

ALIGNING PRODUCT AND PROCESSES TO CUSTOMER NEEDS IN PREFABRICATED HOUSE BUILDING

by

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the Degree of Doctor of Philosophy of Cardiff University



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Abstract

Given the impact of increasing customer choice on operations, this thesis clarifies the role of customer preferences and its impact on the operations of a company in the house building industry. In doing so, an empirical investigation into customer choice requirements is offered and a framework that helps to align customer preferences with the product and processes is presented. A prioritisation of components is provided which ultimately helps to design houses that meet buyer requirements. Furthermore a method is presented that helps in prioritising problem areas.

This study is built on two empirical pillars and the evidence drawn from these sources. First, on the basis of a case study a view of the house as a system of components and sub-components has been developed. This resulted in the set-up of a product architecture in which the Customer Order Decoupling Point (CODP) could be positioned. Second, a preference measurement task applying a pairwise comparison questionnaire was conducted so as to define the level of choice expected by customers for the components.

An important outcome of the survey was to identify how customers actually prioritise categories and components in a prefabricated housing design. Combining the results of these two research exercises helps in making the correct decisions about the level of variety to offer.

The generalisability of the findings is limited. However, the process of conducting the case study as well as the preference measurement is generalisable in research that concentrates on products with a complex product architecture. The framework can thus be adopted by practitioners manufacturing multi-attribute products seeking to pursue a mass customisation strategy.

This research contributes by highlighting the importance of integrating process and product development in order to design a value chain that meets customer needs.

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NOMENCLATURE AND LIST OF ABBREVIATIONS

AHP:	Analytic Hierarchy Process
ATO:	Assemble-to-order
BDF:	Association of German Prefabricated Building Manufacturers (Bundesverband Deutscher Fertigbau e.V.)
BTO:	Buy-to-order
c:	Number of columns
CA:	Conjoint Analysis
CE:	Concurrent Engineering
CODP:	Customer Order Decoupling Point
DF:	Degree of Freedom
DTO:	Design-to-order
e.g.:	exempli gratia (for example)
ETO:	Engineer-to-order
EUR:	Euro
HoQ:	House of Quality
IDA:	Initial Data Analysis
ID:	Identification Number
i.e.:	id est (that is)
IP:	Internet Protocol
m:	Minimum number of rows
MAUT:	Multi-Attribute Utility Theory
MD:	Managing Director
MTO:	Make-to-order
MTS:	Make-to-stock
n:	Number of observations
PCPM:	Paired Comparison-based Preference Measurement
r:	Number of rows

s:	Standard deviation
STS:	Ship-to-stock
QFD:	Quality Function Deployment
TCT:	Total Cycle Time
U.S.:	United States of America
3-DCE:	3-Dimensional Concurrent Engineering

- 1. Out of clutter find simplicity.**
- 2. From discord find harmony.**
- 3. In the middles of difficulty lies opportunity.**

Albert Einstein, Three Rules of Work

Chapter 1

“Houses are built to live in, and not to look on: therefore let use be preferred before uniformity...” (Francis Bacon)

1. Introduction and purpose of study

The European house-building industry, and especially the self-build market, is faced with a clientele demanding homes that are individually configured to reflect personal and unique styles (Hofman et al., 2006). Traditionally, self-build is the practice of building an individual home as opposed to the speculative building where an investor acquires a plot of land and builds a standard shell without any involvement of the end-customer. In meeting the above-mentioned challenge, some house builders have adopted customised marketing strategies combined with operational strategies that involve the transfer of established theory from manufacturing to house building (Barlow et al., 2003; Winch, 2003). This has resulted in houses being prefabricated in a factory environment. It is therefore important to manage the interface between marketing and operations effectively as only this delivers customer value (Mollenkopf et al., 2011). Many researchers suggest that the concept of mass customisation is a solution to this problem. Given the impact of increasing customer choice and, consequently, product variety on operations, the aim of this research is to investigate customer choice requirements in the self-build market so that customer preferences and the operations of a business can be aligned. Ultimately, this will not only result in customer satisfaction but also in a competitive advantage for the business (Fisher, 1997).

This chapter provides the background for this study and establishes the academic as well as practical context. Following this the research motives and objectives of this study are demonstrated. Existing literature gaps then lead to the research questions which this thesis aims to answer. Finally the overall structure and research contribution of the thesis are outlined.

1.1. Industrial and research context

The need to provide homes following the Second World War, combined with the available capacities in the form of disused armament factories, led to a significant drive to produce houses in a factory environment (Gibb, 2001). The result was the prefabricated house, or 'prefab', which was produced in several different designs and erected innumerable times. Even for this era, some of these houses were already well developed and designed. At the same time, mainly in Europe, a different approach to manufactured houses was developed. Companies started to produce reinforced concrete panels which were then used for low- and medium-rise applications. A further alternative approach to manufactured housing was developed in the U.S. where factory-built timber frames were used to build houses. However, these houses were believed to be mainly suitable for low income groups so at first obtained little acceptance among higher income groups. In general the change of the house building sector toward manufacturing strategies has mainly been stimulated by increasing customer demands in terms of design, time and costs (Gann, 1996).

Overall there is a growing demand by potential buyers for individualised products. People make choices based on personal tastes and preferences which are shaped by many different factors: family environment, physical condition, age, sex, education, religion and location (Petersen and Lewis, 1999). It is therefore argued that it is extremely important to integrate customers not only into the production process but also the configuration and specification of products. This does not only increase customer satisfaction as expectations are met but it also increases efficiency and paves the way for a new set of cost saving potential (Piller et al., 2004).

Following the conceptualisation of mass customisation by Stan Davis in 1987, Joseph Pine (1993) refined the idea and has been one of the first researchers to give more detailed recommendations on how the concept can be used as a business strategy to satisfy individual needs with mass production efficiency. However, there currently exists no single form of the mass customisation concept applied to the house building industry. This concurs with the view of Barlow et al. (2003) applied to their case study of the Japanese customised homes industry who said: "... we wish to show that there is no

single form of mass customisation.” (p. 135). Although there has been extensive discussion covering a wide range of academic disciplines (Koskela, 1992; Gibb, 2001; Barlow et al., 2003; Larson et al. 2003; Naim and Barlow, 2003; Cuperus, 2003) in house building the topic is still lacking academic unanimity and rigour. In particular, it has not been appreciated that a house has a multilayer product architecture consisting of many different elements. Furthermore, in contrast to for example the automotive industry there is a number of external factors such as structural issues and building regulations that limit customisation opportunities. Most importantly, however, there is sparse literature looking at the alignment of customer preferences with the lowest level of the product architecture. This can lead to over-simplification and the wrong decisions being made with regard to the appropriate set-up of the operational capabilities.

