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Level of Vertical Integration in tight Buyer-Supplier Relationships for Concept Development in the Conceptual Housebuilding Industry

A case study at MorgenWonen

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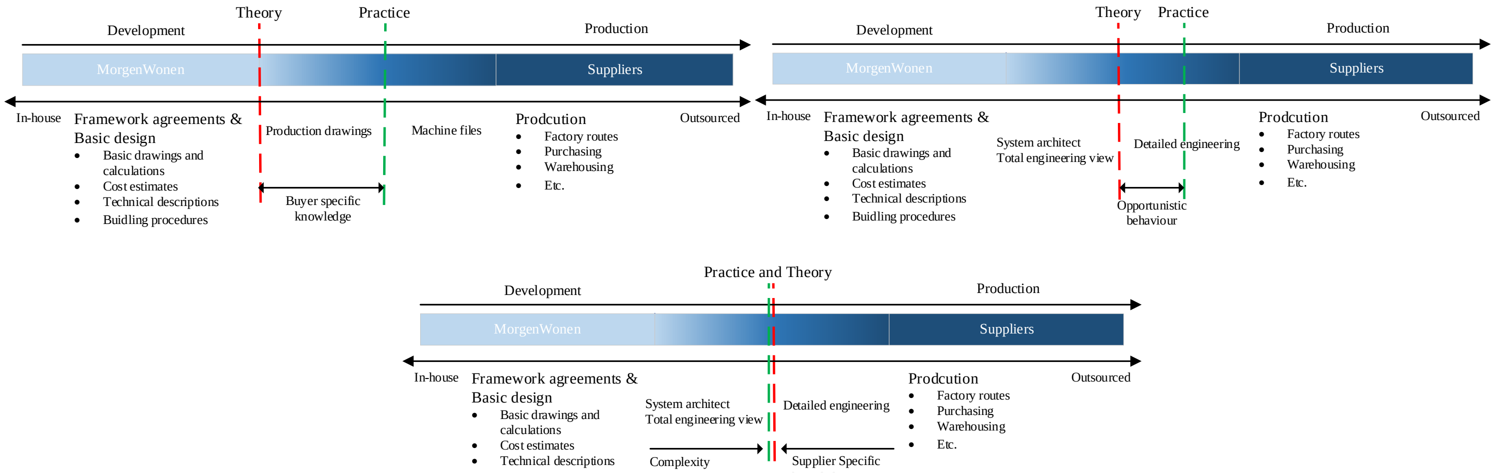
Abstract

The housebuilding industry in the Netherlands is stressed due to availability, affordability and sustainability. This leads to a shift towards industrialised housing construction (IHC). MorgenWonen is a company in the Netherlands that has chosen the path of IHC. The current designs of the MorgenWonen houses are a proven concept, however, when engineering changes are made to the designs is unclear how the responsibilities between MorgenWonen and its suppliers are divided. Therefore, this research aims to design an assessment framework for MorgenWonen to manage development, engineering, and production of elements in the design which are affected by engineering changes. The framework focusses on the level of vertical integration that is preferred for the design and engineering part of the redesign.

A theoretical framework is drawn up based on the three grand theories in purchasing: Transaction Cost Economics (TCE), Resource-Based View (RBV), and the Knowledge-Based View (KBV). The framework, with the influencing factors, is based on a simplified version of the theoretical framework of Wiegard (2020), who also uses TCE, RBV and KBV to determine the level of vertical integration. This research focusses on four influencing factors: 1) product complexity, 2) closeness to current activities, 3) absorptive capabilities, and 4) supplier specific knowledge. The theoretical implications of the framework are compared to reality with the help of a focus group. It is assessed what the differences are between theory and practice and why these differences are in place. Based on these findings a tailormade assessment framework is made that can be used by MorgenWonen to define level of vertical integration. The level of vertical integration is defined for three engineering changes: 1)add standard recess to interior walls, 2) add prefab meter box, and 3)change entry layout.

The results of the practise vs. theory analysis show that product complexity and supplier specific knowledge have the most influence on the sourcing decision. Besides these two influencing factors, another influencing factor was found that was not incorporated in the theoretical framework: buyer specific knowledge. Which is the knowledge from the buyer that the supplier must have to serve the buyer well. In the case of MorgenWonen it refers to the knowledge of the dependencies that is not present at the supplier. The driving forces for changes between practice and theory are given in the figure beneath.



Overview of practice vs. theory for the three engineering changes

From the analysis several conclusions can be drawn. First, large engineering changes with multiple affected elements and involved suppliers should be developed in the structure of a design team. Secondly, small engineering changes that can be developed in isolation from other elements or engineering changes can be outsourced to preferred suppliers if they have the capacity and knowledge in-house. Lastly, completely internalising the engineering work of large engineering changes is not possible, due to the supplier specific knowledge needed to fulfil the engineering tasks.

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1 General introduction

The housing market in the Netherlands has to cope with some huge challenges. Three main themes can be identified: 1) availability, 2) affordability and 3) sustainability. According to the Ministry of Internal Affairs and Royal Relations (Ministerie van Binnenlandse Zaken en Koninklijksrelaties, BZK) the Netherlands faces a housing shortage of 279.000 houses in 2021 (BZK, 2022). Besides that, the demand is not expected to go down. Therefore, the minister sets the goal of building around 900.000 houses before 2030, meaning around 100.000 houses each year (BZK, 2022). Besides the shortages, affordability of housing is another mayor issue in the current housing industry. A report of the McKinsey Global Institute (Woetzel, 2014) estimates that 330 million households are financially stretched due to their housing costs or live in substandard housing conditions. Lastly, housing, as an aspect of quality of life, largely influences sustainable development. The potential for the housing industry to contribute to sustainable development through its construction, use, and demolition is very significant (Winston & Pareja Eastaway, 2008).

The current way of building houses will not suffice in the demand (availability, affordability, and sustainability) that is asked from the market. The need for productivity, yielding the most output with minimum input, is one of the key drivers towards industrialised housing construction. Compared to the old-fashioned style of construction, which is characterised by project-based, one-time constructions, industrialised housing construction focusses more on efficiency, optimalisation and the use of information and communication technology (Kedir & Hall, 2021).

MorgenWonen is one of these companies that has shifted its focus towards industrialized housing construction. It is a sister company of Royal VolkerWessels B.V., one of the biggest building conglomerates in the Netherlands. MorgenWonen builds houses in association with other sister companies of VolkerWessels. Each of the companies is responsible for one of the components of the housing concepts. Around 70% of the components are made by these ‘in-house’ VolkerWessels companies. Currently they are producing around 400 houses a year, but their goal is to reach 2000 houses each year. To manifest this scale-up, MorgenWonen focusses on concept development, not only within their firm boundaries, but over the whole supplier network.

1.1 General problem statement

MorgenWonen offers housing concepts that are made in controlled environments like factories. Currently there are four standard concepts (4.8, 5.4, 5.7 and 6.9m in width) that are offered by MorgenWonen to customers like real estate developers and housing corporations. However, changes are made to these standard designs through two driving forces, one internal and one external. 1) Internally, MorgenWonen continuously wants to evolve their housing concepts, improving on technical and organisational aspects. Technical improvements can be considered as optimising certain building elements, by optimising performance, reducing costs, and enhancing ease of installation at the construction side. Organisational improvements are the improvements that are made to optimise the process of MorgenWonen, including sales, work preparation, purchasing, transport, etc. 2) Externally, customers want to have some freedom in certain design choices. These buyer options are design choices that fit in the standard constructive design of the housing concepts, i.e. different cladding on the facade. However, when the constructive design of the housing concepts is changed due to the customer’s demand, re-engineering is needed. Therefore, these changes are called engineering changes.

The technical improvements and engineering changes are severe and change the constructive design of the housing concept. This means that certain elements of the housing concept must be re-engineered. However, these elements are highly connected with each other, meaning that a change in one element would likely result in a change in another element. The initial engineering change can propagate through the whole system, affecting other elements and multiple suppliers of those elements.

So, the problem lies with engineering changes in the design, either through concept development or customer demand. These changes affect the technical specification of the design. A change in one element causes changes in other elements, and these changes ask for re-engineering. This problem can be divided into two sub-problems. On the one hand, **assessing the impact** of an engineering change cannot be done without a proper model which includes technical, organisational and process aspects. On the other hand, **the responsibilities** among MorgenWonen and its 'in-house' suppliers regarding re-engineering of the changed components **are not determined**. An overview of this problem breakdown structure and the accompanying goals can be seen in Figure 1-1. More detailed descriptions of the problem statements can be found in the devoted theses of that problem statement.

The remainder of this thesis is devoted to the Master Business Administration (BA) regarding the second problem statement (left side of Figure 1-1). Simultaneously with this thesis, another thesis is written devoted to the Master Civil Engineering and Management (CEM) regarding the first problem statement (right side of Figure 1-1).

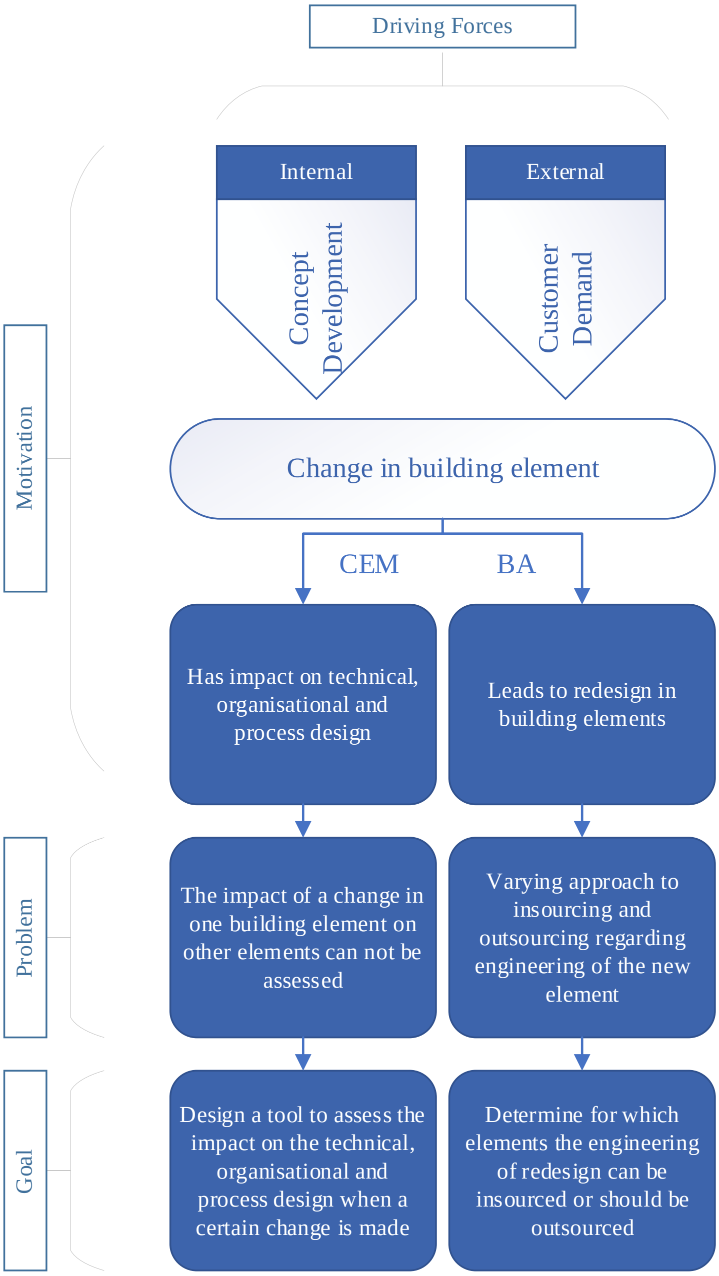

Figure 1-1, Problem Breakdown Structure

2 Introduction

2.1 Context and concepts

The housing industry in the Netherlands is changing. One-time, specific housing projects are exchanged for an industrialised, continuous process. Although the on-site construction of houses will always be project-oriented (location specific, permits, etc.), the processes of designing, engineering and fabricating elements shifts towards standardised production processes in controlled environments. The Industrialised Housing Industry (IHC) is characterised by these factors like prefabrication, modularisation and the use of modern methods of construction (Kedir & Hall, 2021). Opposed to the old-fashioned, project-based construction industry, IHC has the opportunity to develop strategies for continuous process and product innovation. One of these strategies is supplier integration in the development process of new products. Rosell and Lakemond (2012) state that suppliers contribute positively to new product development by providing external resources and knowledge to the resource and knowledge base of the buying firm. In addition, Eggers (2016) suggests that a large portion of the end product (i.e. produced elements, knowledge, services) comes from suppliers, and so supplier integration fosters the performance of the buying firm. Especially in the current industries, where 60-80% of the turnover is spend on purchasing materials and services (Baily et al., 2008). So the need for good purchasing strategies is high, and the standardised production processes of housing elements makes this possible in the industrialised housing industry.

