed supplier network. The case studies show that this requires good governance from the platform owner. Every type of product platform requires a different governance style. Awareness of these facts influences or facilitates the integration of certain platform aspects.

The theoretical and empirical research results have shown that the integration of supply networks occurs at all three strategic levels. While it is mainly about supplier acquisition at the organisational level, there are more diverse ways of forming relationships with suppliers at the other two levels. Figure 24 shows the product and production levels. Three basic characteristics are associated with each; closed to open for the product level and integrated to non-integrated for the production level.

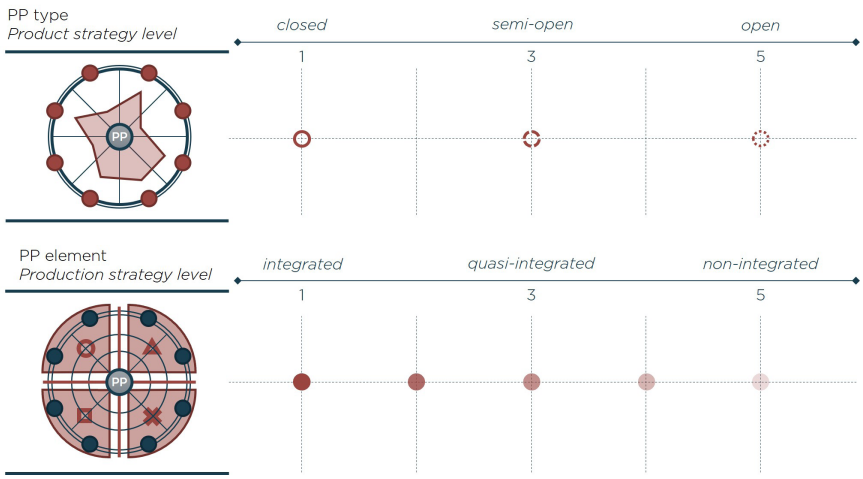


Figure 24

Integration types for product and production level (Source: author)

5.2 Integration Strategies

As presented in the previous chapter, integration strategies appear at all three strategic levels (see Figure 25). The product and production levels are critical to developing the product platform. These can be named Product platform integration strategy and Element integration strategy. There are many combinations of how suppliers integrate each element at the product level. Nevertheless, how these combinations work is not part of the scope of this thesis. However, during the empirical part of the thesis research, possible strategies related to the element were discussed with the executive managers.

This section presents discussed strategies reflecting the four product platform elements. Each strategy is described in a structured way that highlights the most eminent barriers, enablers, and strategic options. Some barriers may be primarily related to a distinct element, yet there may be interconnectivity within the product platform that influences each other. Furthermore, it emphasises the difference in a supplier network that is affected by the proposed strategy. The proposed strategies below utilise obtained theoretical knowledge and insights from empirical research. However, it is worth mentioning that strategy is influenced by many factors that the ones who formulate it must consider. Therefore, those proposed strategies are general.

The thesis reflects that these approaches play a different role in product platform development. The development thus does not only depend on the inclusion of different suppliers in the platform but is influenced by different aspects, drivers and also barriers. The platform is developing in many elements in which the supplier network is integrated. At the same time, it should be noted that this thesis focuses primarily on the supply perspective. To illustrate the specifics of those strategies, the introduced strategic framework (see Figure 13) in Chapter 2 and further elaborated after empirical research is used.

Following, each strategy is explained in further detail following the investigated concepts of this thesis. Figure 26 to Figure 29 summarise strategies with the red accent. The integration of aspects and the significance of barriers can be found below the platform diagram.

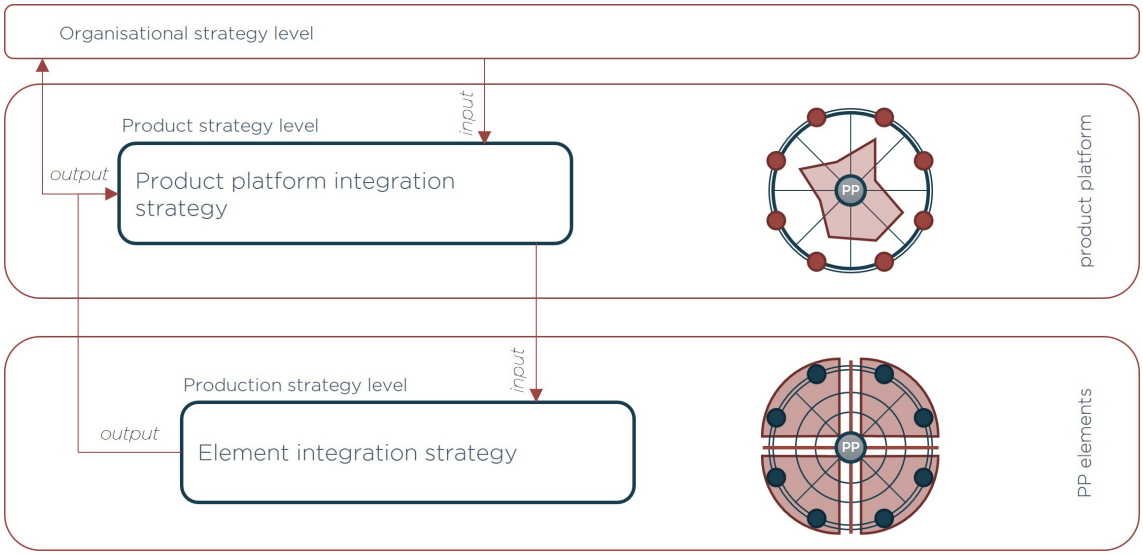


Figure 25

Figure 25: Integration strategic levels (Source: author)

5.2.1 Components Strategy: Component Flexibility

The first strategy presented concerns the component element. This strategy is sensitive from several points of view. Firstly, the technical system solution design primarily influences the supplier network. The objectives of the component strategy are thus very binding and differ significantly in the case of 3D spatial modules or 2D panel solutions. This element is also strongly influenced by market availability in the case of the supplier and by the calculation of investment costs, which significantly impact production volumes or the construction of own production capacities. The component element is strongly influenced by two enablers: off-site manufacturing and logistics.

Strategic goals, motivations, and enablers

The strategic goals of this strategy are to adapt a product to different environments and customer preferences. Additionally, the goal is to optimise the off-site manufacturing processes to enable streamlined production while ensuring high product quality and viable investment and operating costs.

The delivered product must be flexible enough to accommodate various peripheral components by designing standardised interfaces. This approach enables adequate supplier numbers to participate in product development and manufacturing. However, the selected strategy influences the technical solutions that it can utilise. The higher degree of prefabrication limits the latter design flexibility, resulting in more generational updates than a project-to-project variation. On the other hand, the lover prefabrication degree enables lower initial investment costs and provides greater customisability. However, more off-site prefabrication reduces time and thus money spent on-site.

Adaptation of this strategy employs the off-site manufacturing enabler primarily. For obvious reasons, industrialised house-building is related to the prefabrication of building components. Therefore, this approach requires a supplier or own capacities to produce parts off-site. Nevertheless, having such capacities is demanding and often results in buying from suppliers. Next, the logistics of such a product must be considered. Thus, the integration strategy should reflect the internal capabilities of the supplier network and adjust the product accordingly.

To summarise, the motivation for developing more flexible components is to reduce investment costs related to adapting or building a factory. This approach creates more opportunities for external suppliers to participate in the product platform, which increases product variability while preventing expenses related to product adjustments. This integrational strategic goal is especially essential to platform owners who are not required to have their manufacturing capacities.

Barriers

There are several barriers to adopting this integration strategy. The technical solution is a significant determinant of the final product and influences the chosen strategy, especially at the product and production level. Furthermore, a market availability barrier influences the number of available suppliers capable of delivering set components in time and quality. Investment calculation and return is a less significant but essential barrier, leading to the misallocation of priorities and development spending. Other component element barriers are software/process misalignment or know-how development & protection. Those might limit supplier participation on the product platform.

1. Technical solution: The product design must adjust to this strategy. Developing flexible components requires a standardised interface that enables various suppliers to connect with their core assets and peripheral components.

2. Market availability: Manufacturing capacities are a limiting factor that influences product variability. It is also related to the

distance of the factory from a site. It might lead to acquiring the own production facility by the platform owner.

3. Investment calculations & return: Allocating financial resources based on traditional project thinking can neglect the main advantages of industrialised construction, which creates an economy of scale through the repeatability of standardised components.