Moreover, companies are often not aware of the particularities and requirements of a mass customisation strategy. Typically when producing mass customised products, the company has to cope with customer specific requirements due to a high degree of customer involvement (Gosling and Naim, 2009). This increases the need for appropriate order fulfilment strategies. In this regard, the house building industry has adopted strategies found in other manufacturing environments (Barlow et al., 2003). This has resulted in a range of potential set-up of capabilities providing different levels of customisation and an increased logistical effort due to smaller quantities, higher product variety and variable demand rates (Ahlström and Westbrook, 1999).

More variety makes it more likely that customers find their preferred options (Alford et al., 2000). To be able to deliver such variety at an acceptable cost it is important to find out how potential customers assign priorities to the different elements in a house that can be customised. If house building companies were already aware of customers’ preferences they could increase variety where it is really necessary and offer standardised solutions therefore taking advantage of economies of scale (Leishman and Warren, 2006).

One of the key issues in manufacturing mass customised products in an efficient way is to specify the position of the customer order decoupling point (CODP). This is the point

in the supply chain where the product is linked to a specific customer order and separates upstream from downstream processes (Olhager, 2003). Much of the existing literature on the CODP, however, focuses on one single separation point. Through a decomposition of a prefabricated house this study shows that there can indeed be multiple CODPs in the supply network for one product. The determination of the CODP on an overly aggregated level oversimplifies and cannot result in a thorough understanding of the operational processes and a potential improvement. The majority of research in this field defines the CODP as one single point of separation of upstream- and downstream activities in the supply chain. However, for products consisting of many different parts there exist multiple supply chains which are dependent on each other (Verdouw et al., 2006). It is therefore necessary to develop an understanding of the CODP positions in order to keep the complexity manageable.

Whilst determining the position of the CODP, it is important to ascertain who is affected by this particular position. Multiple CODPs in a supply network have different degrees of relevance to the stakeholders. From a company perspective, for example, the complete supply network is relevant and consequently all the CODPs that are positioned within it are relevant. Once the product has been specified and signed off, however, the customer is only interested in delivery time and therefore only the CODP on the aggregate level is relevant. However, both internal and external suppliers are involved in the further upstream processes, which is why not only the CODP on an aggregate level is relevant but also all the appropriate CODPs that exist within the production processes on a component and sub-component level.

The particularity of the house building industry as opposed to, for example the fashion industry, is that a house is a complex product. In this context the adjective 'complex' is defined as describing many different and connected parts (oxforddictionaries.com, 2013). In an operational context, Jacobs and Swink (2011) state that "a system or object (tangible or intangible) can [therefore] be deemed to be complex if it is made up of a multiplicity of diverse, interrelated elements." (p. 679). As a consequence, if one of the aforementioned three attributes (multiplicity, diversity and interrelatedness) increases, then complexity increases as well. In this regard an increased multiplicity means more

elements whereas an increase of diversity means more differences between elements. Finally an increase in interrelatedness refers to the common or interacting functions (Jacobs and Swink, 2011). Therefore, more complex products are those that consist of many different components and sub-component with many different attributes (e. g. many colours, style, size). Thereby the number of decisions a customer needs to make during the configuration process of the product is increased as well (Huffman and Kahn, 1998). Fixson (2005) recommends reducing product complexity by regrouping components into modules.

A house, or in more general terms, a building, is thus a highly complex structure with many connections and dependencies between multiple and diverse numbers of components, sub-components and even attributes. If, for example, the customer wishes to shift an internal wall from position A to position B this could potentially have an overall effect on the structural integrity of the building. Hence, the structural calculation needs to be revised and additional measures to compensate this change might become necessary. Because this complexity increases with added variety, Blecker et al. (2004) recommend identifying how much the market is willing to offer. It is therefore vital to know exactly what customer requirements are to decrease complexity and avoid difficult or impossible component combinations.

Similar problems have been monitored in the automotive industry where the product architecture is also complex. Pil and Holweg (2004) confirm that and conduct research in the industry which presents the total number of variations offered by the top 10 manufactures for their two bestselling car models. They find that although there exists no great difference with regard to the range of engines or paint-trim combinations, the manufacturers differ dramatically in the total product variations they offer. Pil and Holweg (2004) state that this difference is a result of firms offering the variety they think they need to offer. Furthermore, they point out that while variety helps marketing to entice new customers it does provide serious problems for the operations of a manufacturer.

Hofman et al. (2006) claim that interest in mass customised housing solutions has become more widespread. However, in order to be able to customise a house, customer requirements must be identified so that these can be translated into realisable products (Barlow and Ozaki, 2003). In this regard, it is remarkable that the prioritisation of housing attributes in house design customisation is still unknown to house builders. Any company can individualise its product as much as possible. But this cannot be the aim. Rather, it should be the objective of any business providing product variety to produce this variety in an economic way. Furthermore, such variety does not help if the chosen product versions do not correspond to the requirements of the customer base. In 2003, Barlow and Ozaki explored the concept of customer focus in UK house building. Here they state that in order to achieve customer focus, "... the context of a customer's purchase and their choice criteria..." (p. 90) needs to be understood thus adding value to products and services. This indicates the importance of developing an appropriate model to determine customer preferences that can be adapted to different house building methods.

Fisher (1997) denotes that the root cause for many problems is a mismatch between the type of product and the type of supply chain. Hence, an ignorance of customer preferences on the lowest level of the product architecture will influence the supply chain performance in a negative way. Conversely realigning supply and product strategies properly will result in a remarkable competitive advantage (Fisher, 1997). Fine (2000) points out that three activities need to be conducted concurrently in order to increase operational performance: product development, process development and supply chain development. Therefore, it is important to align the product design as well as the manufacturing and supply chain strategy appropriately as only then the business strategy can be operationalised and supported effectively. Therefore, there is a need to identify the operational capabilities accordingly and match these with the target market segment, thereby meeting the needs of the segment concerned and at the same time improving the operational performance of a business (Godsell et al., 2006). However, only few studies have measured and analysed customer preferences in the house building industry in order to create a basis for its customisation efforts.