Despite this potential for product and process innovation, it is widely acknowledged that the construction industry is a slow changing industry where innovation is hardly implemented in practice and productivity is low (Dixit et al., 2019). The main cause of failing to increase efficiency and adapt innovation is the lack of continuous buyer-supplier relationships (Dubois & Gadde, 2000). Construction firms tended to build projects as one-off efforts, therefor characterising the buyer-supplier relationships as a market exchange. In these exchanges buyers set the specifications of the purchased goods or services, but the supplier is not involved in this process (Bensaou, 1999). Due to this project-based design of the process, a construction firm cannot yield the benefits of a standardised work process and involve suppliers in the design and specification process of complex products. Although the previous stated arguments trace back to articles from 1999/2000 and the industry has changed a lot since, it underlines the importance of continuous buyer-supplier relationships to optimise efficiency and adapt innovation.

Both Transaction Cost Economics (TCE) and the Resource-based View (RBV) pay attention to defining a firm's boundaries (in-house or outsource/make-or-buy) (Gulbrandsen et al., 2009). According to the TCE view, firm boundaries are explained by external governance costs like searching, bargaining, monitoring, coordinating, etc., and by internal governance costs using the internal governance structure. Gulbrandsen et al. (2009) argue that transactions with high uncertain outcomes, occur frequently and that require a high asset specific investment are more likely to be produced in-house. However, this theory assumes that productive capability is homogeneous among firms, in other words, every firm has the capability to perform any activity in-house (Berg, 2008). The RBV on the other hand looks at certain characteristics of a firm's resources to define its boundaries. According to Barney (1991), the in-house resources of a firm should be valuable, rare, in-imitable, and non-substitutable (VRIN), making these resources of strategic value. A firm creates strategic value by applying, using and integrating it's recourses in such a way that they comply to the VRIN characteristics. If the resources do not comply to VRIN a firm loses its competitive advantage. When resources of a supplier are close to a buyer's current task/competency/activity, it becomes not rare or in-imitable, and can thus be internalised in by the buyer.

An adaptation of the RBV is the Knowledge Based View (KBV) and it conceptualizes a firm for its ability to develop and integrate knowledge as the most important resource of the firm, since resources without knowledge have no meaning (Berg, 2008; Macher & Boerner, 2012). The knowledge within a firm can be considered as the most rare and in-imitable resource a firm has, and is also called supplier specific knowledge. A sourcing decision, according to the KBV, can be based on the absorptive capacity of a firm to adopt the required skills to perform a certain activity. So, a buying firm can extend its firm boundaries by vertical integration through their absorptive capacity of supplier specific knowledge.

Summarising the above, TCE states that **design impact** (asset specificity and uncertainty) is an important factor for the level of vertical integration in the sourcing decision. According to RBV, the **closeness to current activities** affects the sourcing decision. And lastly the KBV suggests that **absorptive capacity and supplier specific knowledge** influence the firm boundaries. A more in depth review on these theories can be found in Chapter 4 - Theoretical Framework.

There are multiple levels of vertical integration in the buyer-supplier network. Traditional project-based transactions are non-integrated relationships. These are simple one-time market exchanges. Any buyer-supplier relationship with cooperative agreements and a multi-project scope can be defined as quasi-integrated. One speaks of a fully integrated relationship, when a supplier exclusively supplies specific components to the buying firm (Hofman et al., 2009). Vertical integration can be done in four different ways; the buying firm can internalise development and production, internalise development and externalise production, externalise development and internalise production or externalise development and production.

These levels of vertical integration occur in either a centralised or decentralised buyer-supplier network. A centralised network is characterised by one lead firm. This firm is referred to as the system's architect, setting the standards for the whole supplier network (Hofman et al., 2009). The traditional construction industry is characterised by a decentralised network in which standards are jointly set within each buyer-supplier relationship. These different types of networks opt for different processes of coming to a product architecture. The product architecture can be used as an underlying concept in a make-or-buy decision. Therefore, a centralised or decentralised network will influence the make-or-buy decision of the buying firm dependent on the product architecture.

2.2 Vision of MorgenWonen

MorgenWonen is part of the building conglomerate VolkerWessels. The suppliers of MorgenWonen consist mainly out of other VolkerWessels companies. These companies are later referred to as the main suppliers of MorgenWonen. MorgenWonen envisions to produce as much of the building components with these suppliers. A graphical representation of this direct supplier network and which elements they supply can be found in Figure 2-1.

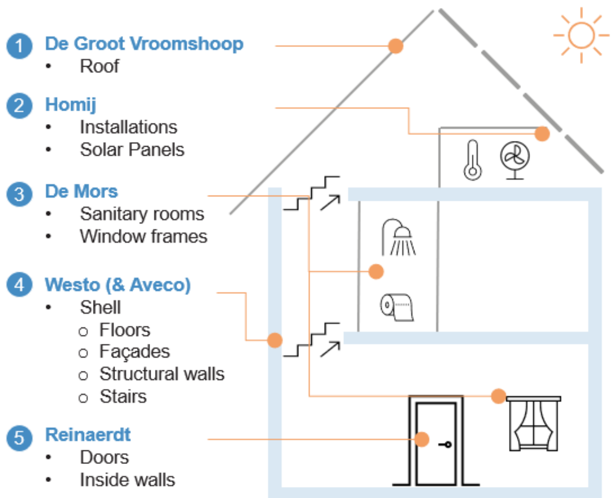

Figure 2-1, Direct suppliers of MorgenWonen

The management of MorgenWonen wants the business to have concept development and service and maintenance of the housing concepts as main task, not the production of the building components. This task should remain with the suppliers in any case. MorgenWonen should be involved in sales, work preparation and execution of the projects in order to be able to facilitate continuous development and service and maintenance. However, engineering that is accompanied with the continuous development is a grey area with no clear distinction of responsibilities between MorgenWonen and its suppliers.

Eventually the goal is to optimise the commercial performance of all the firms on a collective level, so regarding all the VolkerWessels in-house companies. This results in an organisational lock-in, meaning that the in-house companies of VolkerWessels will always be the preferred suppliers of MorgenWonen. The preferences to choose for VolkerWessels companies has multiple reasons. Large asset specific investments needed for the development of MorgenWonen concepts can be made on a conglomerate-level, instead of on a SME-level. Furthermore, financial benefits arise because VolkerWessels earns money over the entire supply chain, instead of only at MorgenWonen. So, optimising commercial performance over the entire supply chain of the VolkerWessels companies brings some organisational lock-ins, but is one of the boundary conditions in this research.

2.3 Problem Statement

As mentioned in the overall introduction, MorgenWonen faces the challenge of developing new housing designs when engineering changes to the current designs are made. The process of developing these designs takes too much time. The underlying problem is the lack of a clear supplier strategy, in which the responsibilities for re-engineering the engineering changes are defined. In other words, which levels of vertical integration are preferred for certain engineering changes. The impact of changes in the designs of MorgenWonen are not clearly defined, and therefore it is not possible to make an appropriate decision of vertical integration. Currently MorgenWonen is responsible for the continuous development of the components of the design (i.e. coming up with new ideas, setting specification, testing to building decree etc), and they are produced externally by 'in-house' companies of VolkerWessels (i.e. building walls, making installation units, etc). However, when an engineering change is made to one of the designs of MorgenWonen, confusion about responsibilities for the engineering part (i.e. making technical drawings, making production files, etc.) arises. An overview of this problem can be found in Figure 2-2. A more detailed overview of which tasks belong where can be found in chapter 5.2.2.

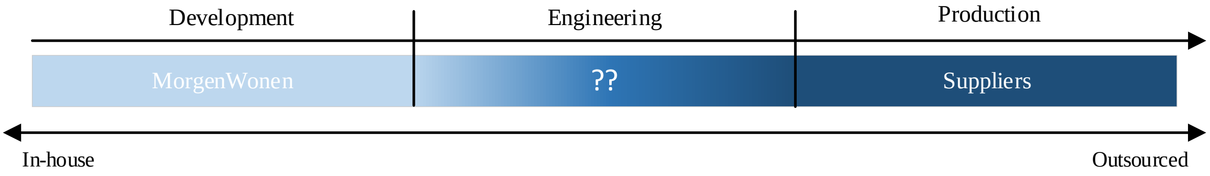

Figure 2-2, Unclear responsibilities for engineering

MorgenWonen is very clear in its vision about concept development and production of the elements, namely development in-house and production outsourced. However, the responsibilities for designing and engineering the engineering changes are not clearly divided or based on theoretical implications. The lack of supplier strategy concerning vertical integration causes non-optimal buyer supplier relationships and do not yield the benefits of proper supplier integration in the concept development process.

2.4 Objectives

This research aims to design an assessment framework for MorgenWonen to manage development, engineering, and production of elements in the design which are affected by engineering changes. The framework focusses on the level of vertical integration that is preferred for the design and engineering part of the redesign. The framework is based on a comparison between theoretical implications and practical considerations. The diagnosis of the theoretical implications are based on three grand theories in purchasing: TCE, RBV, and KBV as mentioned earlier. Eventually, the difference between the current state and theoretically optimal solution is identified and an analysis is carried out to identify which factors play an important role in the sourcing decision or which factors lack in the theoretical framework used in this thesis. Based on this diagnosis, the framework is composed to assess the level of vertical integration for current and future engineering changes.

2.5 Research Questions

To achieve the objective of this research the following research questions will be answered:

Which levels of vertical integration fit best for the dyadic buyer-supplier relationships of MorgenWonen for specific concept developments of the current designs?

To answer this main research question the following sub-questions must be answered:

1. *Which factors influence the level of vertical integration according to Transaction Costs Economics, the Resource Based View, and the Knowledge Based View?*

First of all, theoretical implications for vertical integration must be defined. This is done based upon the three theoretical perspectives as mentioned in the introduction: TCE, RBV, and KBV.

2. *Which engineering changes of the MorgenWonen designs are expected to be developed in the coming time and with which suppliers?*
3. *How do the influencing factors relate to the engineering changes made to the designs of MorgenWonen?*

Secondly, the engineering changes that are used in this research are identified and it is assessed how the influencing factors, identified before, theoretically affect the level of vertical integration.

4. *What are the actual levels of vertical integration during the engineering changes in the buyer-supplier relations of MorgenWonen?*
5. *Which relationships have a fit/misfit in practice related to the theoretical framework?*
6. *Which factors had a greater influence on the choice of vertical integration or which factors are not incorporated in the theoretical framework?*

The buyer-supplier relationships of MorgenWonen are identified to assess whether there is a fit or misfit with what is said in theory and what happens in practice.

7. *How should an assessment framework look like to find the optimal level of vertical integration for the supplier relationships of MorgenWonen during engineering changes?*

Lastly, an assessment framework is composed which should help MorgenWonen to assess the level of vertical integration needed for optimally implementing future engineering changes to the designs of MorgenWonen. The framework consists of multiple guidelines that should be considered within the sourcing process of engineering changes. An overview of the research framework can be seen in Figure 2-3 on the next page.

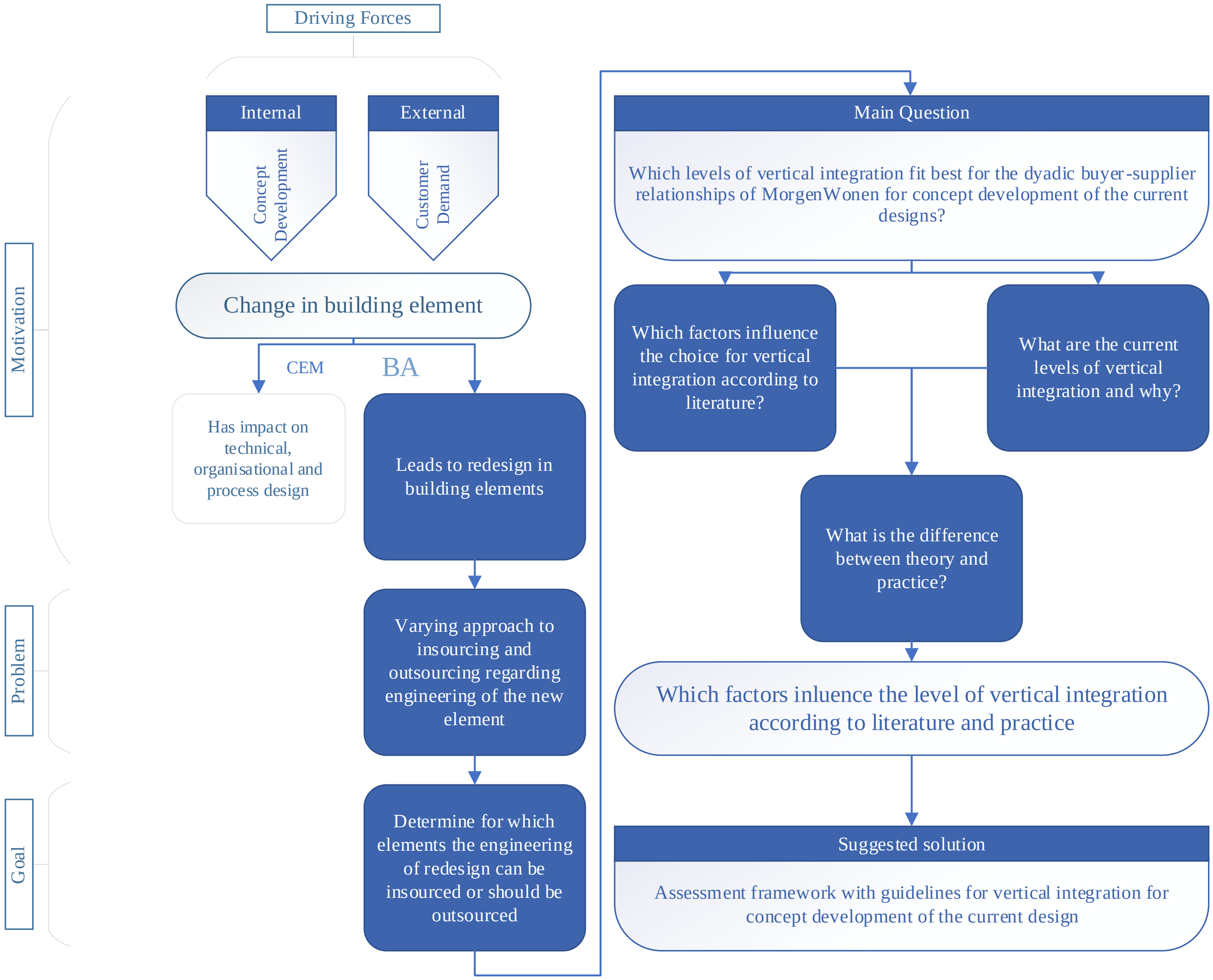

Figure 2-3, research framework BA

2.6 Reader Manual

The remainder of this thesis is structured as follows. Chapter 3 gives the methodology, followed by a Theoretical Framework in Chapter 4. Chapter 3 already refers to some insights given in Chapter 4. The data and results of this research are given in Chapter 5 and 6. Chapter 7 discusses the limitations and areas of concern, and gives suggestions for further research to tackle these points. Chapter 8 and 9 are devoted to the general conclusions and managerial recommendations. Lastly, Chapter 10 focusses on the scientific contribution of the research.