4. Software/process misalignment: Incompatibility of shared documents or digital files might limit suppliers from platform participation or increase transactional costs. It is primarily due to happen in products using more material solutions.

5. Know-how development & protection: during the production process, the know-how must be shared. More robust protection policies usually lead to tighter relationships but limit the number of suppliers.

Supplier network

In the flexible component strategy, a supplier network becomes broader. The opportunity to participate in the product platform can attract more suppliers. According to Gawer (2014), the supplier network can be described as an ecosystem (or, in semi-open platforms, a supply-chain form). This form is desirable to ensure more significant product variability. However, it requires open interfaces – their specifications are shared with suppliers.

In the ecosystem supplier network, the relationships are based on both-sided benefits. The open platform provides suppliers space to develop their business. At the same time, semi-open platforms usually create networks based on contractual relationships. In summary, suppliers are mostly non-integrated into the platform.

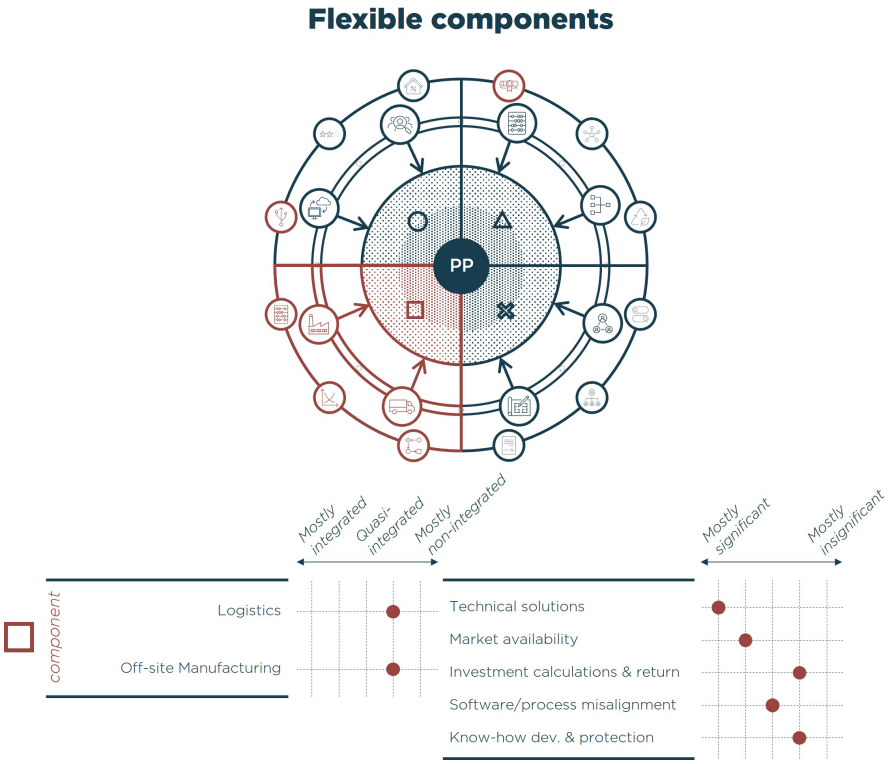


Figure 26

Component flexibility integration strategy (Source: author)

5.2.2 Relationships Strategy: Integration of Suppliers

The second strategy presented in this thesis is related to the relationship element of the product platform. This strategy involves long-term relationships that are built across the supplier network. Relationships can be built by acquisition, contractually or as an ecosystem. Therefore, it depends on the product platform type and the governance style of the platform owner. The integration of stakeholders is mainly related to the closed or semi-open platform as they tend to develop tighter and long-term relationships.

Strategic goals, motivations, and enablers

The strategic goal is to develop a tight relationship with critical suppliers to secure access to skilled workers and utilise their experience with the product. Additionally, tight relationships should secure integrative decision-making and thus greater innovativeness of the product platform.

There are several motivations for integrating stakeholders into the product platform. First, the motivation is to reuse suppliers' experience in product development. Long-term participation in the platform enables one to reflect on processes and streamline the development. Next is to create a stronger market position by making suppliers prefer a platform that is already integrated.

Adaptation of this strategy engages two main enablers. The first one is long-term relationships. The thesis research showed that tighter relationships are built in the long-term run. This approach allows platform owners to build stronger bonds and is also preferred by suppliers who can adjust their capacities better. The second driver is planning & control. As the suppliers are more integrated into the platform, they should be involved in decision-making on certain aspects. With this, the role of the platform owner also changes, acting as a manager in the case of closed platforms, whereas in more open platforms, they act more as a leader or mediator.

To summarise this integration strategy. It serves more as a supportive element to the product platform because it interlinks with other elements such as components or knowledge. This integrational strategic goal is especially essential to platform owners who are willing to control the product platform stakeholders, and it might lead to vertical integration.

Barriers

Supplier management and suppliers' participation in decision-making are the main barriers related to the relationship element. Additionally, the thesis research showed the importance of integrating other stakeholders, such as municipalities, into the product platform. Legislative limitations influence the formation of suppliers, especially related to component suppliers. Additionally, other relationship element barriers are market availability and business model development. Those might limit supplier participation on the product platform.

1. Integrative decision-making: Greater supplier participation in platform development is essential for a close relationship strategy. However, this requires the participation of both parties and, above all, an adjustment of management by the platform owner.

2. Actors management: The platform owner should adjust their approach to product and platform development actors. Tight relationships involve active and transparent communication and sharing of goals.

3. Legislative limitations: Legal requirements affect how the platform will be formed and operate. However, this is linked to technical solutions that involve multiple suppliers. Demands from governmental bodies might lead to design changes. Therefore,

it is advised to maintain tight relationships with those actors too.

4. Market availability: Looser relationships can lead to the loss of key suppliers at times of increased demand. By fostering tight relationships and, for example, coordinating capacity planning, optimal use of production resources can be achieved.

5. Business model development: This barrier is linked to the product and organisational strategy of the platform owner and might lead to vertical integration.

Supplier network

The supplier networks are formed in a closed structure in the integrated supplier strategy. This approach can lead to several tiers of suppliers, with the most essential having a close (integrated) relationship with the platform owner. Further, this group of suppliers is involved in decision-making within the platform or actively involved in product development. In this strategy, the number of close suppliers is relatively small, which is common in closed or semi-open platforms.

The supplier network with tight relationships often manifests by sharing specific capabilities, workforce, or know-how. By bringing suppliers closer together, the development encourages inter-company cooperation. It can lead to teams of workers from multiple companies working together on specific tasks. Furthermore, the platform owner primarily establishes contractual relationships based on long-term cooperation.

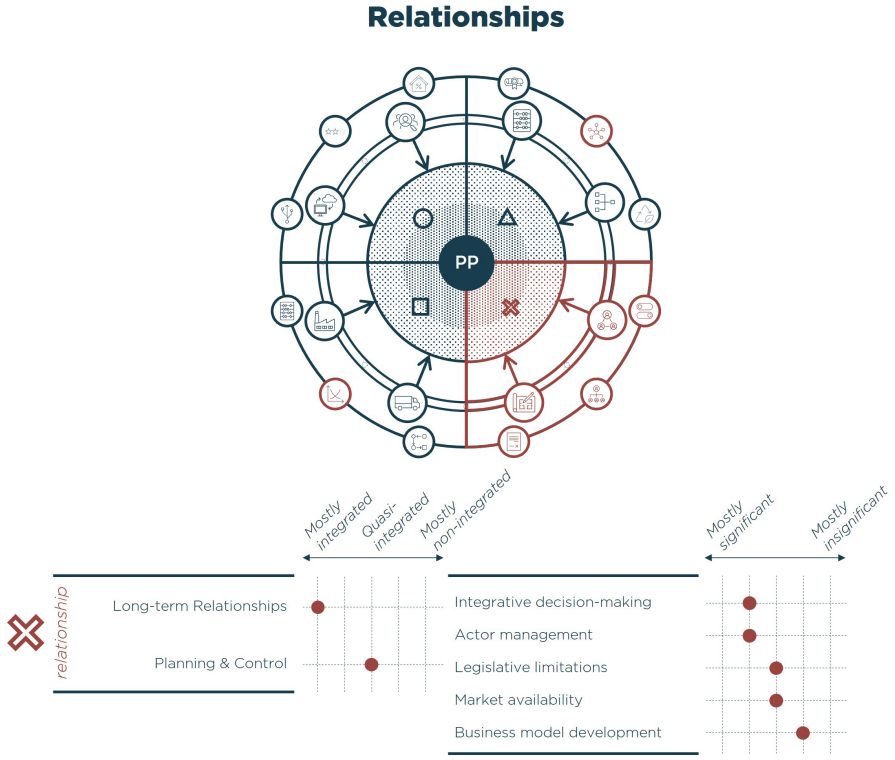


Figure 27

Integration of suppliers strategy
(Source: author)

5.2.3 Processes Strategy: Digitisation of Platform Processes

The third element strategy focuses on standardising platform processes via digitalisation. This approach adopts a significant integration of digital technologies across the product platform involving the supplier network. The main objective of this strategy is to develop a digital platform that would unify various aspects of the platform. However, it requires fully standardising the use of ICT enabler and dealing with several barriers such as software/process misalignment, technical solutions, or know-how development & protection.