This thesis connects the above mentioned topics, thereby clarifying the role of customer preferences for the operations of an off-site builder in the housing industry. A case study of the self-build house building industry and a survey were conducted and both provide the basis for statements made in this thesis.

1.2. Research motives and objectives

In any economy, construction has always been one of the most important industries, providing employment for many levels of intellectual and physical expertise and often creating remarkable, distinctive marks of civilisation (Groak, 1993). In the UK, the construction sector contribution to the GDP is currently at 7% (Trading Economics, 2013). In Germany, the impact of the construction industry is even higher: in 2012, the contribution to the GDP was 8.8% (Die Deutsche Bauindustrie, 2013). This makes it even more important that this sector is continuously brought forward by innovative ideas in order to optimise the operations.

However, the construction industry is not only important from an economical point of view. A house is also associated with offering shelter and protection from the elements. Typically 'house' is conflated with 'home' and the latter is a multi-dimensional concept of which the physical house is only one aspect (Mallett, 2004). Saunders and Williams (1988) for example define home as 'simultaneously and indivisibly a spatial and a social unit of interaction' (p. 82). Thus, the house as a physical structure represents the home and interior design, decorations and room layout can reflect the individual identity of the occupant (Mallett, 2004). This means that it should be the aim of the house building industry to consider individual requirements, thus providing suitable living environments.

But if meeting customer requirements is essential when delivering houses then an inevitable question is how one explains a customer's motivation in the design process. In this regard, Maslow's theory on the hierarchy of needs is considered to be suitable. In 1943, Abraham Maslow developed a motivational theory that argued that while people aim to meet basic needs, they strive to meet successively higher needs in the form of a hierarchy. The hierarchy of needs is often represented as a pyramid with five

levels. At the four lower levels are physiological needs and at the top level is the growth need. Maslow stated that the lower level needs must be satisfied before higher-order needs can be achieved. The five levels are as follows (Jobber, 2004):

- Physiological: the fundamentals of survival (for example hunger, thirst or shelter)
- Safety: protection from the unpredictable (for example security of environment, employment, health, property)
- Belongingness: striving to be accepted by those to whom we feel close and to be an important person to them (for example love, friendship, family)
- Esteem: striving to be regarded highly by other people (for example confidence, self-esteem, achievement, respect)
- Self-actualisation: the desire for self-fulfilment in achieving what one is capable of for one's own sake (for example morality, creativity, problem solving)

It seems logical that living space must be able to satisfy the more basic customer needs. Zavei and Jusan (2012) explore the selection of housing attributes based on Maslow's hierarchy of needs and conclude that ignoring human motivational factors in house building may lead to individual and social dissatisfaction and disorder. Therefore, linking Maslow's concept to the configuration of houses can be useful in establishing knowledge about different customisation requirements.

Apart from the aforementioned rational motives, the author was also personally motivated to conduct a study in the house building industry due to his professional background. In 1995, the author started an apprenticeship as a carpenter in the company that has been chosen as a case company for this particular study. Following the completion of the apprenticeship the author completed his Masters studies before he returned to the business in 2005. Since then it has been the author's desire to find out how operations need to be structured and organised in order to be able to accommodate a particular degree of choice. This is because the author has witnessed the numerous and manifold practical challenges that come along with a customer centric strategy within an industry that manufactures very complex products.

In 2009, in the early days of this PhD research, the “research roadmap” as shown in Figure 1.1 was developed. At the time it acted as a conceptual route map. Although the major steps of the thesis have been identified and highlighted, it is the connection between the steps, and finally the merging of the findings of each step, that was the biggest challenge. However, retrospectively it was very helpful to create the big picture, plot down the major ideas and define steps that need to be completed in order to reach the objective of the research.

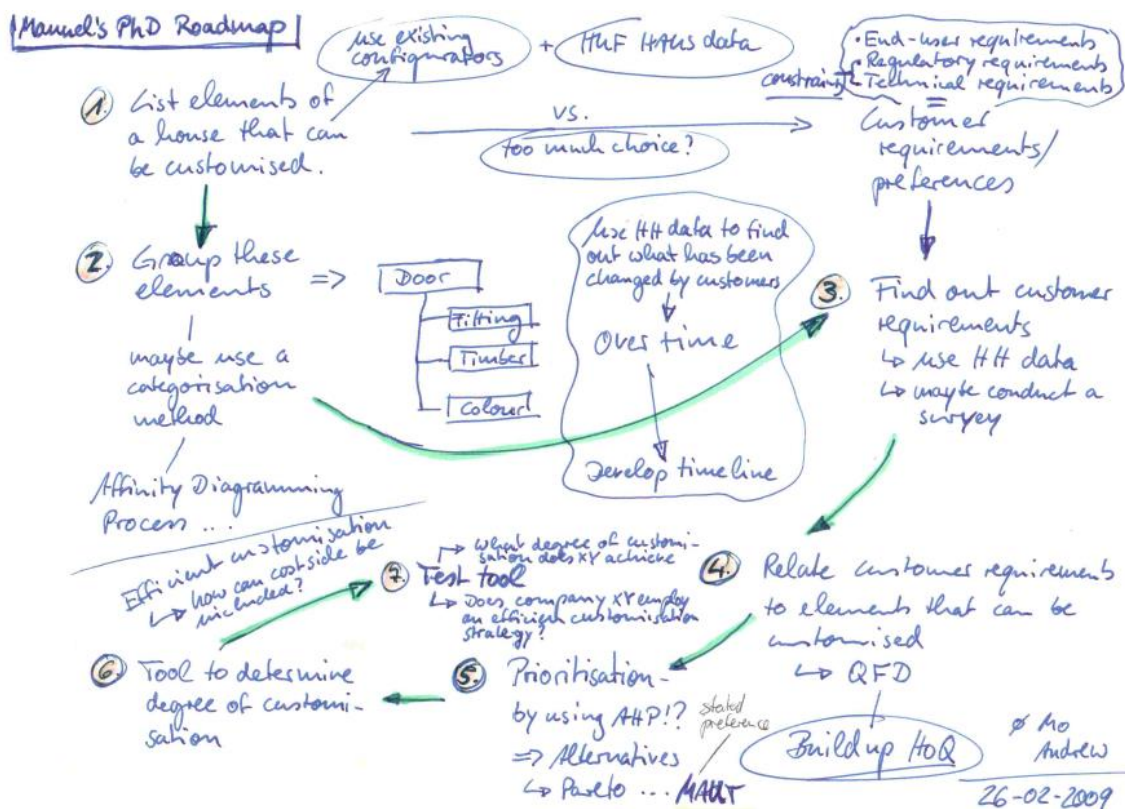


Figure 1.1: Original PhD roadmap of 2009 (source: author)