3 Methodology

The research questions, as described in section 2.5, will be answered following the methodology described in this chapter. The research methodology is structured as follows. First, a theoretical overview is given of the influencing factors concerning vertical integration according to three grand theories in the purchasing industry. Based on the theoretical overview it is assessed how certain buyer-supplier relationships during engineering changes should look like. Secondly, an assessment is done of how these relationships look like in reality. Thirdly, the difference between the theoretically optimal solution and reality is defined. It is assessed why these differences are there, and so, which factors influence the level of vertical integration more than others. Lastly, an assessment framework is drawn up that includes guidelines in which the theoretical implications and practical considerations are taken into account. The remainder of this chapter will describe how these steps are taken.

3.1 Theoretical overview

The theoretical overview mainly consists of a Theoretical Framework. In this framework the influencing factors of vertical integration following the theories TCE, RBV, and KBV are given. They are adopted from other researches in the field of purchasing management. Furthermore, an overview of the possible levels of vertical integration is given. These influencing factors and levels of vertical integration are used throughout the whole research.

3.2 Expected engineering changes

The buyer-supplier relationships are assessed based on three cases. These cases are also used in a simultaneously conducted research by the same author (Burghouts, 2023). The cases are based on the expected engineering changes of the concept development team and are identified through discussions held with the concept development team of MorgenWonen. Based on these discussions and the concept development road map, three possible engineering changes are identified. These engineering changes are all differing in type of supplier and expected impact. However, the process of the engineering changes has already begun, but they are not completely finished. This makes it possible to analyse the buyer-supplier relationships during this research.

The theoretical implications for vertical integration of the proposed engineering changes are structured according to the theoretical framework. In the theoretical framework (Chapter 4) it becomes clear that four factors influence the level of vertical integration; Product complexity (uncertainty and asset specificity), closeness to current tasks, absorptive capacity of the buying firm, and supplier specific knowledge. Theoretical implications are given for these four influencing factors as follows.

The product complexity is based on the findings of the simultaneously conducted research by Burghouts (2023). In this research the technical and commercial impact of the same engineering changes are assessed. The technical and commercial impact are based on the number of affected elements, involved suppliers, engineering hours, and lead times. Specifically the number of affected elements and involved suppliers are the input for defining the uncertainty and asset specificity of the engineering change. The percentage of changed elements and suppliers in relation to the total amount of elements and suppliers gives a quantitative approach of the product complexity.

The closeness to current tasks is defined based on the job description of the concept development team and organisational chart of MorgenWonen. These tasks are identified through a document study. The dispersity between the required tasks for the engineering change and the defined current tasks give the level of closeness to current tasks.

The absorptive capacity of MorgenWonen, and specifically the concept development team is based on the required skills of the employees. These skills are documented in the job vacancy of ‘Technical Concept Developer’. It is assessed whether or not the concept development team can absorb knowledge and competencies to perform the required tasks of the engineering change, based on the prescribed skills in the job vacancy.

Lastly, the supplier specific knowledge needed to perform the engineering change is assessed. This is based on an analysis of the core competencies of the suppliers. If the required tasks of the engineering change fit within the core competency of the supplier, it is assumed that this is supplier specific knowledge. When the supplier is able to perform the engineering change as a ‘side job’ it is assumed that the required tasks can be performed without any supplier specific knowledge.

3.3 Current buyer-supplier relationships

The supplier network for the elements of MorgenWonen houses are identified through discussions with the concept development team. A more in-depth analysis of the supply base is carried out, to grasp the complexity of the supplier network, since the suppliers also supply unfinished products to each other. This gives insight in the complexity of the supply base of MorgenWonen. This analysis of the supply base is carried out based on a document study and further insights from the concept development team and management team of MorgenWonen.

The complexity of the supply base of MorgenWonen is important for managerial implications. However, this research focusses on the dyadic supplier relationships of MorgenWonen (i.e. only the relation between MorgenWonen and Westo) not considering the mutual dependencies between the suppliers themselves. This is done to clearly identify which design and engineering processes are done in-house by MorgenWonen and which are done by the production companies in general.

3.4 Practice vs. Theory

A focus group is held in which these theoretical implications of the buyer-supplier relationships are given. The focus group then focuses on the actual buyer-supplier relationships of the engineering changes, why they are differ from the theoretical implications, and why. The focus group is organised together with the concept development team and management team of MorgenWonen to gain a full understanding of the complexity of the engineering change and the reasoning behind the sourcing decisions during the engineering change. An overview of the focus group set up can be found in Appendix 12.1 - Focus group set-up.

3.5 Assessment framework

Based on the findings in the previous sections an assessment framework for the level of vertical integration is drawn up. This assessment framework includes guidelines from a theoretical and practical viewpoint. The framework helps as a decision-making guidance tool, starting with the expected engineering change, following with some questions about the influencing factors, eventually leading to one of the levels of vertical integration: market exchange, preferred supplier, design team, or in-house. The assessment tool gives insight and guidance into the decision-making process for all future engineering changes of MorgenWonen.

4 Theoretical Framework

This chapter is devoted to three grand theories in purchasing which are shortly introduced in the introduction: Transaction Cost Economics, Resource Based View, and Knowledge Based View. Grant (1996, p. 110) suggests that "The foundation for any theory of the firm is a set of initial premises which form the basis for the logical development of propositions concerning the structure, behaviour, performance and, indeed, the very existence of firms.". In this research the theories are assessed in the light of how they affect the structure of the firm and in more detail the sourcing decision regarding vertical integration of (re)designing and (re-)engineering products. These levels of vertical integrations are first discussed here. In the end of this chapter a theoretical overview is given that shows which factors influence the sourcing decision, how they do so, and from which theories they originate. This theoretical framework is a simplified version of the theoretical framework of Wiegard (2020). The reason for the simplification is the availability of data and the importance of the influencing factors in the light of this case study.

Vertical integration comes in different degrees, ranging from fully in-house production to one-off market transactions. Within this research vertical integration is categorised in four levels as can be seen in Figure 4-1. Not integrated means that the sourcing decision has the characteristics of a market exchange. Most of the time these are simple, one-off products that are project specific. Quasi integrated suppliers are preferred suppliers of the buying firm. These are mostly products or services that occur more frequently but are not of strategic value to the buyer. An integrated supplier can be seen as a supplier that acts in a design team. These goods or services are bought frequently from the supplier and are of strategic importance to the buyer. A fully internalised supplier has simply been brought in-house. The product or service delivered from that supplier is now a core competence of the (originally) buying firm and it belongs to its strategic value.

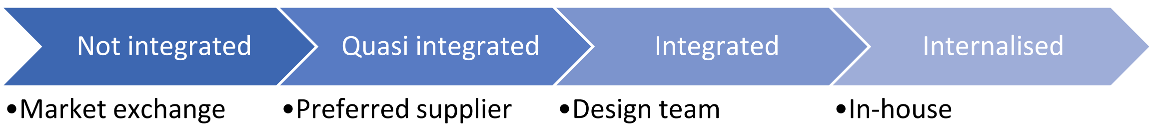

Figure 4-1, Levels of vertical integration

4.1 Transaction Cost Economics

Transaction Cost Economics takes the transaction as basic unit of analysis in the sourcing decision, and thus setting of the firm boundaries, as described by Williamson (1989). The dependent variable in this analysis is the type of transaction: a simple market exchange(outsource) or full vertical integration (in-house) (Novak & Eppinger, 2001). The factors of the transaction that are used in this theory are threefold: "1) the frequency with which they recur, 2) the degree and type of uncertainty to which they are subject, and 3) the condition of asset specificity" (Williamson, 1989, p. 142). Where the first factor is rather self-explaining (more transactions opt for extending the firm boundaries, and thus insource the production or service), the last two ask for more detailed explanation.

Firstly, the degree and type of uncertainty is one of the factors that influence a sourcing decision. High uncertainty makes a buyer tend towards extending its firm boundaries. These uncertainties can be classified in two types: primary and secondary uncertainty (Koopmans, 1957). Where primary uncertainty can be described as uncertainty that arises due to arbitrary factors that are out of reach of the buyer, secondary uncertainty arises due to, for example, bad communication, lack of information management, etc. Both uncertainties are of equal importance in the consideration of the sourcing decision. However, the primary uncertainty is an uncertainty in which the buyer can only minimize the consequences. For the secondary uncertainty, the buyer has the possibility to mitigate possible consequences as much as possible by good communication and information management. So according to TCE, to minimise coordination costs (communication and information management), products with high primary and secondary uncertainty must be internalised.

Secondly, asset specificity is identified as an influencing factor in the sourcing decision. It refers to the level of redeployment of an asset or resource for alternative uses. A high level of redeployment in alternative uses indicates low asset specificity, since this resource can easily be used for other purposes. Williamson (1989) classifies asset specificity in five kinds: 1) site specificity, 2) physical asset specificity, 3) human asset specificity, 4) dedicated assets, and 5) brand name capital. They relate to transaction costs in such a way that highly specific assets need investments in of one of these kinds of specificity and are thus not applicable to alternative uses. High asset specificity usually implies vertical integration of the buyer, to avoid opportunistic behaviour of the supplier. However, when high levels of specificity are reached, "the relationship between asset specificity and vertical integration becomes more complex" (Kvaløy, 2007, p. 20). High asset specificity only induces vertical integration to a certain extent of specificity. When a certain level of specificity is reached, buyer and supplier can engage in a relational contract with incentive schemes, where asset specific investment costs transcend policing and enforcement costs of the contract. So asset specificity opts for vertical integration to avoid opportunistic behaviour. However, when high levels of asset specificity are reached, the level of vertical integration decreases from 'in-house' to contractual relations like a 'design team'.

According to the above mentioned arguments it becomes clear that uncertainty and specificity are important factors in the sourcing decision. Both the needed degree of communication and information management (uncertainty) and asset specificity are highly linked to the complexity of the sourced good or service. Product complexity is described in the literature as 1) multiplicity; having many dimensions, including the number of elements, modules, or finished good variants in a portfolio, 2) the number of interrelations between components, 3) diversity; the commonality of products in an assortment, and the diversity of relations between components, and 4) novelty of the product including new technologies or architectures (Jacobs, 2013; Novak & Eppinger, 2001; Trattner et al., 2019, p. 70). In line with this reasoning, Novak and Eppinger (2001) state that product complexity of the design and in-house production go hand in hand. And so, TCE theory suggests that engineering and production will be internalised for high complex products when a firm wants to minimize transaction costs (i.e. coordination, specific investment, or policing and enforcement costs).

While transaction frequency is also of high importance in TCE, it is not considered so in this research, since this research focusses on one-time engineering changes and how these should be vertically integrated in the firm. So the frequency of this 'transaction' is always one. An overview of the described theory can be found in Figure 4-2.