Strategic goals, motivations, and enablers

The strategic goal of building a digital platform is to standardise the digital processes of the product platform. In addition, the goal is to retain as much knowledge about the platform and clarify the responsibilities or other tasks of suppliers within the product life cycle. This approach does not concern only digital components in the BIM environment but other processes such as filing issues from production or reflecting the customer feedback.

The motivation for utilising this integration strategy is to build a shared knowledge that stays in the product platform (or to the platform owner). It should prevent the loss of knowledge or important contacts if a crucial employee or supplier leaves the platform. It is also a move towards a more standardised way of working national boundaries do not constrain that. It can serve international platforms, which can thus better share knowledge from development and production.

The critical enabler of this strategy is the use of ICT. Adopting advanced digital technologies such as BIM tools and shared cloud-based document storage is essential to building a digital platform. However, this requires the standardisation of digital tools across the product platforms. It involves a commitment by both suppliers and platform owners who must use specific software solutions and follow certain standards in digital files. This requirement represents a limitation to some suppliers because the compatibility between software must be ensured.

In summary, the motivation to build a digital platform is to have a standardised environment for knowledge sharing, collect feedback from various product platform aspects, and store digital components. This approach requires adapting standardised processes via digital tools, such as BIM or a shared document library. Additionally, the goal is to retain as much knowledge of the product platform.

Barriers

A standardised digital platform must overcome several barriers. Those are primarily related to software and process misalignment between suppliers and platform standards. Additionally, the technical solutions might limit the adaptation of a full-scale digital platform due to its complexity. The know-how protection might be a barrier in building a standardised digital platform, and some suppliers would avoid adopting it to their workflow.

1. Software/process misalignment: Currently, the AEC industry utilises different software tools that lack compatibility. It is a significant barrier for BIM solutions. Additionally, switching to new software can be difficult for financial and knowledge reasons.

2. Technical solutions: The product design and thus supplier selection might limit this strategy. Some specialised suppliers, i.e., the woodworking and concrete industries, use different standards for their digital environment, and their compatibility is not entirely achievable.

3. Know-how development & protection: Some suppliers have unique solutions. Sharing them on a common digital platform may not be desirable.

Supplier network

In the case of a standardised digital platform strategy, the supplier network might be broad or closed depending on introduced standards. Ecosystem (industry-wide) platforms have more relaxed standards, while closed platforms require relatively unified solutions. Therefore, a standardised environment poses a challenge for many suppliers from different sectors and may lead to non-participation in the platform. However, digital platforms are no stranger to other industries, and their adaptation can simplify and streamline the product platform operations.

Supplier networks are formed closer to the platform, and often only the critical suppliers must standardise on a full scale. However, a product platform size puts more pressure on lower-level suppliers to mimic specific standards. In all platform forms, the platform owner is the leader who sets those standards after a discussion with suppliers. Suppliers appear to be integrated or quasi-integrated.

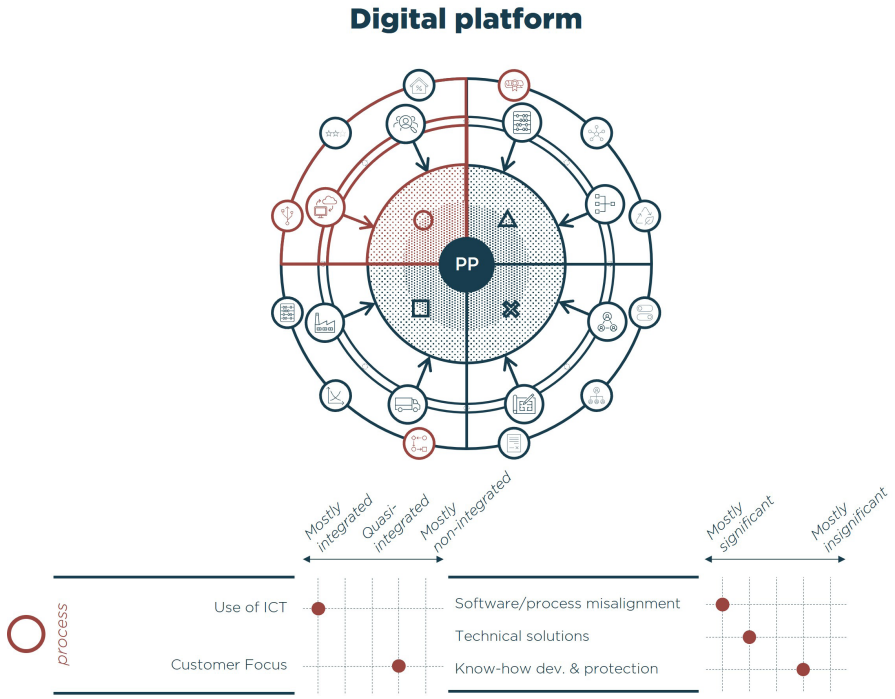


Figure 28

Digital platform process integration strategy (Source: author)

5.2.4 Knowledge Strategy: Knowledge Governance

Lastly, the fourth integration strategy presented concerns the knowledge element. This approach involves two enablers: technical system development, KPIs, and experience reuse. This element may pose a challenge, especially for new platform owners. To acquire the required knowledge, owners can choose from two strategic options; firstly, to develop it in-house, or secondly, to opt for outsourcing. However, the aim should be to ensure that the know-how remains on the platform. The integration strategy of knowledge management aims at integrating aspects essential for the functioning of the platform.

Strategic goals, motivations, and enablers

The strategic goal is to create a common platform of knowledge. With this goal, it will facilitate suppliers in future product development. However, this does not concern only production but also other activities such as land acquisition or sales. Furthermore, the strategic goal is to capture the product lifecycle experience that can be reused to improve a product.

There are a couple of motivations for supplier network integration. With more suppliers participating in the product platform, the knowledge about specific product parts might get lost with suppliers leaving the platform. It is mainly related to semi-open platforms, which rely on a compact supplier network. Additionally, the motivation is to develop a unique solution for the platform that would differentiate it from the competition.

Platform owners should focus on two enablers to achieve this strategy. The first is KPIs & XP reuse which involves setting platform-wide key performance indicators and reusing the experience from the product lifecycle. The second one involves technical system development. This enabler is particularly critical as it differentiates the product platform from its competition. While the technical knowledge might come from outsourced suppliers, the integration strategy strives to retain it on the platform.

The knowledge governance integration strategy creates an environment that keeps the developed knowledge on the platform. This approach gives an advantage to new platform owners to quickly develop technical systems and learn from data from product lifespan.

Barriers

A couple of barriers emerge to this integration strategy. The first one is the know-how development & protection. For obvious reasons, some suppliers want to protect their distinctive solutions. Next is business model development which influences the approach to technical system development and the supplier network structure in general. It is closely related to the relationship and component element of the product platform. Another barrier related to this strategy is integrative decision-making which might influence the overall governance of advanced knowledge.

1. Know-how development & protection: It might take much time to develop a unique system that would deliver a desirable product. Closed platforms integrate such knowledge with contractual agreements, but for semi- and open platforms, this might be a more significant challenge.

2. Business model development: This barrier represents a far more significant challenge. It involves defining, for example, the target group or developing a product. Therefore, it impacts the supplier network formation, which would participate in knowledge integration to the platform.

3. Integrative decision-making: Suppliers who participate in platform development are usually well integrated into the platform, often involving particular governance involvement.

Supplier network

The supplier network in this strategy might vary significantly. The platform owner mainly influences the selected governance style. However, in the case of an open platform, knowledge management becomes a collaborative ecosystem. In such a case, knowledge integration resembles mainly technology platforms, where the owners provide a repository of necessary data that is further shared with the whole ecosystem for better development. In this case, suppliers are mostly quasi-integrated.