Step one in Figure 1.1 involved the identification of components within the product architecture that can be customised. At the time there was a concern that the data collected in the case company could not be sufficient and needed to be complemented with additional data from online configurators. The second step involved a grouping of these components, potentially using a categorisation model such as the Affinity Diagramming Process. Next to step two in the diagram there is a sketch of how the grouping exercise can result in a product hierarchy. Step three then involved the identification of customer requirements either using the case company’s data or data

that was collected by conducting a survey. In step four, the product architecture was linked to customer requirements. Following the first literature review in that area, the idea at the time was to apply Quality Function Deployment (QFD) and the House of Quality (HoQ). Step five involved the prioritisation exercise using the Analytic Hierarchy Process (AHP). Pareto and Multi-Attribute Utility Theory (MAUT) were considered as alternatives. As will be seen in Figure 1.3 and Chapter 3 all of the aforementioned methods have not been applied. This is because the literature review identified a modus operandi that is more suitable for this particular study. Step six was aimed to develop a tool with which the degree of customisation could be determined. This tool then needed to be tested.

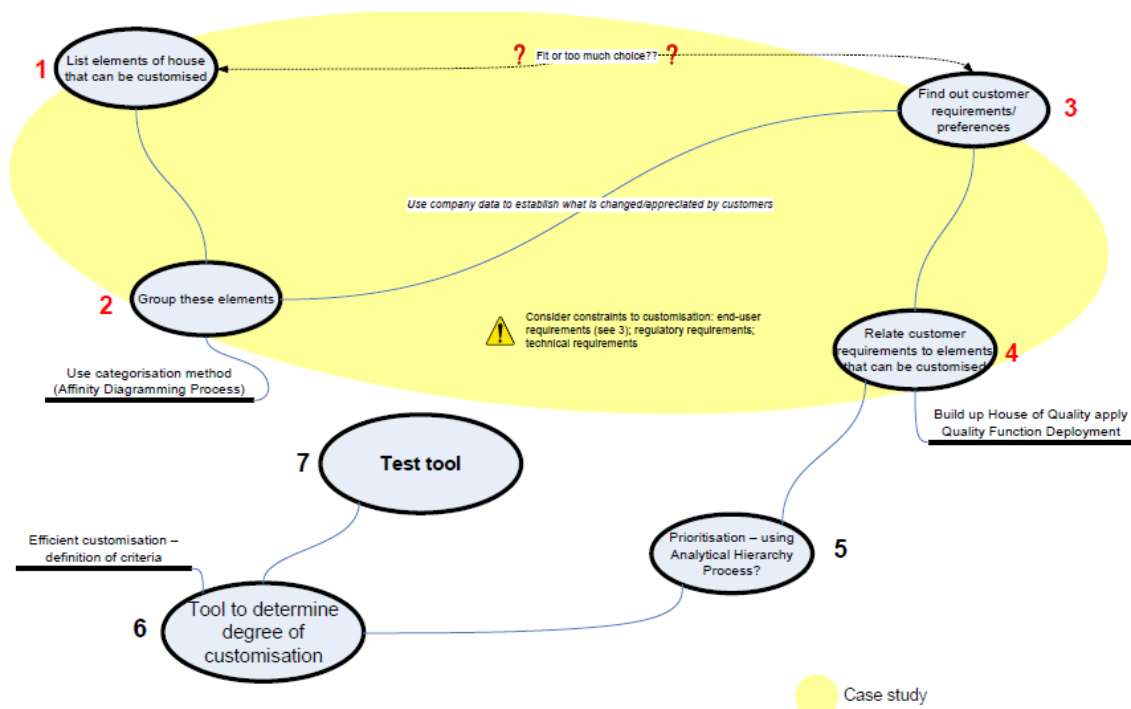


Figure 1.2: Simplified PhD roadmap of 2009 (source: author)

Figure 1.2 shows a simplified version of the PhD road map. In order to increase readability only the major steps are shown. The area highlighted in yellow shows the steps for which empirical work are required. For this thesis this involved a case study and a customer preference survey.

During the research the above roadmap was adapted: new ways needed to be located and the objectives have been restated. Steps three, four and five, for example, have

been merged and could be completed by setting up an online customer preference survey. The basis for this survey was the product architecture, which has been identified in steps one and two. However, as mentioned above, it was very helpful to start with the big picture, which during the process condensed into realistic and relevant contents.

In addition to Figures 1.1 and 1.2, Figure 1.3 shows how the research was actually conducted. It shows that the core of the research consists of three steps: case study, customer preference measurement and development of an alignment framework. Contrary to what is shown in Figure 1.2 the actual research process resulted in the establishment of a product architecture, which was determined by a combination of primary and secondary data. The point of customer involvement, that is, the degree to which the product and its components are customised, could be identified by considering the positioning of the CODP. These methods were not in the simplified roadmap as their suitability for the research was identified only during the literature review.

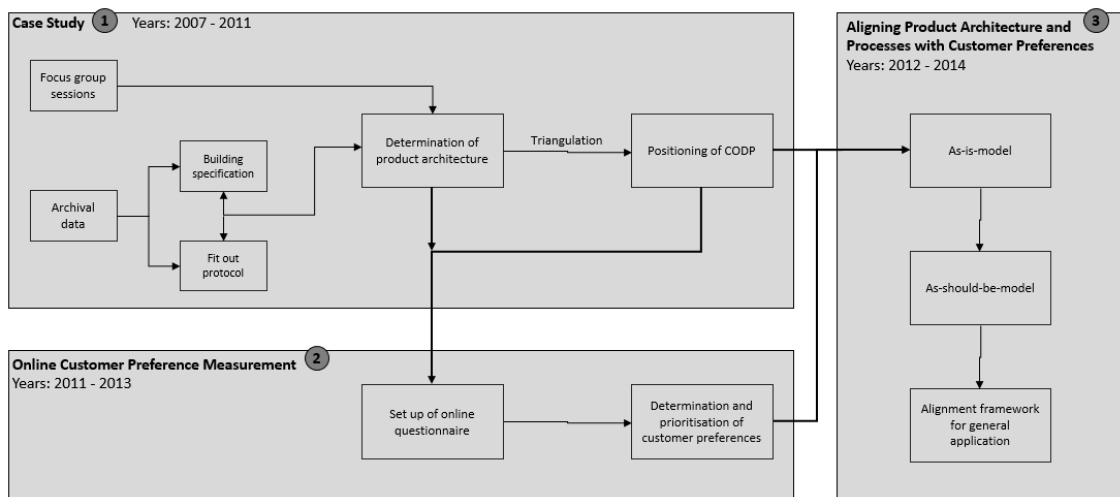


Figure 1.3: Overview of actual incremental research process (source: author)