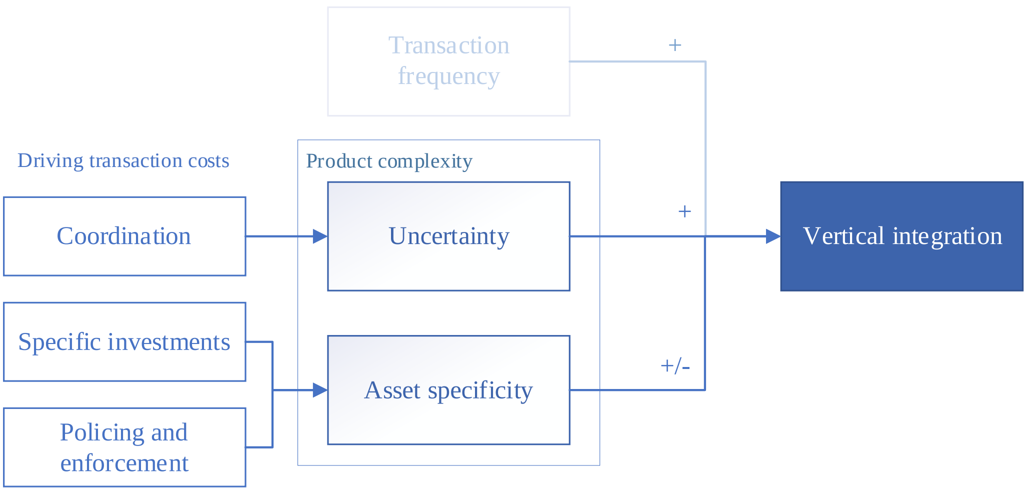

Figure 4-2, Influencing factors for vertical integration according to TCE

4.2 Resource Based View

In this research the principles of the Resource Based View (RBV) are adopted from Barney (1991) in which it is argued that sustained competitive advantage is obtained through VRIN-resources: Valuable, Rare, Inimitable, and Not substitutable. These resources involve intangible assets (i.e. knowledge and capabilities) and tangible assets (i.e. firm attributes and machinery). The RBV assumes that it is not possible for a firm to have competitive advantage over competitors when homogeneity among resources exists. In other words, when all firms in a certain industry can deploy exactly the same resources one cannot win competitive advantage over the other, because these resources do not comply to VRIN. However, a firm can be seen as a unique composition of resources and capabilities (Teece, 1993). And so, according to the RBV, firms are described as heterogeneous entities with asymmetric resources (Gulbrandsen et al., 2009).

A firm can extend its boundaries according to the RBV by performing tasks in-house that are closely related to their current tasks. The reason for this argument is that the ease of development of new competencies is closely related to closeness to current tasks (Gulbrandsen et al., 2009). Comparing the RBV with TCE, this argument would imply that closeness to current tasks minimises internal governance costs when developing new competencies or performing tasks in-house. So, from an RBV viewpoint, it is very likely that a task or competency is internalised when it is closely related to current tasks or competencies, since the internal governance costs will be less than the expected external transaction costs. This might seem as an argument from the TCE viewpoint. However, the RBV and TCE complement each other strongly in terms of setting firm boundaries and vertical integration. Gulbrandsen et al. (2009) argue that it is possible to combine both perspectives of vertical integration and thus broaden the theoretical perspective of both TCE and RBV. According to Lockett and Thompson (2001) economic activity (e.g. vertical integration vs. outsourcing) is fundamentally related to efficient allocation of the resource base. So they suppose that the RBV offers important insights in determining firm boundaries.

In this research, the argumentation of Gulbrandsen et al. (2009) is adopted. Meaning that the closeness to current activities is taken as a factor that positively affects the choice for vertical integration. The reasoning behind this is that the RBV complements TCE in the sense that external transaction costs can exceed internal governance costs when tasks and competencies are closely related to in-house tasks and competencies. This means that a task performed in-house will have lower overall costs than the outsourced alternative. An overview of the described theory can be found in Figure 4-3.

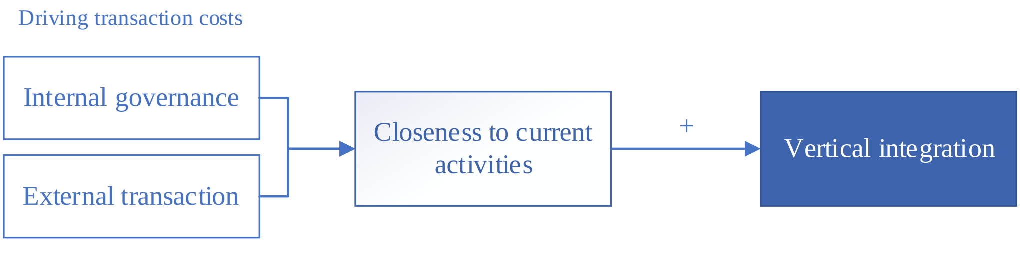

Figure 4-3, Influencing factors for vertical integration according to the RBV

4.3 Knowledge Based View

The principles of the Knowledge Based View (KBV) are adopted from the work of Grant (1996). Up to that time the KBV was not a recognised 'theory' of firms. It was merely an establishment of interests in new ways of thinking about a firm. The KBV is an adaptation of the RBV and takes human capital as the most valuable, rare, inimitable and not substitutable resource a firm can have. This means that knowledge of the employees is the most strategically valuable resource of the firm. However, in the previous chapter it was already discussed that the RBV also includes intangible assets like knowledge and capabilities. So Eisenhardt et al. (2000, pp. 1-2) question whether the KBV is just a "re-labeling of resource-based thinking that adds little value to our current understanding of superior performance" or "does it represent the emergence of a new theory of strategy, contributing to our ability to understand the sources of superior firm performance?". In this research the KBV is seen as a self-contained theory in which knowledge as a resource is taken as the dominant perspective, and can thus give new and different insights in the logical development of propositions regarding the firm.

Lin (2000) studies how organisational costs and technical uncertainty affect vertical integration and how this effect is moderated through absorptive capacity from the viewpoint of the KBV. She argues that there are two opposing opinions in literature regarding vertical integration and how this is influenced by organisational costs and technological uncertainty. On the one hand, outsourcing is advocated due to the reduces organisational costs and flexibility during uncertain times. On the other hand, it is argued that knowledge-based capabilities can decrease organisational costs, making vertical integration possible. In her empirical study, Lin (2000) finds that firms with high absorptive capacity can benefit from vertical integration, due to the reduced organisational costs.

Reasoning from the RBV, that the right constellation of strategic resources gives a firm the possibility for sustained competitive advantage over other firms, would also imply that a firm's supplier has such a constellation of its strategic resources. In light of the KBV, where knowledge is seen as the most strategically important resource of the firm, this would imply that a firm's supplier also has supplier specific knowledge which gives the supplier sustained competitive advantage. Following this argumentation, supplier specific knowledge of a good or service negatively affects the choice for vertical integration. An overview of these theoretical implications can be found in Figure 4-4 on the next page.

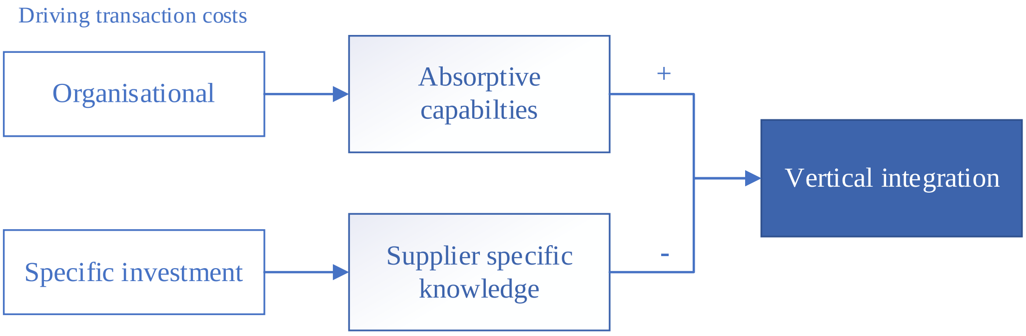

Figure 4-4, Influencing factors for vertical integration according to the KBV

4.4 Theoretical overview and guidelines

In this chapter three grand theories of purchasing were brought to light. All three theories have been described regarding their influence for the sourcing decision of vertical integration. This research draws on all three theories, and therefore a theoretical overview of the influencing factors on vertical integration from different theoretical perspectives is made and can be seen in Figure 4-5.

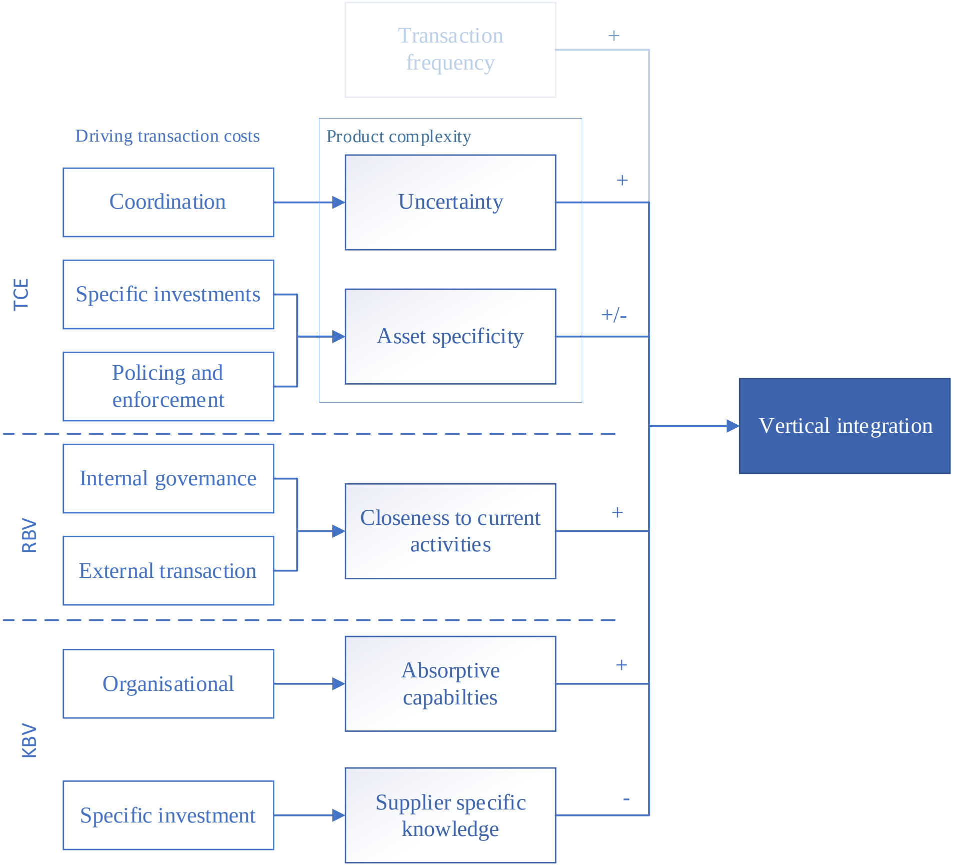

Figure 4-5, Theoretical overview for vertical integration

Besides this theoretical overview, some guidelines regarding theoretical implications can be drawn. The guidelines serve as a support tool for the decision on vertical integration and are based on the influencing factors as described in the literature above.

In this research all product development processes and design or engineering changes are seen as one-time projects, and therefore the transaction frequency is considered is one. So the transaction frequency has little influence on the level of vertical integration. This factor becomes of influence when goods or services are sourced from suppliers more often.

As can be seen in Figure 4-5, uncertainty and asset specificity are grouped into one factor: product complexity. As stated in the literature, high product complexity leads to vertical integration. This leads to the conclusion that engineering changes with high uncertainty and high asset specificity would be engineered in-house or in the form of a design team, but explicitly not like a market exchange.

Furthermore, closeness to the current activities , absorptive capabilities and supplier specific knowledge also relate to each other when considering setting up guidelines for vertical integration. The re-engineering that is needed due to the engineering change could be a capability or skill that is very closely related to current capabilities and skill of the concept development team. If so, the task can be internalised and external transaction costs can be avoided. If this is not the case, the question is whether or not the concept development team has the absorptive capability to internalise supplier specific knowledge. When the concept development team is able to absorb new knowledge, and the specific knowledge of the supplier is easy to absorb, the task can be internalised.

How these guidelines and influencing factors relate to each other is not clearly described in literature. Besides that, the practical implementation of these guidelines in the setting of industrialised housing construction can also differ from theoretical implications. The next chapter explains how these theoretical implications relate to practical issues in the setting of industrialised housing construction.

5 Data

5.1 Expected engineering changes

The expected engineering changes which are used in this thesis are based on the roadmap of the concept development team and are defined as follows: Add standard recess in indoor walls for sockets or other applications, add pre-fab meter box to the design, and change entry layout from front façade to sidewall.

The **recesses in interior walls** are currently drilled at the construction site. This takes time and is most of the time inaccurate (i.e. they are not completely horizontal or the recess is made too big for the sockets). To avoid these inaccuracies and to speed up then process at the construction site, standard recesses can be added to the interior walls when they are at the factory. Reinaerdt is responsible for supplying the interior walls and have the machinery to add these recesses to the interior walls. However, production files and logistics should be taken into consideration to actually carry through this engineering change.

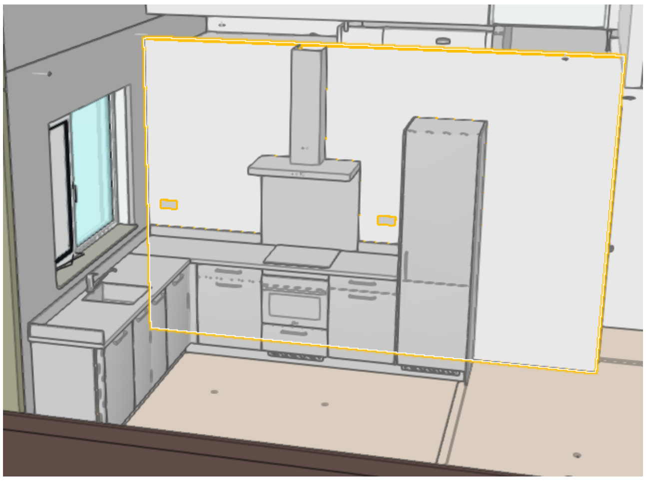

Figure 5-1, Standard recess in indoor walls

Utilities like water and electricity are currently installed by experts on the construction site. The exterior of the meter box is shaped with interior walls and doors and the contents are installed during construction. **A pre-fabricated meter box** should avoid this extra work on the construction site, with a more 'plug and play'-kind of installation of utilities. The exterior and interior of the meter box are constructed in controlled environments which makes construction more efficient and accurate.