For more closed platforms, the network is primarily formed through contractual relationships. These subsequently determine how data is shared within the platform and its owner or how newly created know-how is handled. In this case, the supplier network is formed based on the expertise needed to be added at any given time. For certain types of platforms, mainly closed, so-called firm-based platforms, and in the case of a fundamental type of activity, there may be an acquisition by the platform owner. This approach leads to integrated suppliers.

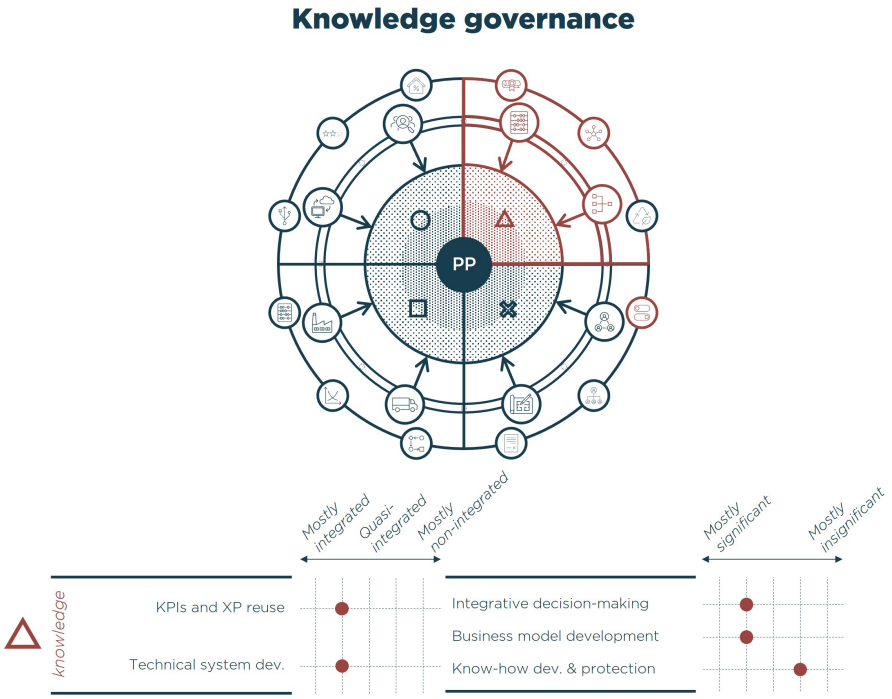


Figure 29

Knowledge governance integration strategy (Source: author)

5.3 Recommendations

Based on the general findings and the integration strategies presented, several recommendations can be made about product platforms in general and integration platforms for practice more precisely. The formulation of strategies is complex, and other aspects that influence strategies should be considered.

General recommendations

1. The governance style must be adjusted to the type of product platform: More open (industry-wide) product platforms require different leadership styles by the platform owner. It might strongly influence the supplier network creation.

2. The network effect is on the demand- and supply-side: Even though the observations were made based on the supply side, the network effect is present on both sides. Therefore, it is recommended to be aware of it and create general networks. Customer focus is a critical enabler in this regard.

Integration strategies recommendation

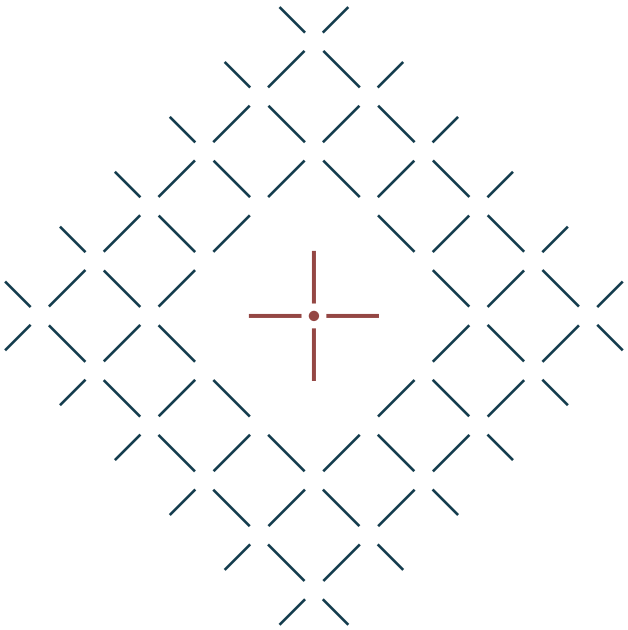
1. Align element and product platform integration strategies with organisational strategic goals: The product platform is a complex organism with many parties involved. Integration strategies must be in line with internal goals and complement internal resources.

2. Integration is a long run: It requires time to achieve the set goals. Integration of any element of the product platform is complex and is influenced by many aspects concerning, for example, scale or a good establishment.

3. Acknowledge the role of different suppliers (actors) in the decision-making process: Suppliers play an essential role in the product platform, and the more open the platform is, the more they might provide insightful opinions. It mainly concerns product development.

4. Municipalities and governmental bodies integration: Those actors might play a significant role in product development. Thus, it is recommended to integrate their insights at the beginning of the development.

5. Select such partners that share the platform owner's values: Closed or semi-open platforms have the power to select participating suppliers to some extent. The integration, for example, of digital processes might be more straightforward if all suppliers share the same attitude.



– 6 –
CONCLUSION

6 – Conclusion

In the following section, the conclusion of this thesis research is presented. Furthermore, the contributions of this thesis are highlighted in a separate subsection. Research evaluation regarding validity and reliability is introduced. The whole section completes with a discussion of the limitations and possible future research concerning the limitations and findings of this thesis.

6.1 Conclusion of the Research

This thesis research aimed to identify supplier network integration strategies for platform owners in product development. Based on theoretical and empirical qualitative analysis of two case studies, it can be concluded that there are two strategic options for four product platform elements complemented by eight strategic enablers. Furthermore, twelve barriers shape the supplier network and thus the overall strategy.

Integration strategies can be found in all three levels of strategic organisational management. Firstly, the organisation level formulates a strategy related to industrialised house-building. Secondly, the product level formulates product platform integration strategies. Additionally, it shapes the overall platform and the supplier network to gain a competitive advantage. Lastly, production level concerns element integration strategy.

Theoretical and empirical research has shown that organisations in industrialised house-building are looking for ways to integrate the supply chain through product platforms, thereby creating supply networks. However, there was a lack of knowledge about which areas of the product platform needed this integration. This issue was investigated and answered by the following research questions:

SQ1: What are the critical aspects of product platform development?

According to the study, there are four elements of product platforms. Each of these fulfils different areas of successful development and creates opportunities for different suppliers to get involved in development. These elements are further complemented by eight strategic enablers that support strategy formation. Therefore, successfully building a product platform depends on the elements of components, processes, knowledge, and relationships. It means, in effect, that teams of people and parts of companies are involved in developing an assembly of a certain number of standardised parts by sharing and codeveloping knowledge with each other.

In addition, on the production strategy level, two strategic options were identified for each element. Thus, the platform owner chooses between two positions, whether to integrate or not to integrate, specifically whether to buy from someone or produce by themselves. However, the integration seems to happen between these two extremes.

A basis for the integrative framework was developed and further complemented by empirical research findings within this question. It divides the platform into four areas following the PP elements. The associated strategic enablers complement these. In addition, some barriers were identified that could also be seen as strategic enablers. An example of this is the relationship element, for which one of the enablers is the creation of long-term relationships. One of the barriers is actor management. It impacts the strategic options of whether to create close or loose relationships with given suppliers.

SQ2: What are the types of supplier network relationships in a product platform development?

Product platforms differ in their openness and the way they are organised. The platform's openness has the most significant impact on the formation of supplier networks. Open platforms encourage the formation of broad networks shared by many suppliers. Furthermore, it appears that with openness, the chain of interested suppliers deepens to subcontractors. At the same time, networks are very loose in this type, and suppliers can freely enter and exit the platform. The empirical study shows that voluntary integration increases in such networks and relationships are thus formed based on different motivations.

In contrast, closed platforms mainly create contractual relationships. The platform owner usually seeks suppliers. Their integration is often based on long-term relationships where there is a greater alignment of, for example, processes and greater standardisation. It can be seen that such networks tend to be made up of a smaller number of suppliers who specialise in a particular aspect of product platform development. As openness increases, the breadth of the network increases. Semi-open networks offer a mix of more closely integrated suppliers who are involved in the development and other suppliers who remain more like external partners. It can be summarised that the types of supplier networks mimic the platform's openness.