The online preference measurement proved to be more demanding than originally anticipated. However, it was possible to combine steps 3 to 5, as shown in Figure 1.2, by applying an AHP based approach. Finally, contrary to what is stated in Figure 1.2, the result of the research is not a tool to determine the degree of customisation. In fact a method has been developed which shows a way of how to align a company's product

architecture and processes with customer preferences. Each of the steps as shown in Figure 1.3 and its interdependencies is explained in detail in the following chapters of the thesis.

As indicated above the research was an incremental process. Hence, most of the research was conducted in consecutive steps and each step provided the basis for the next step. The findings of each step were incorporated in the alignment framework as presented in chapter 6. Figure 1.3 also shows the timeline of the complete PhD project from year 2007 to 2014.

1.3. Aim and purpose of study

The primary research aim of this thesis is to present a method of how product and processes can be defined and aligned with customer preferences. From this process and product based analysis valuable conclusions for the set-up and management of the supply chain can be drawn. The latter, however, is not within the scope of this research.

In doing so, an empirical investigation into defining the product architecture and customer choice requirements in self-build house building is conducted and as a result a framework that helps to align customer preferences and the product is presented. Therefore, this thesis researches the interface between marketing and operations management in a house building specific environment.

The unit of analysis in this research is the single case with embedded units of analysis. This will be further clarified and elaborated on in depth in chapter 3.4.

There is clearly a need to clarify what customers prefer when configuring a house. Furthermore, there is sparse literature looking at the alignment of the identified customer preferences with the product and processes of a business. This thesis offers an empirical investigation into customer choice requirements and suggests a framework that helps to bring customer preferences and operational capabilities in alignment. In doing so, the author has developed an approach that helps to identify the architecture

of a product. This was necessary so that the impact of choice could be traced into the lower levels of the product architecture.

This research concentrates on the principles of concurrent engineering by which product development and production are aligned so that the process is not linear but more concurrent. Knowing that supply chain development is an integral part of meeting customer's needs, this work offers good starting points for further, supply chain focused research. However, due to the content of this research it cannot be claimed that the end-to-end supply chain will be the focus, as this would require an analysis of the supply chain structures, logistics and inventory. Hence, this study's aim is to highlight the importance of alignment between the processes and operational capabilities of a company, which enables the business to meet customer requirements more efficiently.

1.4. Four research questions depending on literature gaps

The overall research aim as mentioned above can be separated into four research questions. Each of these research questions represents a specific literature gap which is discussed in more depth in the literature review in chapter 2.

- **Research question 1:**

What relevance does product architecture have for the provision of a customised product?

This question addresses the problem of simplification when only looking at the upper level of the product architecture. This is particularly problematic when customer choice can penetrate the product architecture at all levels. Incorrect conclusions for the set-up of the list of options can be one negative consequence. It is proposed that a decomposition of the product into categories, components, sub-components and attributes is required in order to be able to determine the correct order fulfilment strategy.

- **Research question 2:**

How do customers prioritise their preferences with regard to the configuration of a prefabricated house?

This question focuses on clarifying the role of consumer preferences measurement for complex, multi-attribute products. Measuring preferences for complex products is a challenge as the list of options is usually very long. Determining these preferences can also be a burden for respondents.

- **Research question 3:**

How can customer preferences be aligned to what is offered in terms of customisation?

This question addresses the problem of what exactly needs to be offered in terms of options and degree of choice in order to achieve customer satisfaction. One way of determining this is to measure customer preferences on a continuous basis so that the option list can be updated according to changing requirements, such as life-style and technological trends (for example home automation). For this, however, an awareness of the product's architecture is needed as well as a positioning of the CODPs in the supply network. Thereby it is identified where the customer order penetrates the supply chain.

- **Research question 4:**

Can lessons in aligning the product and processes with customer preferences be generalised to different industry sectors?

Here the focus is on the question of generalisability of this research and its contribution to the general body of knowledge on mass customisation. This question emerges from the literature review and will be answered in the synthetical part of this research (Chapter 7).

It will be highlighted in the literature review in chapter 2 that the frequency of house building specific mass customisation research has increased during the last ten years. However, there is a lack of research providing an understanding of the interaction of the six areas with which this thesis is concerned: mass customisation, supply chain management, multiple CODPs, customer preferences, product architecture, alignment and house building. The specific gaps that will be elaborated in chapter 2 are as follows:

- Lack of research in establishing the link of a product's architecture to customer preferences.
- Not sufficient research into the measurement of customer preferences in prefabricated house building. Furthermore only few studies look at the prioritisation of the preferences that have been determined.
- Lack of research in scrutinising the link between customer preferences, product and process development and alignment strategies.
- As the link between customer preferences and the product architecture has not yet been established in the house building industry it is assumed that the findings of this study can be relevant to industries producing products which are comparable to a prefabricated house (e.g. automobiles, computers).

1.5. Layout and structure of thesis

The structure of this thesis is shown as a schematic in Figure 1.4. This schematic is meant to act as a guide for the reader. As can be seen, chapters 1 – 3 are of theoretical content, whereas chapters 4 and 5 represent the empirical part of this thesis. In chapter 6 and 7, the empirical findings are synthesised.

As highlighted in Figure 1.4, the theoretical part consists of the introduction and the derivation of the research questions by contextualising the research in the general body of knowledge. A detailed review of the literature helps to identify the research gaps resulting in the above mentioned research questions. Following this the methodological approach used in this research is explained. The case study approach is defended in addition to the other chosen research methods. Due to the application of both qualitative and quantitative research, a mixed methodology has been applied in this research.

The empirical part of this thesis can be separated into two substantial parts: case study and online survey. The case study was conducted in order to determine the product architecture and identify the regularly customised components of the case company. An online survey technique was then applied to measure the preferences of potential customers based on the product architecture previously determined. As indicated in

Figure 1.4 the empirical part of this research also provides the basis for an answer to research questions one and two.