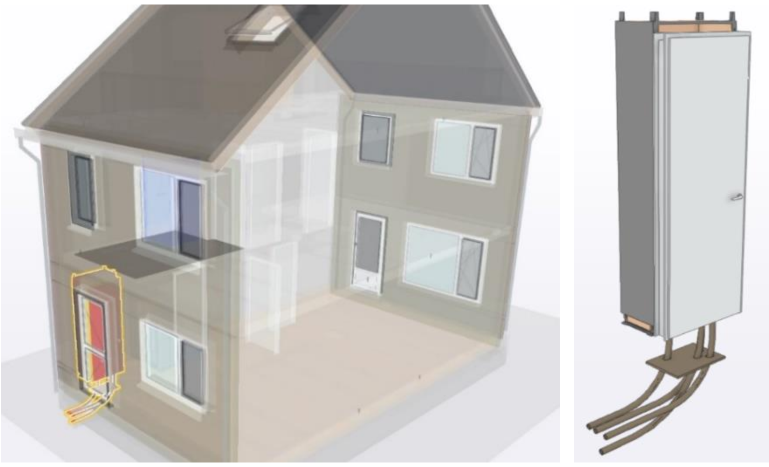

Figure 5-2, Pre-fab meter box

Lastly, one of the proposed engineering changes from the concept development roadmap which is used in this thesis is **the change of entry layout**. MorgenWonen wants to offer more options to buyers in their designs. Therefore, the engineering change of a side entrance is introduced. This option is possible for corner houses. Figure 5-3 shows two corner houses, the left one with a front entrance which is the current design for side houses, and the right one with a side entrance which is an option for the proposed engineering change.

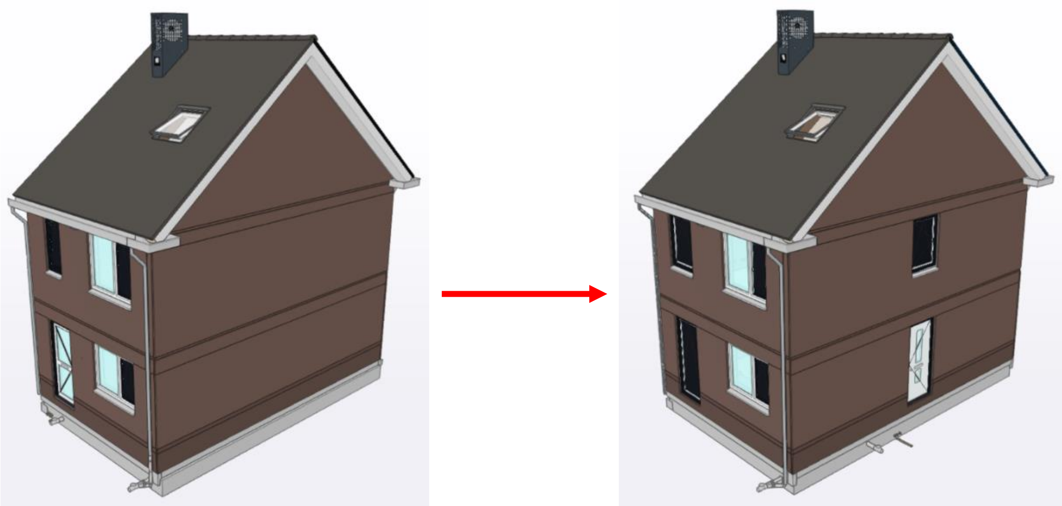

Figure 5-3, Change entry layout to sidewall

5.2 Theoretical implications

In this chapter the theoretical implications for the influencing factors regarding vertical integration are given. Uncertainty and asset specificity are combined into complexity. Furthermore, closeness to current tasks, absorptive capability and supplier specific knowledge are assessed for each engineering change. From these theoretical implications it can be concluded that the first engineering change, adding a standard recess, can be outsourced to a preferred supplier. While the second and third engineering changes, the prefab meter box and change of entry layout, should both be vertically integrated to the level of a design team. The following sections will give the argumentation for these conclusions.

5.2.1 Complexity

The design complexity of the engineering changes is based on the uncertainty and asset specificity of the product. The uncertainty is based on the research done simultaneously to this research by the same author (Burghouts, 2023). In this research the technical and commercial impact of the same engineering changes are assessed. The number of affected elements (design uncertainty) and number of involved suppliers (sourcing uncertainty) define the overall uncertainty of the engineering change. The impact is based on the Design Structure Matrix (DSM) and Domain Mapping Matrix (DMM) as seen in Figure 5-4 on the next page. The research of Burghouts (2023) elaborates on the DSM and DMM in more detail. The asset specificity is ranked according to the needed asset specific investment needed to realise the engineering change.

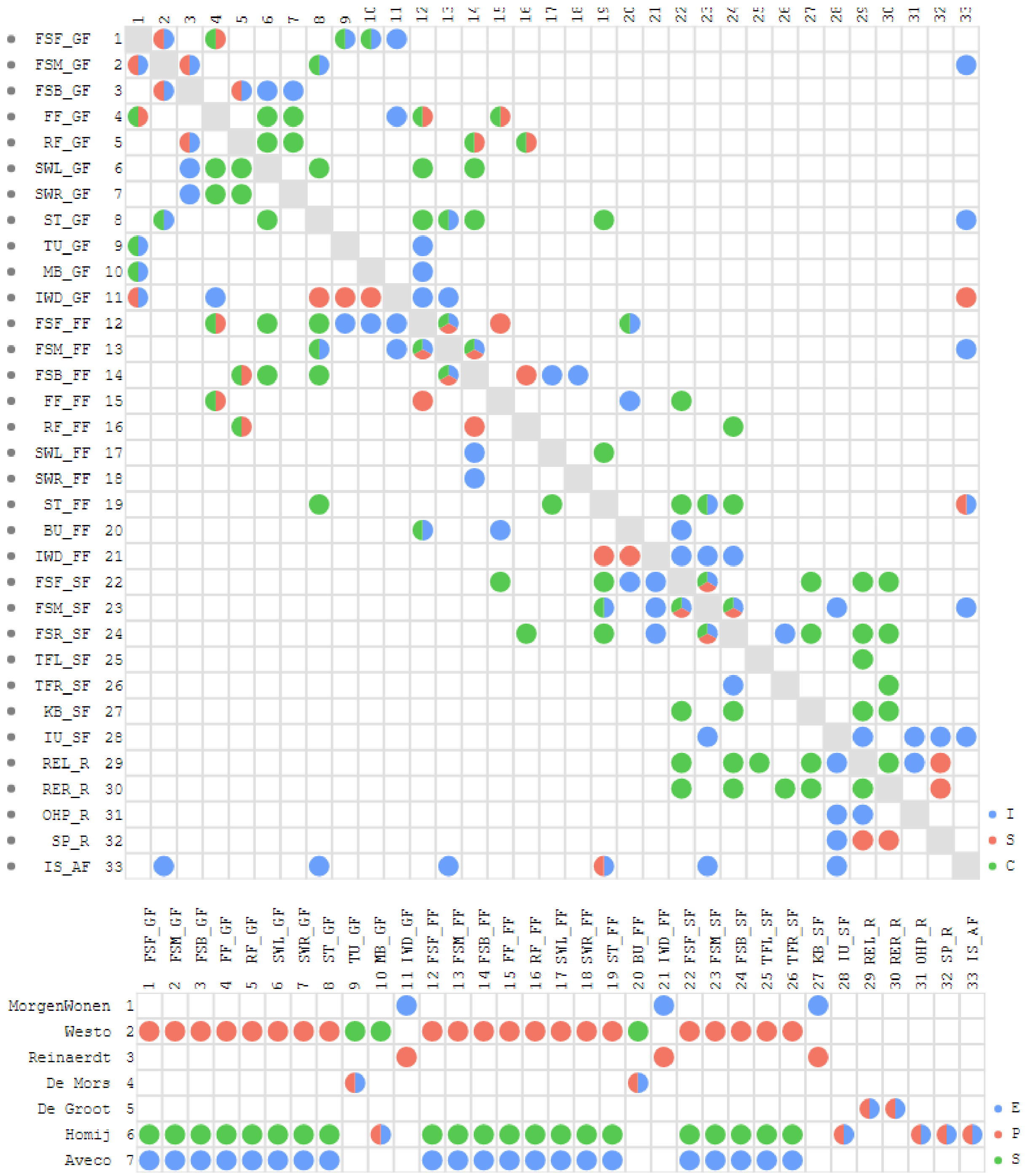

Figure 5-4, Technical DSM and Supplier DMM

Indoor walls

The design complexity of the engineering change adding a standard recess to the indoor walls is generally low. The change has low uncertainty since this engineering change is small and internal, so it will not propagate to other elements. Furthermore, the involved organisations only entail MorgenWonen and Reinaerdt for engineering (E) and producing (P) the indoor walls with a standard recess respectively. This means that only 1/33 elements and 2/7 organisations are involved in the engineering change. In short, the design uncertainty of this particular engineering change is very low. Furthermore, the knowledge and machinery needed to realise the engineering change are not asset specific and can be re-used or reallocated to other projects of Reinaerdt. The low product complexity of this engineering change opts for a low level of vertical integration.

Pre-fab meter box

The design complexity of this engineering change is significantly higher than the previous one. Introducing the pre-fab meter box into the design of MorgenWonen has consequences for other elements in the design. Since the engineering change is categorised as large, the change will propagate to other elements. The floor slab at the front side of the ground floor is changed through this engineering change by adding a recess for the meter box. Furthermore, the indoor walls and doors at the ground floor are affected as well. Before introducing the prefab meter box, the meter box was constructed on site with the material of the indoor walls. This material is no longer needed and should be exchanged for other indoor walls to serve as finishing of the meter box. Besides the affected elements, multiple suppliers are involved in this engineering change. Initially, Homij in collaboration with MorgenWonen and Westo are involved in designing the meter-box. Through change propagation, Westo and Aveco are involved to redesign the floor slab on which the meter-box will come to stand. Lastly, Reinaerdt has to adapt the indoor wall panels to the new design. Overall, we could say that the design uncertainty of this engineering change is high, since 3/33 elements are affected and 5/7 suppliers are involved.

The pre-fab meter box needs asset specific investments as well. First of all the complete engineering design of the meter box has to be made. This includes an engineering design and new moulds for the floor element (Westo) as well as the meter box and its contents itself (Homij). Furthermore, the main supplier, Homij, makes this investment solely for MorgenWonen, since the design of these pre-fab meter box only fits within the design of MorgenWonen. So the design of the prefab meter box is highly asset specific.

The high uncertainty and asset specificity of the engineering change opt for a more vertically integrated approach, i.e. a design team.

Entry layout

Changing the entry layout of the MorgenWonen design initially seems as the biggest engineering change. The elements that are directly affected by this change are the front façade and the side wall on the ground floor. An extra recess for the front door has to be added to the side wall, while the recess in the front façade has to be changed from front door to window. This new layout then affects the interior walls and doors, which have to be re-engineered. Besides, cables and piping in the floor slabs at the front and middle and ground and first floor of the house are adjusted to the new design. In total seven elements have to be re-engineered, and to do so five organisations are involved in the engineering change; MorgenWonen, Westo, Aveco, Homij and Reinaerdt. In conclusion, changing the entry layout has a high uncertainty, since 7/33 elements are affected and 5/7 suppliers are involved in the engineering change.

Furthermore, changing the entry layout affects the front façade and right side wall on the ground floor. Adding/changing the recesses in these elements has as a consequence that new production models should be made. These production models are asset specific investments since they can only be used to make wall elements for MorgenWonen houses. Furthermore, new moulds need to be bought to have a durable solution for these new elements. Again these are asset specific investments, since these moulds are customised for the specific elements.

Overall the product complexity of this engineering change can be categorised as high, and this engineering change opts for vertical integration.

5.2.2 Closeness to current tasks

The current tasks of the concept development team of MorgenWonen are described in the organisational chart. The tasks consist of making basic designs, which includes basic drawings and calculations, cost estimates, technical descriptions, and building procedures. Besides the basic design tasks, the concept development team has the responsibility to set up framework contracts with the internal suppliers of VolkerWessels (Figure 5-5). In this section it is assessed how close the detailed engineering tasks for the proposed engineering changes are to the current tasks of the concept development team.