MRQ: What are the strategies to integrate supplier networks to product platform development in industrialised house-building?

First, the integration strategies need to be organised by strategic level into organisational, product and production levels. At the former, there is a formulation of direction; here, there is a formulation of direction in the direction of industrialised house-building. At the product level, the product platform integration strategy is created. The production strategy level integrates the platform elements. On this level, it can be said that organisations have two strategic option extremes for the four elements of the platform. Eight strategic enablers influence these. Thus, individual suppliers can be integrated, quasi-integrated, or non-integrated. It follows the openness of the platform on the product level.

According to this study, four general types of strategies for integrating supplier networks in platform elements exist. These strategies have different implications regarding standardisation, joint knowledge creation, component production, and relationship proximity. At the same time, these strategies are influenced by the constraints that shape the resulting strategy. These include:

First, Component Flexibility strives to broaden the variety of components by developing a standardised component interface but keeping the platform open to various off-site manufacturers. Components thus come from external partners. Second, Integration of Suppliers is a relationship element strategy to build tight long-term collaboration and enable suppliers to participate in decision-making. It creates a stronger integrated supplier network. Third, the Digitalisation of Platform Processes deals with standardising processes during a product lifecycle. Suppliers participating align their software and, i.e., reporting processes with a platform owner. Four, Knowledge Governance strives to integrate commonly developed knowledge into the platform. It requires close collaboration of various suppliers.

6.2 Contribution of the Research

This thesis contributes to the design and construction management field and strategic management by providing knowledge about aspects of product platforms in industrialised house-building. The main contribution of this thesis relates to supplier network integration strategies by identifying elements and aspects of the product platform and recognising barriers to those strategies. It proposed the integration strategy framework that illustrates the different elements and their relation to the supplier network in line with research goals.

Furthermore, the thesis research broadens the knowledge about platform owners. Their role fosters several challenges in establishing, developing, and governing product platforms. This explored information is particularly relevant for both current and future platform owners, specifically managers who formulate strategies, as it highlights specific barriers and drivers that have emerged from theoretical and empirical research. It gives a broader idea of focus points for organizations considering implementing a supplier network integration strategy in the foreseeable future.

This thesis contributes to the existing body of knowledge and closes the gap in the literature by studying the formation of supplier networks and elements of product platforms concerning integration strategies from the perspective of platform owners. The thesis provides insights into the product platforms' problematics from the supply-side perception. It creates a more comprehensive view of the topic as the studied topic is relatively novel to strategic management in the construction industry.

The thesis provides valuable theoretical and practical information that can assist managers and higher executive officers in industrialised house-building in taking strategic decisions and leveraging the attributes of supplier network integration to product platforms.

6.3 Evaluation of the Research

The quality of research can be evaluated through four tests. It includes construct validity, internal and external validity, and reliability (Yin, 2009). Internal validity assessment is primarily linked to explanatory and causal studies (Yin, 2009). However, the nature of this thesis is mainly exploratory. Therefore, this test is not considered in the research evaluation.

6.3.1 Construct validity

According to Yin (2009), construct validity refers to correctly identifying operational measures for the concepts under investigation. In this regard, two tactics were used to improve the construct validity of the study; first, the use of multiple sources of evidence to support convergent lines of inquiry. The study is based on cross-checking and triangulation of data collected from three data sources – published documents, platform owner's perspective and suppliers. It enhances the objectivity of the findings regarding the concepts under investigation.

Secondly, the creation of a chain of evidence supports the findings. Therefore, APA-style citations are used throughout the text to show and support the findings. Additionally, the sources of evidence are cited in the text to increase the transparency of the evidence.

6.3.2 External validity

External validity refers to the generalizability of research findings outside the context under study (Yin, 2009). In line with Yin (2009), the following techniques strengthened the study's external validity. First, replication across all case studies was used for the empirical research. Second, preliminary research findings were discussed with managers responsible for strategy formulation. Thirdly, the findings from the empirical research were compared with the theoretical knowledge that was obtained and described in Chapter 2 Theoretical Framework, which allows for the consistency between the research findings and existing theories to be established, leading to either confirmation of previously identified theoretical concepts or contributing to their extension with new concepts that emerged from the study.

6.3.3 Reliability

Reliability of findings refers to how the research can be repeated and produce the same results (Yin, 2009). Yin (2009) states that this requires a record and description of the procedures used in the research. With this in mind, the data collection process was described in Chapter 3 Research Methods. At the same time, additional documents (interview protocols, informed consent, or sample interview coding) can be found in Appendices A-C. Confidential materials, such as audio and video recordings, interview transcripts, and data analysis using ATLAS.ti software, were archived by the researcher for the necessary length of time as outlined in Chapter 3 Research Methods

6.4 Limitations and Future Research

Some limitations mar the findings of this thesis concerning context, location and time. At the same time, the research methodology and scope impact the findings, which need to be considered. These limitations thus create an opportunity for future research. In the following section, one can find recommendations for research focus areas based on the limitations and others based on the findings of this thesis.

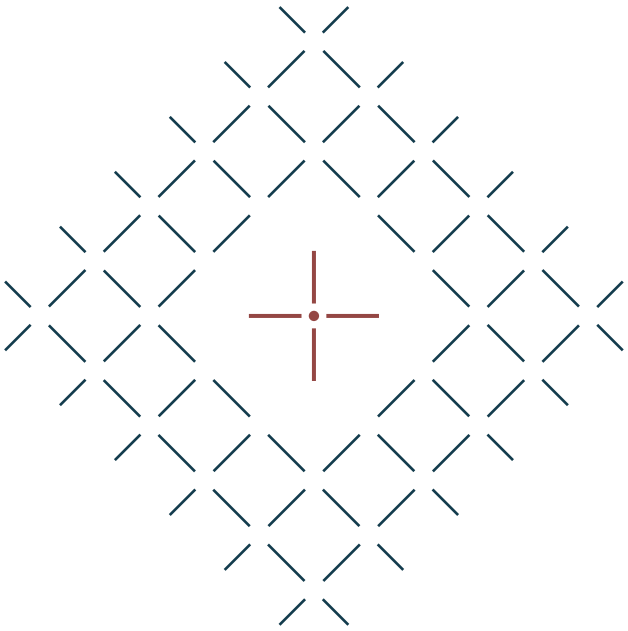
First, the empirical research is based on information collected from companies and individuals in Sweden and the Czech Republic. Therefore, the findings are influenced by the country's social, political, historical, and economic context in question. For example, the market analysis results conducted prior to the empirical research suggest different barriers and potential outcomes of integration strategies. Therefore, further research should focus on more cross-border case studies that account for the difference in context.

Further, product platforms at IHB are a relatively new concept that has only recently gained more academic attention. In this respect, this thesis is only influenced by available academic knowledge and similarly by practitioners' familiarity. Several promising product platform projects that have received much investor attention have recently failed. This phenomenon needs further investigation. It seems clear that product platforms will continue to evolve, so it is worth following the case studies presented here in line with this work. It could yield further insightful findings.

Third, this thesis is based on qualitative research, primarily from the perspective of the platform owner. This approach has provided many significant insights concerning product platform development. However, further research is needed to explore the approach of firstly suppliers and the impact of product platforms on their business. It could show the benefits or pitfalls of suppliers in this specific industry.

Concerning the scope of this thesis, further research should focus on the demand side. This thesis focuses solely on the supply side, and there is little consideration of the demand side. The demand side is an essential and quite integral part of business relationships. The construction industry is more supply-driven rather than demand-driven. That is why IHB product platforms are primarily oriented around supply. It differentiates them from other platforms that are currently emerging and operating.

Finally, this work focused on product platforms with residential construction. However, many new projects that use product platforms for other typologies and directions in construction nowadays are emerging. Thus, the direction of this field is very dynamic, and further research should focus on innovative projects, other construction typologies, or construction digital platforms. At the same time, the importance of individual enablers of IHB, such as advanced ICT use, has not been explored in-depth in this thesis. Their combination related to a different degree of supplier integration should be further explored.



– 7 –
REFLECTION

7 – Reflection

This thesis is a part of the Management in the Built Environment track of the Master programme of Architecture, Urbanism & Building Science (AUBS) at the TU Delft. The field of the thesis research is Design and Construction Management which focuses on managerial aspects of construction. In line with this, the thesis focuses on the emerging trend of industrialised house-building and the strategic management of product platforms. Notably, it provides insights to support the decision-making process in what elements of product platforms integrate concerning supplier networks.