Finally, the synthetical part merges the two aforementioned parts. Here the findings of the empirical part are discussed and a model is presented that can be used to align customer preferences with the product architecture. Furthermore, the synthetical part discusses the empirical findings and evaluates these. Moreover, in this chapter the findings are positioned within the scope of established research in the field of prefabricated house building. In chapter six research questions one, two and three are answered and a basis for answering research question four is established.

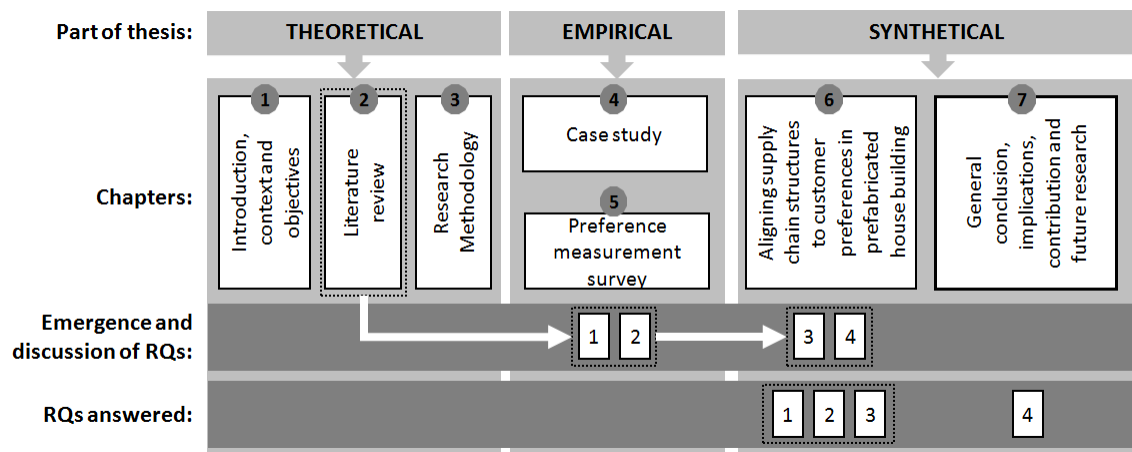


Figure 1.4: Structure of the thesis (source: author)

Chapter 7 concludes the research and in doing so, specific answers to the research questions are presented. As mentioned before, the basis for these answers is established in chapters 4, 5 and 6. Furthermore, the generalisability of the findings is discussed as well as the academic and practical contributions. An important element of chapter 7 is the recommendation that can be made for further research, not only in the house building sector but also in other sectors producing complex, multi-attribute products.

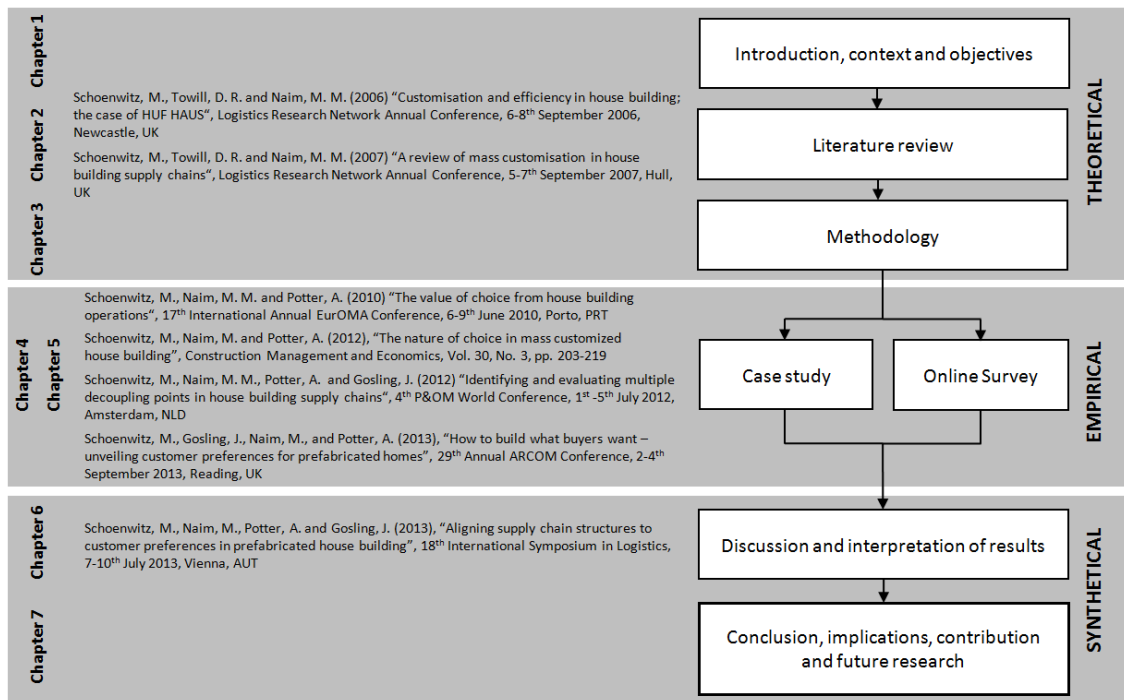


Figure 1.5: Publication outputs from the various research stages (source: author)

Figure 1.5 is an adaptation of Figure 1.4 and shows the publications that have been generated from the different research steps. These publications form the skeleton of this thesis.

1.6. Research contribution

This research provides an incremental approach to bring customer preferences and the company's operational capabilities in alignment. It is proposed that this approach can be adopted by other practitioners that manufacture multi-attribute products and seek to pursue a mass customisation strategy. Combining the results of the two empirical research streams helps to make the correct decisions about the level of variety to offer. The findings can be generalised and therefore the framework developed in this thesis can be adopted and applied in other industries. However, the testing of the framework within other industries and sectors was outside the scope of this research. There is therefore an opportunity to transfer the approach and compare the findings of this house building specific study with companies that manufacture different mass customised products. From a pragmatic point of view, the framework will deliver valuable insights into the alignment of a company's capabilities with customer requirements thereby making operations more efficient.

From a scholarly perspective, the research presented in this thesis contributes to a better understanding of the applicability of mass customisation strategies in the self-build house building industry. Furthermore, past as well as current research on customisation in the construction industry is primarily concerned with an evaluation of strategic effects. To date, there is little scholarly work in exploring the consequences of a customisation strategy on the operational capabilities of a company, particularly at the component level.