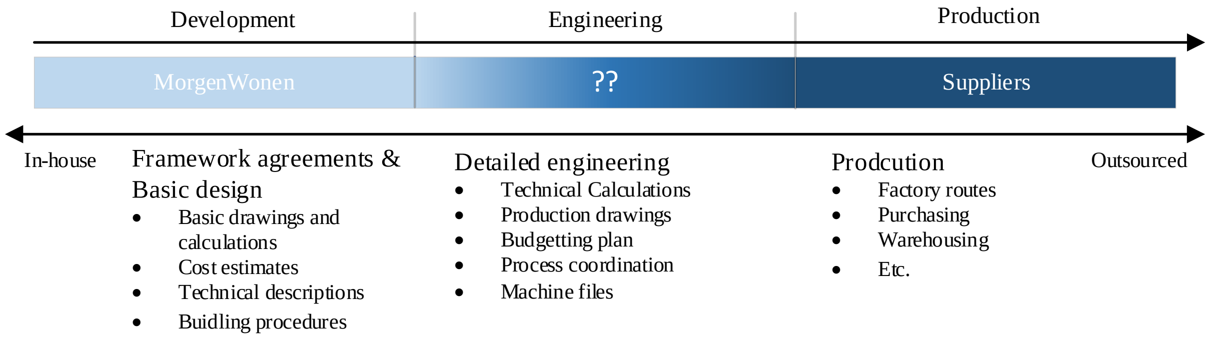

Figure 5-5, Tasks and responsibilities in the development-engineering-production process

Indoor walls

The engineering part of adding the standard recess in the indoor walls incorporates two main tasks. First of all, production drawings have to be made. These are drawings of the design of the indoor walls that indicate materials, dimensions, and the method of construction. Once these drawings are made, machine files can be adopted from these production drawings. The machine files control the machinery in the factory and make sure that the indoor walls are made exactly like the production drawings.

Making production drawings is a tasks that is close to the current tasks of concept development team and work preparation. These kind of production drawings can be made by these due to the simplicity of the product. However, making machine files for the specific machinery of Reinaerdt is far from close to current tasks and capabilities of the MorgenWonen personnel. Defining machine operations and detailed settings are not competencies of the concept development or work preparation teams. So this implicates that these tasks should be outsourced to a preferred supplier according to this factor.

Pre-fab meter box

Designing the pre-fab meter box incorporates a lot of engineering during the process. First, basic engineering of the prefab meter box has to be done. This includes setting boundary conditions, like dimensions, weight, functionality, etc. Detailed engineering is done to actually fill in the contents of the pre-fab meter box and compute the concrete floor slab on which it stands.

Setting the boundary conditions for the prefab meter box is a core task of the concept development team. However, detailed engineering for computing the floor slab and filling the contents of the meter box are not competencies of the concept development team and also not close to the current tasks. This factor implies that the tasks of detailed engineering should be outsourced to the preferred suppliers.

Entry layout

Changing the entry layout affects the front façade and right side wall on the ground floor. Adding/changing the recesses in these elements has as a consequence that new production models should be made. Besides the production models, new moulds have to be ordered and detailed engineering of the wall elements (rebar calculations etc.) have to be done.

All these activities are not closely related to current tasks and competencies of the concept development team. These kind of activities are mostly outsourced to the concrete element supplier, Westo, and other suppliers like Aveco. The skills and competencies for these tasks are not fulfilled by the concept development team of MorgenWonen, and are also not close to current tasks. Outsourcing to preferred suppliers is the solution according to this influencing factor.

5.2.3 Absorptive capacity

The absorptive capacity of MorgenWonen to actually execute the engineering changes is based on the skills, knowledge and expertise mentioned in job vacancies for a 'Technical Concept Developer' at MorgenWonen. In short, the vacancy requires a Bachelor's or Master's degree in construction engineering or civil engineering, remarkable project management skills, and affinity with the industrial construction industry. Furthermore, some design skills and a practical attitude are asked.

For the analyses of the absorptive capacity the asked skills in the job vacancy are made concrete. The definition of engineering design skills are adopted from Mourtos (2012) and consist of the following:

- Analytical skills; *solid fundamentals in mathematics, physics, and mechanics*
- Open-ended problem solving skills; *identify, formulate, and solve problems*
- Total engineering view; *system perspective, overviewing the manufacturing process, awareness of knowledge boundaries*
- Design tools; *freehand drawing, and computer aided drawing/design*
- Interpersonal, communication and team skills

For each engineering change it is assessed whether or not the concept development team has the absorptive capacity to perform the engineering tasks in-house based on the above mentioned skills.

Indoor walls

The absorptive capacity of the concept development team to internalise competencies and capabilities to make production drawings for this engineering change is high. The concept development team should be able to make these drawings based on the required design skills (design tools) as described above. However, making the machine files for the specific machinery of Reinaerdt, cannot be absorbed that easily. This is also not in the job description of a technical concept developer nor in the definition of engineering design skills. So, making the production drawings is a task that can be internalised, however creating machine files should be outsourced. This level of absorptive capacity opts for cooperation in a design team, where MorgenWonen can make the production drawings, and the supplier only has to translate these into machine files.

Pre-fab meter box

Designing the prefab meter box requires some design skills. Since the job description of MorgenWonen asks for experience in integral design of housing construction, it can be assumed that the absorptive capacity of these skills (total engineering view) are high according to the definition of engineering design skills. However, the detailed engineering of the floor slab and contents of the meter box is not a competency that a technical concept developer should have and is also not included in the needed skills of a design engineer. When it comes to this detail the role of the technical concept developer is coordinating the process from a system perspective. Therefore, the overall design process can be guided by MorgenWonen, whereas detailed engineering should be done by suppliers according to this influencing factor. This asks for a level of vertical integration like a design team.

Entry layout

Changing the entry layout has great consequences for the design and it impacts multiple elements. Absorbing the competencies for detailed engineering of these elements cannot be expected from the concept development team since these are not the required skills of a design engineer. When it comes to this level of detail, the role of the concept developer becomes coordinating the process from a system perspective (total engineering view). So again, the level of vertical integration reaches a design team to optimally integrate this engineering change in the design.

5.2.4 Supplier specific knowledge

The assessment of supplier specific knowledge is based on the core competencies of the suppliers. It is assumed that the core competency of a supplier is supplier specific, otherwise everyone could perform the tasks of the supplier. If the tasks for the proposed engineering change do not comply to the core competencies of the suppliers, it has no need for supplier specific knowledge and can thus be performed in-house.

Indoor walls

Adding the standard recess to the indoor walls does not require supplier specific knowledge. Adding the standard recess is not a core competency of Reinaerdt. The only specific knowledge that is required is creating the machine files, but this will be the case for any supplier of indoor walls and does not belong to the core competency of Reinaerdt. The same reasoning can be done for the production drawings, and therefore this task can be performed in-house.

Prefab meter box

The pre-fab meter box does require supplier specific knowledge. Detailed engineering of the contents of the meter box and the computation of the floor slab are done based on the knowledge of the suppliers and it belongs to the core competencies of Homij, Westo and Aveco de Bondt. They have the specific skills and knowledge to fulfil these tasks. Therefore, this engineering change opts for a preferred supplier according to this influencing factor.

Entry layout

Changing the entry layout of the design also includes a lot of detailed engineering of the concrete elements that is done by the suppliers of MorgenWonen. The detailed engineering belongs to the core competencies of Westo and Aveco de Bondt and it requires supplier specific knowledge. Therefore, this influencing factor theoretically implies that the activity should be outsourced to these preferred supplier.

5.2.5 Summary of theoretical implications

A summary of the theoretical implications as described above is given in Table 5-1. The level of vertical integrations that best fits is given in the last column. This decision is based on equal importance of the influencing factors as described in literature. So the average of the indicated level of vertical integration for each influencing factor determines the overall decision.

Table 5-1, Summary of the theoretical implications

		Standard recess	*Prefab meter box*	*Entry layout*
TCE	*Uncertainty*	Preferred Supplier	Design Team	In-house
	Asset specificity	Preferred Supplier	In-house	Design Team
RBV	*Closeness to current tasks*	Preferred Supplier	Preferred Supplier	Preferred Supplier
KBV	*Absorptive capacity*	Design Team	Design Team	Design Team
	Specific knowledge	Design Team	Preferred Supplier	Preferred Supplier
Decision		**Preferred Supplier**	**Design Team**	**Design Team**

5.3 Current buyer-supplier relationships

The current buyer-supplier relationships are characterised by an organisational lock-in. MorgenWonen, as daughter organisation of VolkerWessels, has preference for supplying products and services within the conglomerate. Therefore, the buyer-supplier relationships of MorgenWonen and the supplier network are characterised as tight. None of the relationships are merely market exchanges, since all suppliers did some asset specific investment for the concept of MorgenWonen. The supplier network can be seen in Figure 5-6. It shows the mutual interdependencies among the suppliers of MorgenWonen, giving insight into the complexity of the supply base. The specific buyer-supplier relationships for the proposed engineering changes are described on the next page.

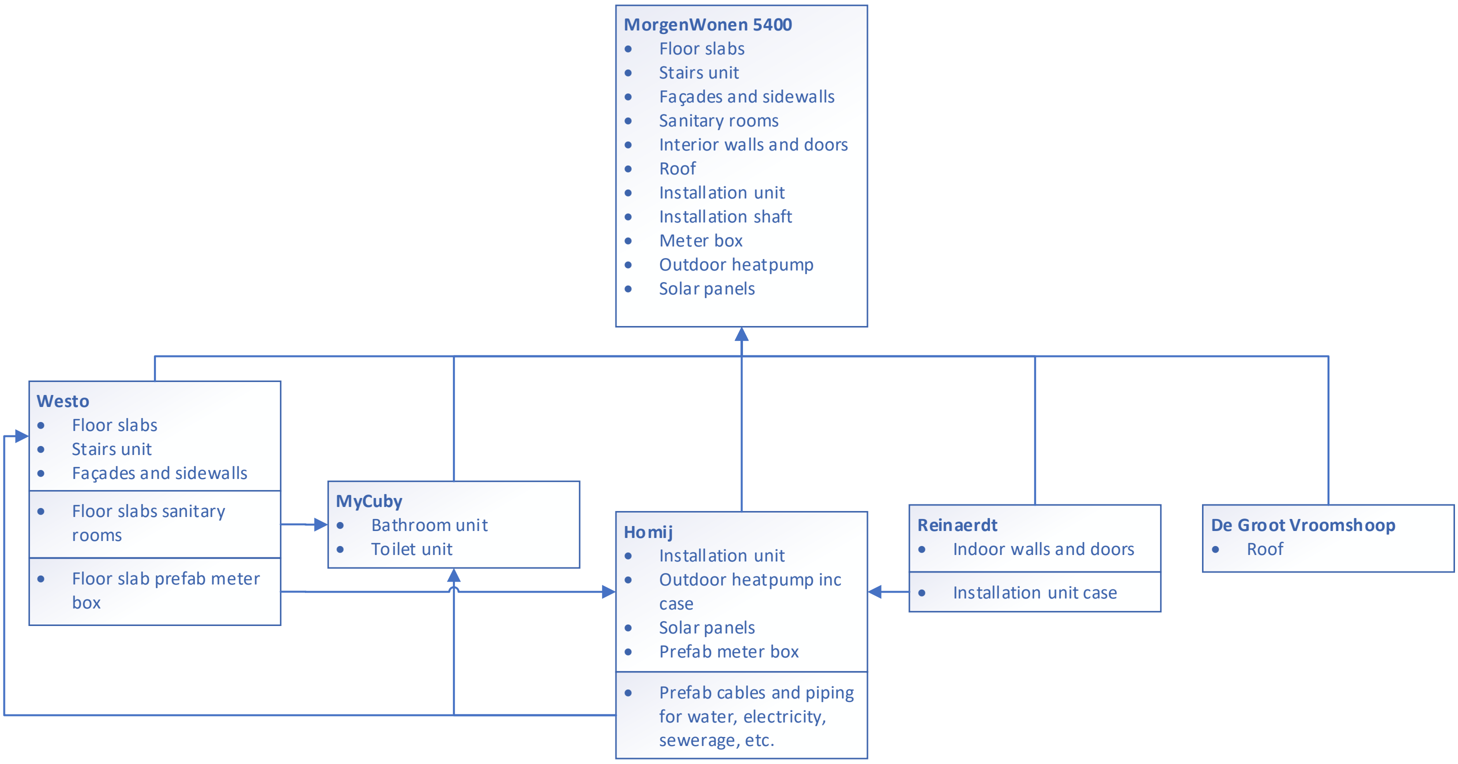

Figure 5-6, simplified supplier network of MorgenWonen

5.3.1 Standard recess

Adding a standard recess to the interior walls only affects one of the elements in the concept of MorgenWonen: the interior walls and doors. As can be seen in Figure 5-6, the interior walls and doors have no connection with other suppliers in the supplier network. The only two parties involved in the engineering change are Reinaerdt and MorgenWonen. In practice MorgenWonen does most of the engineering for Reinaerdt, which mostly includes making production drawings for the interior walls.

5.3.2 Prefab meter box

The prefab meter box is designed in collaboration with Homij. As can be seen in Figure 5-6, Reinaerdt and Westo are also involved in the supplier network for the prefab meter box. In practice MorgenWonen wants to act as the systems architect, functioning as the middle man between the three parties involved in the engineering change. MorgenWonen should set the boundary conditions for the suppliers, and the suppliers are responsible for the detailed engineering of their element. However, MorgenWonen still performed most of the detailed engineering, due to unclear division of responsibilities in the process. Therefore, MorgenWonen is right-oriented (R) in the level of vertical integration. This will become more clear in the next chapter 0 – Practice vs. Theory.

5.3.3 Entry layout

Changing the entry layout initially changes the front façade and sidewall, and through this engineering change floor elements, and indoor walls change. Figure 5-6 shows that the floor elements, and façades and sidewalls are dependent on products from Homij. In this relation, MorgenWonen sets the boundary conditions for Westo, who is responsible for ordering the right cables and piping for their concrete elements in accordance with Homij. Furthermore, MorgenWonen is responsible for ordering the right types and dimensions of interior walls and doors.