Relevance

The thesis findings are relevant for both academic and practical fields. Concerning the academic relevance, the study fills a knowledge gap by identifying product platforms' elements, aspects, and barriers in industrialised house-building concerning supplier network integration. Furthermore, it adds empirical evidence of Czech and Swedish cases to the literature. It also provides new insights about integration strategies that platform owners can pursue to form and integrate supplier networks in line with their organisational, product and production strategies.

Additionally, the thesis provides practical contributions regarding several things. First, the overview of enablers and barriers related to platform elements is presented. Next, the strategic examples enrich the dynamically evolving field of industrialised house-building. It is essential since this field draws much attraction from investors, and new start-ups and already established companies try to infiltrate this market.

Methodology

Thesis research questions developed during the year significantly. Their absence in the first half of the year could contribute to some difficulties in the theoretical study. They also changed after P2 when the thesis direction became more explicit. Thus, finding the proper questions is an important lesson.

The thesis research used a straightforward but challenging method of case studies. This research method allows for a deeper understanding of the case under study but limits the objectivity of general conclusions for the whole sector. At the same time, the interviews conducted represent only a sample of the knowledge and experience of the case study. To this end, multiple interviews were conducted with interns from different levels of the product platform hierarchy. The semi-open interviews provided valuable and relevant information that enriched the empirical research. However, this method has its pitfalls in the form of a wide range of sweating information that is not very relevant to the research questions of this thesis.

The coding process was relatively straightforward and followed a logic based on the theoretical framework. It allowed for a more detailed analysis of the objects under study. However, several pieces of information emerged during the process that provided unexpected findings. These are unlikely to have emerged if the interviews had been conducted more closed-ended or using questionnaires. On the other hand, for some interviewees, the vagueness of the questions at first contact was more of a barrier. Initially, it led to a refusal to be interviewed. However, when the questions were more specific, they gave an agreeable attitude.

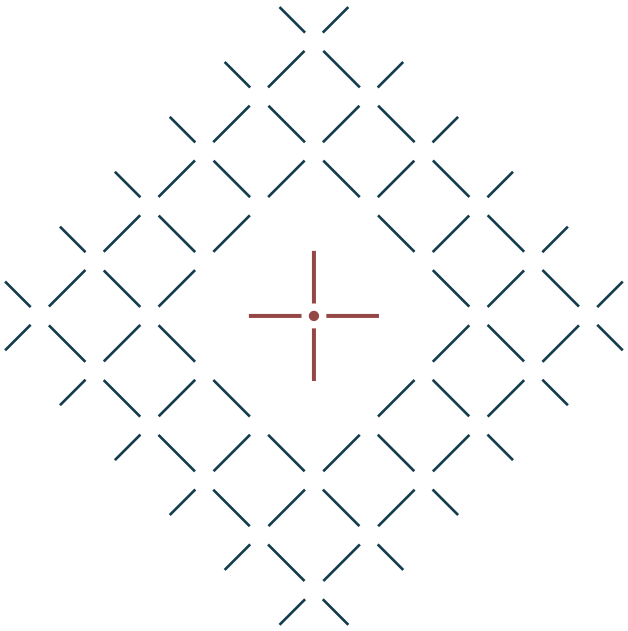
Personal Reflection

The research process was a new adventure with many unexpected steps. It resulted in several difficulties during the P2 period. Despite initial excitement about the topic and a positive impression from the first meeting with the first mentor during the summer, it became increasingly challenging at the beginning of the semester. The opening session brought confusion about what to begin with and how to organise ideas and new insights. After P1, the problem became evident and resulted in reorientation in the research. The research topic moved from implementation to integration and prefabrication to industrialised house-building.

Furthermore, the initial assumption and motivation to conduct case studies in the Czech Republic and Sweden was to explore what was not working in the Czech case. Although some clues confirmed the original assumptions, they were refuted during the empirical research. This finding confirms the diversity of approaches. At the same time, it has shown that the Czech case could be assessed as better in some respects. However, those initial assumptions appeared to be a burden during the process.

The work on the thesis initially seemed very exhausting without a clear goal. It may have been due to distractions from other school and extra-curricular activities and the vagueness of the thesis at that time. In fact, with each completed part, the thesis becomes more comprehensible again. First, one needs to define the topic and the scope clearly; then, it is good to compose the research questions and further specify the research. Without this procedure, it is easy to get lost.

Last but not least, I must mention the indispensable help of my thesis supervisors Paul, Tuuli, and Herman. Unfortunately, one supervisor could not continue during the process, which did not seem to be a significant problem. However, in hindsight, it can be said that multiple perspectives on the topic are beneficial. During P3, Herman became the new second mentor. Paul's help and Tuuli's and Herman's comments were essential to completing the entire thesis process.



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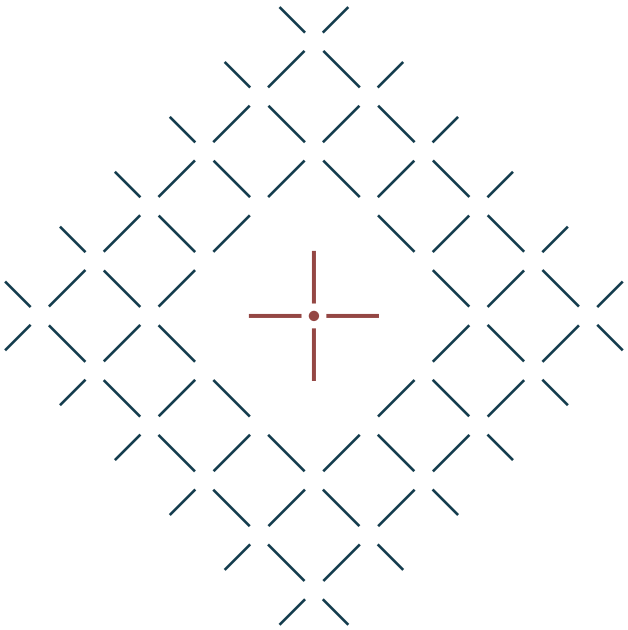

– 9 –
APPENDICES

9 – Appendices

Appendix A: Consent Letter and Form

Interview Consent Letter

Management in the Built Environment
Graduation Lab 2021/2022
Krystof Kratochvil

Dear [Name],

With this letter, I would like to invite you to participate in my graduation research focusing on *supplier network integration strategies in industrialised house-building product platforms*. This study fulfils my master's thesis in the Faculty of Architecture and the Built Environment, Delft University of Technology. This thesis aims to formulate a strategy framework for platform owner companies developing their product platform. The research output will provide guidance to those companies to successfully integrate those networks.

The interview will last approximately 45 to 60 minutes. I would like to ask you for recording permission to be able to transcribe and analyse provided information. The transcript will be coded anonymously. The recording will be deleted as soon as the accuracy of the transcript is confirmed. Simultaneously, you can refuse participation in this research. You can also change your mind in the later stage and withdraw your participation. You are free to omit any questions during the interview.

If you agree to participate, I ask you to sign this consent form on the next page and return it to be scanned. The mutually signed form will be shared between us. I am doing this to ensure that your details and responses are treated confidentially. Your organisation will not be able to read the interview report unless you give your consent. I only produce a general and anonymous report on managers' experiences. If I quote your words, your name will not be used, and I will ensure that it is not clear who may have said it. I will delete your name and contact details when the investigation is complete.

If you have any questions about this study, please do not hesitate to contact me at my email address k.kratochvil@student.tudelft.nl or by calling +420605906363.

Please complete and sign the statement below and send it back scanned if you agree with the participation.

Sincerely,

Krystof Kratochvil

Management in the Built Environment
Graduation Lab 2021/2022
Krystof Kratochvil

TU Delft Delft University of Technology

Interviewee: [Name] Organisation: [Institution Name]

To be filled by the interviewee and interviewer

I declare that I have been clearly informed about the research's nature, method, and purpose.

My questions have been answered satisfactorily.

I understand that the audio and/or visual material (or the editing) and other collected data will be used exclusively for analysis, scientific presentation, and publications.

I reserve the right to terminate my participation in this study at any time without stating reasons.

I have read this form, or the form has been read to me, and I agree to participate in the study.

☐ I would like to receive a thesis results summary at the end of the study. For this reason, I permit to keep my name and address details until the end of the research.