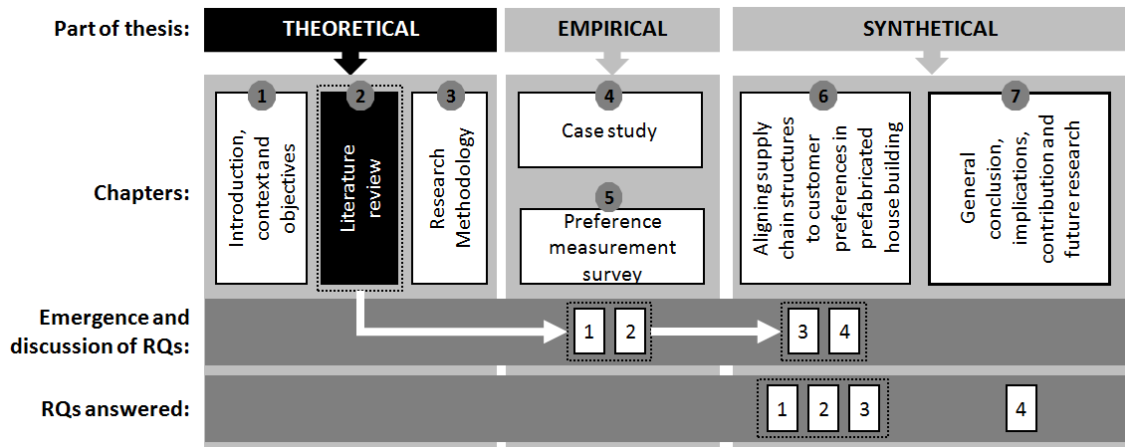
Overall, this research contributes by highlighting the importance of the marketing/operations interface where customer preference information is transferred into the operational processes of a business. Furthermore, our understanding of the nature of choice and how to deliver it is addressed.

1.7. Summary

The main purpose of this prolegomenon is to describe the scope of this research. First the background for this study has been presented in order to familiarise the reader with the main elements and literature relevant for this research. Following this the research aim has been specified with the further articulation of four research questions, which will be addressed in the following chapters. The overall layout of the thesis and the streams of the empirical research have been outlined in order to explain the structure of this thesis. The overall contribution of this thesis has been anticipated in order to emphasise the relevance of this research. The following chapter will contextualise the study within the general body of literature and carve out the gaps and shortcomings that have been identified and which this study will address.

Chapter 2

“Whether you like it or not, the house is a reflection of yourselves.” (Jeremias Gotthelf)



2. Literature review based on three research areas

2.1. Introduction

Knowledge does not exist in a vacuum and academic work only has value in relation to other people’s activities (Saunders et al., 2003). Therefore, there is a need to establish what research has been published in the areas of interest. The purpose of this chapter is first to identify intersections of the main research areas focusing on house building and second to present key publications that influenced the research for this thesis. These are then reviewed in a systematic manner and grouped by main subject area for ease of understanding. The purpose is to provide readers with the necessary theoretical foundation of the research questions. For the research area germane to this dissertation there are a considerable number of publications available which of course cannot all be reviewed. Therefore this chapter attempts to focus on the main references. Their content, however, is reviewed in detail and limitations are pointed out.

The following literature review is grounded in the areas as shown in Figure 2.1. Nevertheless, it begins with a sociological introduction to the home as such. This is done to emphasise the importance of a house as a place of shelter. This section is followed by reviewing how the construction and house building industry developed over the

decades and how the application of methods from other industries finally enabled the move towards mass customised buildings. The term mass customisation and its origin is then explained before its application within the house building industry is reviewed. Following this, the literature review concentrates on the influence of customers on a mass customised product. In this section methods for customer preference measurements are explained and the most suitable method for this study is identified. Following this, the marketing and operations interface is reviewed in order to highlight why it is so important to know exactly what customers want. It is then discussed how the product architecture and the appropriate processes need to be integrated in the operations of a company in order to make mass customisation work. The subsequent section clarifies how competitive advantage can be achieved. Finally, a summary section provides a synthesis of the most influential literature.

2.2. Main research areas

Figure 2.1 shows the areas of academic research which form the basis of this thesis. Four main areas are identified: operations management, mass customisation and product, as well as process, design. The outer layer identifies the industry in which this study was conducted. Due to the fact that the construction industry consists of multiple segments, this research area is even more specified into house building and furthermore into self-build housing. Thus, within this specific industry this study examines how the mass customisation paradigm can be applied as a customer-centric business strategy. Driving a sustainable business requires competences built around a set of capabilities.

As mentioned before the core of this study is an analysis of the product and process design, with the aim to highlight the importance of combining and connecting these activities. The thesis utilises a framework developed by Fine (2000) wherein he extended the traditional two-dimensional concurrent engineering frameworks which are mainly concerned with matching the product and manufacturing process. Fine (2000) added a third dimension: supply chain design. The message from Fine (2000) is that only if process, product and supply chain design go hand in glove, will the company be able to gain sustained competitive advantage. However, the supply chain development and, indeed, the management of the supply chain in general are not in the spotlight of this

study although some of the issues discussed in this thesis will also touch upon the overlapping areas. Hence, in order to reflect the scope of this study, the supply chain design circle is depicted as a dotted line and is the subject of future research.