An overview of the theoretical implications and practical findings is given in Table 5-2

Table 5-2, theoretical implications and practical findings

	Standard recess	*Prefab meter box*	*Entry layout*
Theory	**Preferred Supplier**	**Design Team**	**Design Team**
Practice	**Design Team**	**Design Team (R)**	**Design Team**

6 Results: Practice vs. Theory

The previous two sections described theoretical implications for the level of vertical integration and actual situation. This chapter focusses on why theory differs from practice. A focus group is carried out with the management team of MorgenWonen to identify which influencing factors are more important than others, or if there are any factors missing in the conceptual framework. It is found that product complexity is an important influencing factor for the management team for the choice of vertical integration. Furthermore, the lack of buyer specific knowledge from the supplier is an important influencing factor in the sourcing decision which was not incorporated in the theoretical framework. The argumentation is given below according to the three proposed engineering changes.

The first engineering change should be structured like a preferred buyer-supplier relationships according to literature. In this relationships MorgenWonen should only set the boundary conditions of the engineering change and give full responsibility to Reinaerdt to do the engineering work. However, in practice most of the engineering work is done at MorgenWonen in collaboration with Reinaerdt, who only makes the final machine files. This characteristically describes a design team rather than a preferred supplier relationship. The main reason as discussed in the focus group for this choice was the lack of man power and understanding of the product and process of MorgenWonen at the supplier. The supplier was simply not capable of performing the job due to lack of 'buyer specific knowledge'. An overview can be seen in Figure 6-1.

It is important to note that buyer specific knowledge differs from supplier specific knowledge. Buyer specific knowledge entails knowledge of the supplier about the product and process of the buyer, while supplier specific knowledge refers to knowledge of the supplier about its internal products and processes that are hard to imitate.

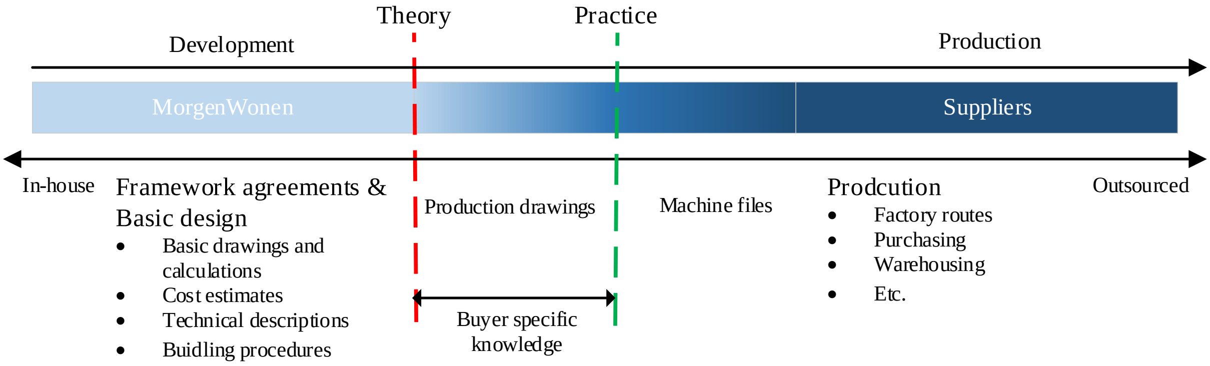

Figure 6-1, overview of practice vs. theory for engineering change #1

The second engineering change, the prefab meter box, should be designed and engineered with a design team, according to literature. In reality this has also been the case, where the concept development team of MorgenWonen acted as the system's architect of the engineering change. The most important factor for the choice of this level of vertical integration is the product complexity, with high uncertainty due to the number of affected elements and involved suppliers, and with high asset specific elements. In the focus group it was concluded that product complexity was the driving motivation for the level of vertical integration. According to literature it can be seen that the process could be internalised for the influencing factor asset specificity instead of a design team (Table 5-1). This is to avoid opportunistic behaviour of the supplier. In reality this behaviour is observed at the supplier from the prefab meter box, and therefore the actual level of vertical integration has shifted to the right (R) as seen in Table 5-2 and Figure 6-2. For a long time Homij held on to their proven concept without innovating since the responsibilities were unclear in designing and engineering the prefab meter box. Especially for this type of behaviour, literature suggests to internalise these processes. However, due to the lack supplier specific knowledge and organisational lock in (as described before) MorgenWonen stuck to the buyer supplier relationship to fulfil the engineering change.

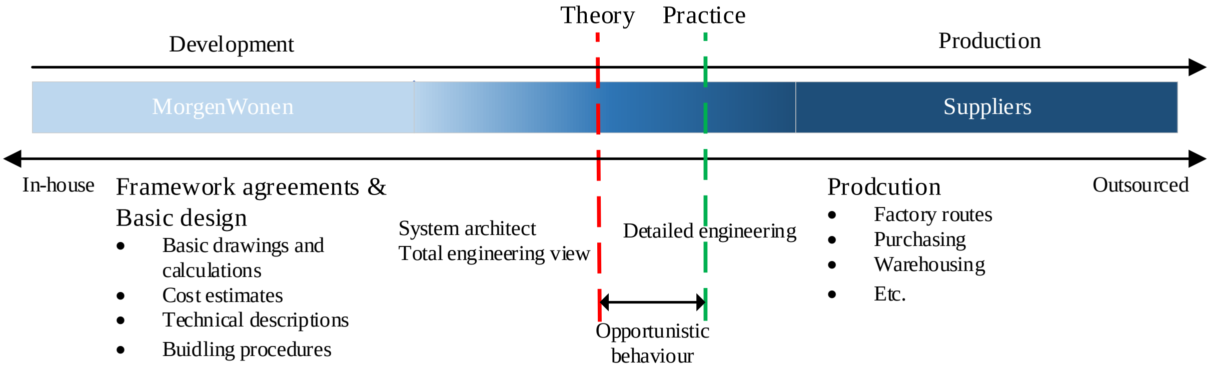

Figure 6-2, overview of practice vs. theory for engineering change #2

For the last engineering change, changing the entry layout, literature opts for a design team as well. In reality MorgenWonen acts as the system's architect, but in a more complex system where Homij (installations) also directly supplies to Westo (concrete elements), who should be responsible for sourcing the needed parts at Homij. Furthermore, Reinaerdt is involved in this engineering change, and gets the order from MorgenWonen as the system's architect. This engineering change has not been implemented yet, however, similar changes including the same types of elements and suppliers have had the same level of vertical integration. Therefore, this level of vertical integration is assumed for the engineering change. So, again the choice for a design team is made due to the product complexity of the engineering change (affected elements and involved suppliers) and needed supplier specific knowledge, according to literature and the management of MorgenWonen. The dispersity between theory and practice is minimal An overview is given in Figure 6-3

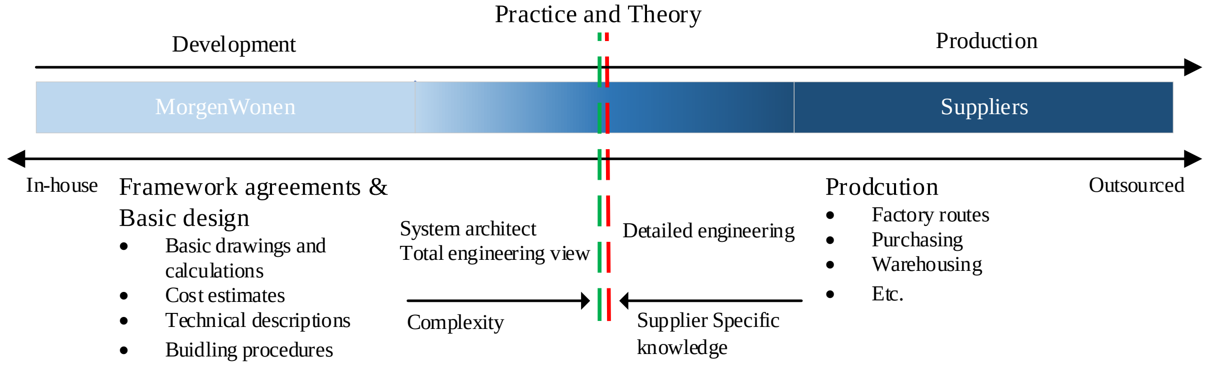

Figure 6-3, overview of practice vs. theory for engineering change #3

6.1 Assessment framework

It can be seen that the product complexity, and supplier and buyer specific knowledge are important factors in the level of vertical integration. A commonality between these factors can be observed. High product complexity makes it hard for a supplier to understand the product and process to a level that they are able to fully engineer the product. The supplier needs to have a lot of knowledge about the whole system to be able to comprehend the complexity of the engineering change. Furthermore, since most engineering changes have a high product complexity (due to the complexity of the whole system) and require supplier specific knowledge (for detailed engineering) it can be concluded that most engineering changes require a 'design team'-approach, where MorgenWonen acts as the system's architect, overarching all buyer-supplier relationships, and utilise the supplier specific knowledge of their products to a full extend. This makes product complexity, supplier specific knowledge and buyer specific knowledge the most important influencing factors in determining the level of vertical integration. The theoretical framework is adapted to these practical insights at MorgenWonen (Figure 6-4 on the next page), where the most important influencing factors are highlighted. The new framework gives more insight in the influencing factors than solely basing it on theory.

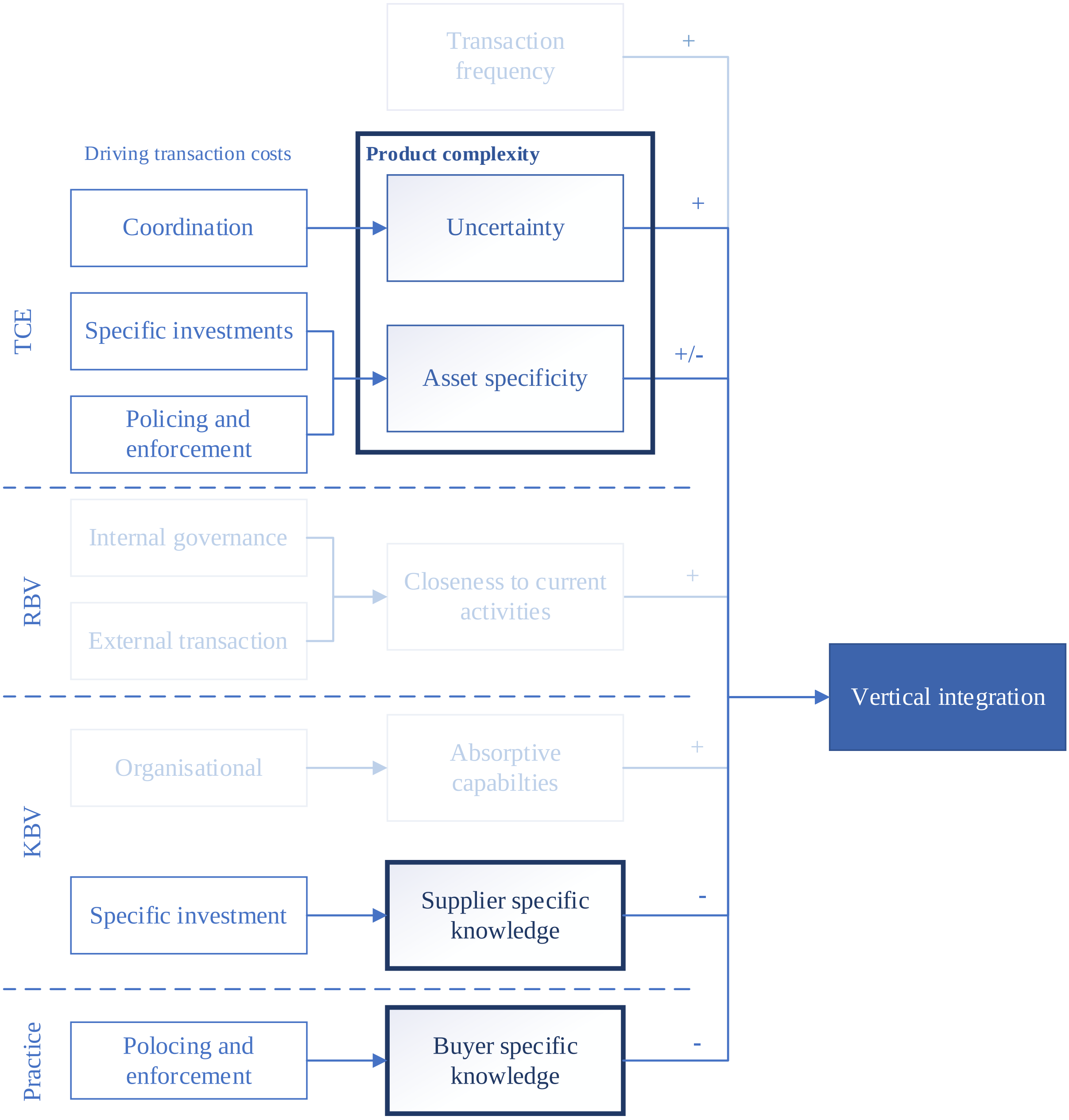

Figure 6-4, theoretical framework adapted with practical considerations

From this new 'theoretical' framework an assessment framework can be drawn in which the optimal level of vertical integration can be assessed. The picture on the next page (Figure 6-5) shows how the assessment framework for vertical integration looks like based on the theoretical and practical implications found during this research. The most important influencing factor considered in this research is the product complexity. Once an engineering change affects multiple elements or involves multiple suppliers the level of vertical integration is directly at the design team or higher, since MorgenWonen acts as the system's architect in these changes. The framework leads to a design team when supplier specific knowledge (core competencies of the supplier) is needed to carry out the engineering change. If this is not the case, the task can be performed in-house. Engineering changes that are not complex (one affected element and involved supplier) can be outsourced to the preferred suppliers, but only when they have the capability to do so. This means that they should have the capacity (man power) and knowledge of the product and process of MorgenWonen to perform the tasks. When this is not the case, the concept development team should perform the task in-house, if they know how to, or in a design team.