Place and Date: _____

Full name: _____

(full name, in capital letters)

Signature: _____

(participant's signature)

"I have explained the investigation. I declare my readiness to answer any emerging questions about the research."

Signature: _____

(Krystof Kratochvil)

Appendix B: Interview Protocol

Interview protocol

Management in the Built Environment
Graduation Lab 2021/2022
Krystof Kratochvil

TU Delft Delft University of Technology

Interviewee: [Name] Organisation: [Institution Name]

The interview begins with a formal introduction of the thesis study, the interview purpose, and an explanation of the consent. Moreover, permission for interview recording should be granted. Then the concept of informed consent needs to be explained.

After that, questions about the basic background information of the participant and his/her work will be asked. Some examples of the questions can be seen in the text below. The following question set might differ by the role of interviewed manager.

The interview will be transcribed for further analysis and checking. At the same time, the audio recording will be kept during the processing period.

Script

Before we start the interview

Hello, nice to meet you. I am pleased to have you here for our interview. I am a student of the Faculty of Architecture, following the Management in the Built Environment track. I conduct this interview as a part of my master thesis research. The aim is to study the relationships and integration tendencies between product developers and their suppliers and how they integrate supplier networks into their product platform development and production. First of all, let's work out a few formalities. I need your consent for the interview recording. I would record this interview to transcribe the interview and its further analysis. Do you agree?

There are core questions organised into several sections:

General section

- Can you describe what is/was your position in the company?
- What was your role in LIVO/BoKlok product development?
- What is/was your capacity and involvement over time?

Components and the product

- What are the motivations and barriers in component development for your company?
- Can you explain your company's motivation in participating in LIVO/BoKlok product development?
- Which barriers do/did you face during the development and later in production?
- Can you tell more about the modularity of the product?

Relationships and collaboration

- Can you describe the collaboration with other parties in the development and production?

the development team?
- How would you evaluate such collaboration?
- How does the feedback loop work?

Processes

- How would you describe process development and use of ICT?
- How did/do you share information between parties, and is the used software aligned between them?
- How do you align and develop shared processes with others
- Was there any plan to align more of such processes

Knowledge

- Can you describe the know-how sharing and how it influenced the final product?
- How was the current and newly built know-how shared with partners?
- What are the KPI's for your company in LIVO/BoKlok development?
- How all of these influence customer focus and the final product?

Conclusion

We are now coming to the end of the interview. Is there anything else you would like to add? Or have I left anything out of the interview that you want to explain? At the end of the interview, we learned from you that;

(summary)

I am grateful for the information provided. Your personal information in this interview will be anonymous. As the research comes to an end, would you like to be informed about its result? Thank you again very much for the interview and the time you shared.

Appendix C: Research Coding

Illustrative quotes, observation notes, etc. (transribed interviews)	1st order (motivations, means goals)	2nd order (strategic options)	Elements (PP elements)
"We aim to have a long-term agreement with the company and work with them as partners. We do not buy from that factory that product, and then we go to the next factory, so we have to change all the time. We strive for a long-term agreement with one supplier, and then we are working with them not only with product development. We work with them in numerous areas like health and safety, ethics, and green. because when one has a product, it always needs to be maintained and done better." (Interviewee A.2, March 2022)	*Long-term relationships* : it builds stronger ties with suppliers who become partners	*Tight* : contractual agreements build tight relationships	*Relationship* : goals such as building long-term relationships or means like planning and control lead to integration of relationship element.
(...) while she set the agenda for our meetings, which were very intense. But we all sat at the same table and discussed different aspects of [product] development. Various experts from our companies were also invited to the meetings. (Interviewee B.3, March 2022)	*Planning & Control* : the platform owner plans the development, but under his control, suppliers share capacity and participate in product development decisions		
It's a good reason for aligning the way you work with processes and the process support in terms of different software and so on. So in our case we have found our way in how to handle information from external designers and consultants. And we have found our way to have the same programs, CAD, and BIM programs. But also remember a lot of the work is done in-house. And then translating that and adjusting that for the factory production. It's a good example of as I said, uh, how the long-term aspect plays together with digital investments or choices of platforms, digital platforms and so on. (Interviewee A.1, March 2022)	*Use of ICT* : technology plays a vital role in working with data from external partners and in-house processes. Together, they have inpact on design, production and so on.	*Standardised* : partners must align software environment on the long term run. The strategy is to create a common platform that requires a use of a specific software	*Process* : Data collected during the product lifecycle influences all processes within the platform.
Well, it was clear to us from the beginning that the product that we want to deliver to the market like this is not a product that we are used to and know how to deliver (...). That was something that we just don't normally do and we don't have the know-how, the knowledge and the capacity to do that. That's why from the beginning we actually started to count on the fact that we would cooperate with partners here, especially in the area of prefabrication, prefabricated concrete and those wooden buildings. (Interviewee B.1, March 2022)	*KPIs & XP reuse* : experience plays a vital role in knowledge creation. This also has an impact on setting KPIs.	*Outsource* : the lack of knowledge leads to a search for partners who have such knowledge and experience. This can concern technical aspects as well as production capacities.	*Knowledge* : collaboration with external partners results in building shared knowledge that is unique to the platform.
We need to gather input. And the quality of that input, the level of how it's drawn is not critical to us. That is, if Supplier, knows exactly what glue to use there and draw it by hand, or send it to us by email, we incorporate it. And of course we had our own designer to detail the woodwork design. The crucial thing is the know-how. For someone to tell me that it's necessary to use this detail, this screw in there. And it worked without a problem. On the one hand, in the regular meetings and on the other hand, we could exchange documents by e-mail or through the depository so that by telephone or a consultant came to the office. (Interviewee B.6, March 2022)	*Technical system development* : The partners jointly create knowledge about technical systems that are specific to the product and platform under development.		

Appendix C.1 Table: provide illustrative data segments, as well as a coding structure.

Code	Code Groups
• BAR: Business model development	Barriers Knowledge Element
• BAR: Customer Perception	Barriers Process Element
• BAR: Integrative Decision Making	Barriers Relationships Element
• BAR: Investment calculations and return	Barriers Components Element
• BAR: Know-how development and protection	Barriers Knowledge Element
• BAR: Legislative limit	Barriers Relationships Element
• BAR: Market Availability	Barriers Components Element
• BAR: Market Position	Barriers Process Element
• BAR: Soft/process Misalignment	Barriers Process Element
• BAR: Stakeholder management	Barriers Relationships Element
• BAR: Sustainability Adaptation	Barriers Knowledge Element
• BAR: Technical system development	Barriers Components Element
○ Component Element	Platform Elements
• COMPONENTS	Platform Elements
• ENABLER: Off-site Manufacturing	Enablers
• ENABLER: Logistics	Enablers
○ Important	
○ Industrialisation	
○ INTEGRATION	
• External	
• Internal	
• Loose integration	Integration strategies
• Tight integration	Integration strategies
• KNOWLEDGE	Platform Elements
• ENABLER: KPI's and XP reuse	Enablers
• ENABLER: Tech. Systems Development	Enablers
○ Knowledge Element	Platform Elements
○ Location	
• Modularity	
• Motivation	
○ Municipality	
○ Network	
• PERC: negative	
• PERC: positive	
• Platfrom Organisation	
• Process Element	Platform Elements
• PROCESSES	Platform Elements
• ENABLER: Use of ICT	Enablers
• ENABLER: Customer Focus	Enablers
○ Product Management	
○ Relationship Element	Platform Elements
• RELATIONSHIPS	Platform Elements
• ENABLER: Planning & Control	Enablers
• ENABLER: Long-term Relationships	Enablers
○ Transparecny	

Appendix C.2 Table: provide a list of used codes in ATLAS.ti.

Appendix D: Market Analysis Overview

Market Analysis Overview

Management in the Built Environment
Graduation Lab 2021/2022
Krystof Kratochvil

Skanska Reality CZ is one of the largest housing developers in Prague, the Czech Republic, and its focus is on mid-range apartment buildings. This company is a subsidiary of the international construction and development Skanska Group. Their origins are in Sweden. Their brand Livo™ was intended to enter a new affordable housing segment in the ring area around Prague. The development took approximately two years but was halted without physical realisation. The product offering consisted of three types of houses. The technical part of the platform was based on the same prefabricated design principle. The so-called flat-pack principle is that the individual parts are brought in and assembled on site. The prefabricated elements were to be from two suppliers. One was to supply the load-bearing part of the precast concrete elements, and the other supplier was to supply the timber part of the building, including the external façade panels (Skanska Reality CZ, 2021). There is no vertical integration across the value chain.