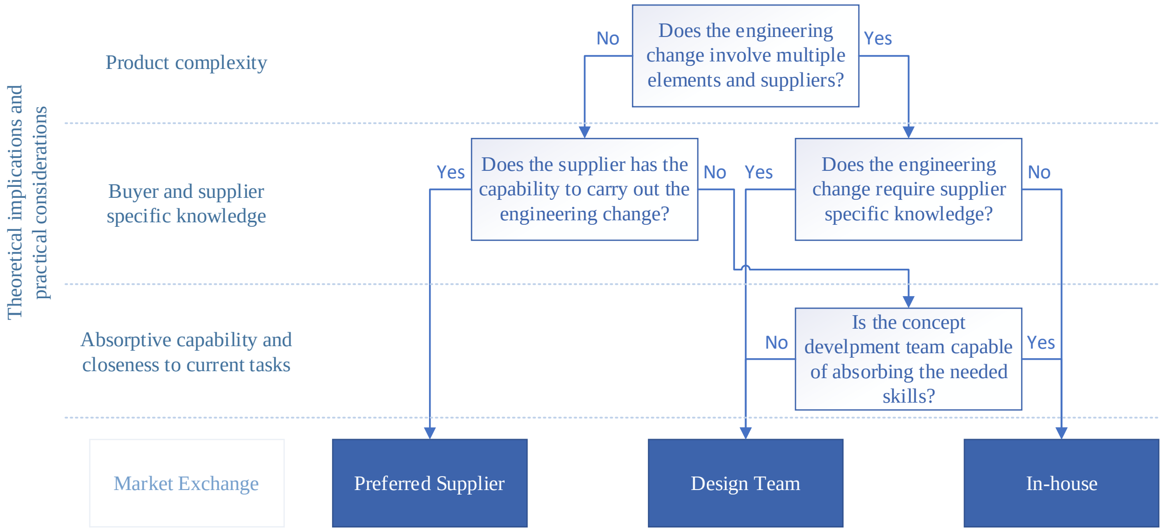

Figure 6-5, Assessment framework for vertical integration

7 Discussion and Suggestions for Future Research

This research adapts three grand theories of purchasing, and uses them to explain and justify choices for vertical integration. However, the RBV and KBV are originally theories that describe a firm's competitive advantage rather than giving arguments for setting firm boundaries (Eisenhardt et al., 2000; Mesquita et al., 2008). The RBV and KBV explain how a set of specific resources can give a firm competitive advantage over other firms, while TCE-theory actually explains how firm boundaries are determined. Still, researchers argue that the RBV and KBV can complement TCE with argumentation for setting firm boundaries (Gulbrandsen et al., 2009). Whereas TCE is concerned with market failures that determine the transaction costs of a resource, and thus minimising these costs, the RBV focusses on internal resources and competencies, emphasising on performance gains resulting from boundary decisions based on these internal resources and competencies. This argumentations applies to the KBV as well, since the KBV is an adaptation from the RBV with knowledge as the most strategically valuable resource. So, while the RBV and KBV are initially not theories that explain firm boundaries, they do complement TCE-theory with other perspectives of setting firm boundaries.

These three theories are not the only grand theories in purchasing and organisation management. For example, the resource dependency theory or relational view are theories that take a firm as the primary unit of analysis (Dyer & Singh, 1998; Pfeffer & Salancik, 2003). However, both theories do not touch upon any argumentation for setting firm boundaries. The relational view according to Dyer and Singh (1998) states that a firm's critical resources can transcend firm boundaries. Opposed to the RBV, the relational view states that it is not necessarily needed to have all strategic resources in-house, but within your supplier network. When one might say that the supplier network of a firm is a strategic resource, the relational view can be seen as an adaptation of the RBV where the supplier network is of most strategic importance. On the other hand, the resource dependency theory from Pfeffer and Salancik (2003) states that dependence on critical resources affects the actions of organisations and organisational decision-making. The organisational decisions, like the level of vertical integration, can be explained by the dependency situation (Nienhüser, 2008). In this light, further research is suggested, where the power and dependency structures between the buyer-supplier relationships are examined for its effect on vertical integration for industrialised housing construction.

Furthermore, this research is conducted for industrialised housing construction as mentioned above and in the introduction. However, generalising the conclusions from this study for the whole industry would be too short-sighted. The analysis for vertical integration is done in the setting of industrialised housing construction, but within a specific company with its own organisational characteristics. Therefore, it is important to keep the organisational structure of VolkerWessels and MorgenWonen in mind when adopting argumentations from this study. This also leads to suggestions for further research. Similar research, in the same industry, but with a different subject company could lead to more general conclusions and argumentation for the level of vertical integration in the supplier network of firms in industrialised housing construction.

Not only the amount of researched companies influences the reliability of the conclusions of this research. The amount of cases that are used within this research only count up to three. More cases could give a better implication for the optimal level of vertical integration. In most of these cases the level of vertical integration was not consciously made based on theory, but developed due to historical events. Furthermore, these historically developed sourcing structures are not made by the management team of MorgenWonen with whom the focus group is held. Another suggestion for further research is to do a similar analysis at the same organisation in a view years. In this way, the levels of vertical integration within the buyer-supplier relationships are more consciously taken and based on the assessment framework given in this thesis. The future research should give more precise indications of which influencing factors are of more importance than others, since they are based on experience rather than insights of the management team.

8 Conclusions

This chapter focusses on the conclusions that can be drawn from this research. Three main conclusions are identified. First, large engineering changes with multiple affected elements and involved suppliers should be developed in the structure of a design team. Secondly, small engineering changes that can be developed in isolation from other elements or engineering changes can be outsourced to preferred suppliers if they have the capacity and knowledge in-house. Lastly, completely internalising the engineering work of large engineering changes is not possible, due to the supplier specific knowledge needed to fulfil the engineering tasks.

The first general conclusion that can be drawn from this research is that complex engineering changes should be developed in the structure of a design team. The complex engineering changes include multiple affected elements and involved suppliers. MorgenWonen should act as the system's architect, coordinating the process and making use of the specific knowledge from the suppliers. Especially the complexity of the process (high complexity means insource) and supplier specific knowledge (high specific knowledge means outsource) causes the choice for a design team as can be seen in the theoretical framework and assessment framework in chapter 6.1. How a this design team should be organised and what competencies should be present is discussed in chapter 9 – Managerial Recommendations.

The second general conclusion is focussed on the smaller and isolated engineering changes. These changes only affect one element and one supplier. These engineering changes can be outsourced to the preferred supplier due to the low complexity. However, in practice the supplier does not always have the knowledge about the whole product and processes of MorgenWonen or the supplier does not have the capacity to engineer the design change. In this case the concept development team can become responsible for the engineering change if they have enough knowledge of the product of the supplier. So, both supplier specific knowledge and buyer specific knowledge are important factors in the sourcing decision for low complex engineering changes.

Lastly it can be concluded that fully internalising the engineering tasks accompanied with an engineering change hardly ever occurs. This conclusion can be made due to the supplier specific knowledge that is needed to engineer specific elements. For example, rebar calculations for concrete elements are done by an engineering firm that is specialised in these types of tasks. Another example is engineering the contents of a prefab meter box, which requires supplier specific knowledge to determine the elements that should be incorporated into the meter box. So, fully internalising these engineering tasks is not possible, since this knowledge is not in-house and are core competencies of the suppliers.

9 Managerial Recommendations

The managerial recommendations are given in this section. The first recommendation is to follow the given guidelines from this research. Besides that, a sourcing strategy for the 'in-house' companies of VolkerWessels should be developed. Further details about these conclusions and recommendations can be found below.

The conclusions above lead to the first managerial recommendation: defining a sourcing strategy for the 'in-house' suppliers of MorgenWonen. In the current situation MorgenWonen is on the same level as the other industrialised construction firms of VolkerWessels (which are the suppliers of MorgenWonen). However, in the author's opinion, MorgenWonen should function as system architect for the MorgenWonen concepts, making them the lead firm for concept development and coordinating organisation in engineering changes. This gives the concept development team more control over the processes of the engineering change. Skills and competencies are needed to take this responsibility. Especially the total engineering view as described earlier is an important skill that the concept development team should possess. This skill entails that the concept developer is able to: 1) **oversee the manufacturing process**, understanding the industrial perspective and engineering aspects of the process. In the context of MorgenWonen this means that the concept developer should be able to completely oversee the industrialised construction process, with all the interrelations among and specific processes within the different suppliers. 2) work in **multidisciplinary teams**, with a system perspective. The concept developer is able to work with all suppliers of MorgenWonen with their different expertise, but also with the different internal teams of MorgenWonen. He/she can link the internal needs of the company with the external possibilities of the suppliers. 3) have **awareness of the limitations** of the concept development team, internal teams, and external suppliers. In this way the concept developer is able to coordinate the needed knowledge and expertise within the process of the engineering changes. These three skills have two things in common: supervision and coordinating. Therefore, the concept development team should have supervision and coordination skills to develop and engineer complex engineering changes with multiple affected elements and involved suppliers.

It is also recommended that the management team of MorgenWonen follows the prescribed guidelines as given in the assessment framework in this thesis. These guidelines are specifically defined for MorgenWonen with a theoretical background and practical considerations, making them tailor made for the organisation, since theoretical implications only might be to generalised. It should be noted that the conclusions of this research are based on the currently assessed buyer-supplier relationships. Therefore, it is recommended that the assessment framework is used for all other buyer-supplier relationships during engineering changes. The situation (complexity, buyer specific knowledge, supplier specific knowledge, etc.) must be critically assessed every time that the framework is used. In this way it becomes clear what the division of responsibilities are, not only for MorgenWonen, but for all the involved parties in the engineering change. In short the following recommendations of division of responsibilities can be made: 1) if the engineering change involves multiple affected elements and involved suppliers, MorgenWonen should act as a system's architect, coordinating the process. 2) if the engineering change entails only one element and supplier and the supplier has the capability to perform the task, outsource the engineering change to the preferred supplier. 3) if the engineering change cannot be outsourced due to the lack of capabilities of the supplier, try to work in a design team where the concept development team has a supportive function to the supplier.

10 Scientific Contribution

This research contributes to the current knowledge of industrialized housing construction in a way that it integrates supply-base management actively with the changes in design. Up to the author's knowledge this perspective has not yet been used in the IHC literature for sourcing decisions. Where, for example, modularity and design rules as input for the sourcing decision (Hofman et al., 2009), complexity in traditional construction industries (Dubois & Gadde, 2002), and product platforms in the housebuilding industry (Veenstra et al., 2006) have the most similarities with this research, they do not take the same approach as used in this thesis, where the level of vertical integrations is determined based on three grand theories and practical insights.

However, the conceptual framework used in this research is similar to the framework of Wiegard (2020), who does make use of TCE, RBV and KBV to conceptualise the sourcing decision. However, her conceptual framework is applied to the automobile industry, whereas this research focusses on the industrialised housing construction. In her research, Wiegard (2020) assesses how the three generalised theories in purchasing and organisational management are applicable for embedded software in the automobile industry. The results show that the theoretical implications from the three proposed theories are only partially applicable. This research found similar results, where the theoretical implications do not perfectly match with the practical insights. So this research supports the conclusions of Wiegard (2020), that the generalised theory is partially applicable for certain researched business areas or industries.

Furthermore, TCE assumes that the market can always offer a buyer's demand. Berg (2008) states that TCE assumes that productive capability is homogeneous among firms, so every firm has the capability to perform their key tasks in-house. However, this research has found that this does not apply in practice. The capability of the supplier, consisting of knowledge and capacity, can lack in practice. This affects the sourcing decision of the buying firm, resulting in vertical integration of the initially outsourced tasks or services. So this research contributes to the scientific literature in a way that it found evidence for differences in theoretical assumptions and practice, especially when talking about TCE.

Lastly, the importance of this research is stressed by Fixson (2005) who states that the interdependencies within a product can affect the sourcing decision; where simple commodity items can be outsourced, but performing tasks with high strategic value should be done in-house. This research looks at the interdependencies within the product architecture to determine the design impact of the sourced goods and services. So applying this in practice at MorgenWonen is of great importance for optimising the supplier strategy.

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12 Appendices

12.1 Focus group set-up

1. First show the theoretical implications of the level of vertical integration for the proposed engineering changes.
2. Discuss how the current supplier relations look like within these proposed engineering changes.
3. Discuss why there is a difference between practice and theory.
4. Look for specific influencing factors in the sourcing decision of vertical integration.