YIT CZ is another housing developer in Prague, CZ. Their business goes directly against Skanska Reality. However, they differentiate with lower prices. YIT CZ is also part of the international group of YIT with origins in Finland. YIT introduced their prefabricated bathroom pods in Prague's housing project "Suomi". After positive feedback from customers, it will use this technology in other projects. The bathroom cells are manufactured in a specialised factory that optimises their production based on the designers' input. The bathroom cells are developed by an external supplier who provides production standards to the designers. The developer is only the initiator and coordinator (YIT CZ, 2021). The platform, in this case, is limited to a small part of the construction. However, to ensure that each bathroom pod type fits the overall housing project, particular standardisation is required across the whole development process.

BoKlok is a Swedish housing developer and manufacturer. The company is a joint venture of IKEA and construction company Skanska. Their business is also located in Norway, Finland and the United Kingdom, with a target group of families and individuals with lower income. They own a production hall where they manufacture and assemble prefabricated modules (BoKlok, n.d.). These are fully equipped and are only assembled and connected to the necessary infrastructure on-site. BoKlok is a highly integrated company. The team also includes designers. It uses IKEA stores to sell the units. BoKlok wholly covers the product platform development. The platform can be categorised as closed with limited customisation options of the offered products. BoKlok is a frequent object of scientific research. During its history, the company has gone through several levels of prefabrication. With increasing levels, there has been greater integration across the value chain (Lessing & Brege, 2015; McRobert, 2018).

Kärnhem is another Swedish housing developer. A sizeable Norwegian housing corporation acquired the company in 2013. The company is well established in the Swedish market—its product portfolio targets mid-income customers (OBOS, n.d.). Houses are based on timber-frame panelised systems produced in the company's factory. In order to increase control over their production, Kärnhem purchased this factory from that time key supplier. They depend on a network of external partners such as architects, consultants,

tionship. However, each project has its architect to increase flexibility and originality. Also, customers can customise their future homes extensively (Lessing & Brege, 2015). The product platform is based on standardised vital elements and flexible, customisable parts with a standardised interface.

RAD Urban is a vertically integrated company located in California, US. They produce volumetric modules when assembled, creating housing for various target groups. The company has evolved from a general contracting firm with architects and structural engineers in-house. After a factory acquisition, they evolved into a vertically integrated housing developer with a unique product family (RAD Urban, 2018). One of their competitive advantages is the constant evolution of the product family. This rapid evolution is made possible by the short distances between departments within the company and the blurred boundaries between traditional professions. The company constantly prototypes unique variants (Hall, Whyte, & Lessing, 2020). The product platform is broad, enabling adjustments to various types of programme requirements. RAD Urban shut their business at the time of writing this thesis.

Katerra is discontinued construction and development start-up that has attracted significant attention from investors. They intended to revolutionise the built environment with a fully digitalised manufacturing process of CLT panels. The company was considered vertically integrated. Another part of their business was a digital platform providing software for other builders to use Katerra's product platform (Hall, Whyte, & Lessing, 2020). According to the Failory website (n.d.), which specialises in start-ups that have failed, being too wide open in scope and platform thinking was the reason their business stalled (Obando, 2021).

To arrive at a brief extract of the market analysis, only essential companies that most underscore the objectives of this examination have been selected. Many other companies have been investigated in the market research, such as the Dutch company VOS Construction, the American company DPR Construction, and the Swiss company ERNE.

Appendix E: List of Barriers

ID	Platform Element	Topic	Type	Author
○	Process	Legislative restrictions	Proper land aquisition	(Lessing et al., 2015)
x	Relationship	Stakeholder management	Fragmentation of stakeholders	(Hall et al., 2022, p. 298)
○	Process	Market position	Specification of target groups and product ranges	(Hall et al., 2022, p. 298)
x	Relationship	Stakeholder management	Supply-chain management	(Hall et al., 2022, p. 298)
○	Process	Software misalignment	Digital and automated processes	(Hall et al., 2022, p. 299)
○	Process	Process planning	Scope-of-work perspective	(Hall et al., 2022, p. 301)
x	Relationship	Stakeholder management	Self-interested behaviour, passing cost to others	(Hall et al., 2022, p. 301)
□	Component	Investment return	Cost fluctuation causes reluctance in innovation	(Hall et al., 2022, p. 301)
○	Process	Technical systems development	Technological risk aversion	(Hall et al., 2022, p. 301)
○	Process	Business models development	Cost reduction focus	(Hall et al., 2022, p. 302)
x	Relationship	Stakeholder management	Longitudial continuity	(Hall et al., 2022, p. 303)
Δ	Knowledge	Market position	Market requirements and offerings	(Hall et al., 2022, p. 303)
□	Component	Market availability	Fragmentation of a construction industry	(Abu Bakar et al., 2011, p. 142)
x	Relationship	Stakeholder management	Organisational (team) structure	(Abu Bakar et al., 2011, pp. 151-152)
Δ	Knowledge	Market availability	Low market share	(Goulding et al., 2014, p. 164)
○	Process	Customer perception	Customer perception	(Goulding et al., 2014, p. 164)
x	Relationship	Stakeholder management	Miscommunication between stakeholders	(Goulding et al., 2014, p. 164)
x	Relationship	Stakeholder management	Multidisciplinary team complications	(Goulding et al., 2014, p. 165)
Δ	Knowledge	Technical systems development	Building systems alignment	(Goulding et al., 2014, p. 165)
Δ	Knowledge	Integrative decision making	Design process	(Goulding et al., 2014, p. 165)
○	Process	Software misalignment	BIM adaptation	(Goulding et al., 2014, p. 165)
x	Relationship	Investment return	Clearer supply-chain benefits	(Goulding et al., 2014, p. 165)
□	Component	Software misalignment	Automation of construction	(Goulding et al., 2014, p. 165)
○	Process	Software misalignment	Information exchange and data processing	(Goulding et al., 2014, p. 165)
□	Component	Technical systems development	Flexibility and reconfigurability of manufacturing systems	(Goulding et al., 2014, p. 165)
□	Component	Investment return	Manufacturing payback	(Goulding et al., 2014, p. 166)
□	Component	Market availability	Coordination of different building components manufacturing	(Goulding et al., 2014, p. 166)
Δ	Knowledge	Investment return	Better understanding of risk analysis in IHB	(Goulding et al., 2014, p. 166)

○	Process	Market position	Value-adding processes	166)
x	Relationship	Stakeholder management	Impacts on stakeholders	(Goulding et al., 2014, p. 166)
x	Relationship	Business models development	Better life-cycle process analysis	(Goulding et al., 2014, p. 166)
○	Process	Business models development	Business models development	(Goulding et al., 2014, p. 166)
○	Process	Software misalignment	Integration of processes	(Goulding et al., 2014, p. 166)
□	Component	Market availability	Leaveriging production flexibility	(Goulding et al., 2014, p. 166)
Δ	Knowledge	Technical systems development	Component interface and coordination	(Goulding et al., 2014, p. 166)
□	Component	Technical systems development	DfMA and logistices	(Goulding et al., 2014, p. 166)
x	Relationship	Know-how protection	New design and management skills	(Goulding et al., 2014, p. 167)
Δ	Knowledge	Integrative decision making	Integrative decision making	(Goulding et al., 2014, p. 167)
○	Process	Long-term relationship	Product-focus over project-focus	(Goulding et al., 2014, p. 167)
○	Process	Sustainability adoption	Sustainability promotion	(Goulding et al., 2014, p. 167)
Δ	Knowledge	Know-how protection	Upskilling personal, new job roles	(Goulding et al., 2014, p. 167)
x	Relationship	Technical systems development	Health and Safety focus	(Goulding et al., 2014, p. 167)
○	Process	Customer perception	Customer perception	(Shibani et at., 2021, pp. 10-11)
○	Process	Investment return	Investment returns	(Shibani et at., 2021, p. 11)
□	Component	Market availability	Low adaptation limiting economy of scale	(Shibani et at., 2021, pp. 11-12)
Δ	Knowledge	Legislative restrictions	Building code limits	(Shibani et at., 2021, p. 12)
□	Component	Investment return	Material costs	(Shibani et at., 2021, p. 12)
Δ	Knowledge	Sustainability adoption	Circular know-how	(Silva, 2020)
Δ	Knowledge	Sustainability adoption	Waste reduction	(Silva, 2020)

PRODUCT PLATFORM INTEGRATION STRATEGIES

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