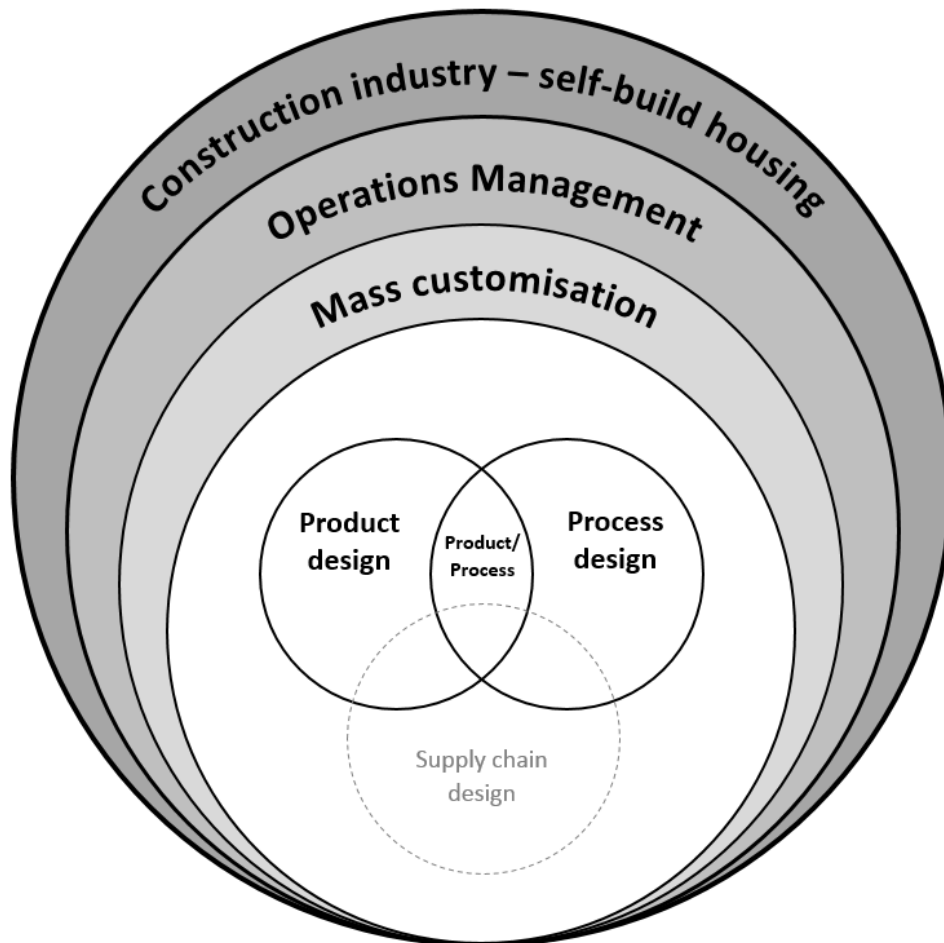


Figure 2.1: Research areas (source: partly from Fine, 2000)

In order to provide a basis for the customer preference measurement tools and methods from the marketing discipline have been applied. Furthermore, as marketing management is mainly concerned with identifying what kind of product or service the customers require, whereas operations management needs to find ways of how to satisfy the demand and deliver the required products or services, the interface between the two disciplines will be scrutinised as well. The aforementioned interface needs particular attention as pointed out by Christopher Tang (2010) in his review on the marketing operations interface. He states that the interface needs to be managed successfully so that the company can "... do the right thing (by the marketing group) and

do the thing right (by the operations group).” (p. 23). Hill (2005) emphasises the need to align operations and marketing strategy as this links the basic tasks in any company: the sale and delivery of products or services. This, however, is no easy task as there exist interfunctional differences. In this regards one example that is given by Hill (2005) is the following:

Product range:

Marketing – Customers typically seek variety. Restricting range reduces segment coverage and sales revenues.

Operations – Restricting range enhances volumes, helps reduce cost and simplifies control.

Hence, there is a need to resolve these interfunctional differences in terms of what is important for the business as a whole (Hill, 2005).

With this, the importance of the interface management is highlighted, which becomes more challenging with an increase in the degree of customer integration into the product design process. Furthermore, the more complex the product architecture is, the more options are available to customers. Therefore the strategy of providing choice to customers’ needs to be embedded in the overall operational strategy.

The following literature review will show that there is considerable existing research with regard to responsiveness and on how to provide a certain degree of choice in order to satisfy customers. However, there is little research on how to identify what the customer base really wants in terms of configuring the house and how these insights can be used to combine and organise resources in a way that differentiated customer needs can be fulfilled and, indeed, competitive advantage can be gained.

2.3. Importance of the house: a sociological view – the house as living space in the past and present

Construction is an economic sector like car manufacturing or electricity generation. It makes a contribution to the competitiveness and prosperity of the economy (Lawson,

2014). However, as Sebestyén (1998) points out, "... while modern manufacturing has only a short history, construction and its 'products' – buildings, villages, towns and cities – can be traced back several thousand years." The development of the construction sector was dependent on the availability of building materials and the ability of craftsmen and engineers. Industrialisation enabled the production of building materials such as, for example, bricks on a large scale, and due to developments of new means of transportation it was possible to transport materials over greater distances. Furthermore developments such as steel and concrete changed the type and style of buildings that could be built (Lawson, 2014). However, as Cox and Ireland (2002) point out the literature on operations management has largely overlooked the construction industry and preferred to research the more popular sectors such as electronics, IT and automotive. Given the importance of the sector with regard to revenue, number of firms and employees, this lack of attention is surprising. Furthermore, apart from the economic importance of the construction industry, the house as a physical structure is also associated with offering shelter and protection from the elements for its occupants.

A house touches centrally on personal lives. It is a place of comfort and safety. Following the changes in people's own lives, the home is always adapted to needs and requirements. However, as Mallett (2004) points out, no matter whether one builds a new house or lives in an established dwelling, individual preferences or choices are always constrained by cultural and economic factors. This means that developers, architects, urban planners, engineers, builders and interior designers all have their own ideas about how a living space needs to look.

For most people, building or buying a house represents their biggest single lifetime investment (Groak, 1993). Houses offer a place of shelter and protection. Among other factors, the house represents the home which can be defined as a place of security into which a retreat from the external world is possible and which can be personalised (Sime, 1986; Moore, 2000; Spottiswood, 2013)

The famous actor and dramatist John Howard Payne (1791-1852) highlighted the importance of the home when he spoke his legendary words: "Mid pleasures and

palaces though we may roam, be it ever so humble there is no place like home". 'House' and 'home' are not synonymous. 'Home' can be defined in many different ways such as a country, town, and street, but it is our house or flat where people usually spend most of our time (Craig et al., 2000). Builders produce houses that are mere physical structures at the beginning. However during their life cycle people attach meanings and memories to these houses, turning them into homes. Occupants invest in these in a number of ways, including physical, psychological, social and financial (Craig et al., 2000).

Many authors note that people's ideas of the perfect home are not influenced by the interests of capital or the house builders' marketing department. These authors rather suggest that personal experiences as well as significant social change have a considerable impact on the preferences and desires with regard to designing a house (Saunders and Williams, 1988; Saunders, 1989; Douglas, 1991; Mallett, 2004).

In this regard' it can be concluded that in order to really feel at home, the house needs to be specified according to the wishes of the persons planning to live in it. Individuals make choices based on their personal tastes and preferences which are shaped by many different factors: family environment, physical condition, age, sex, education, religion and location (Petersen and Lewis, 1999). However, it was not until the end of the 20th century that researchers started to scrutinise concepts of mass customisation in house building.

2.4. Development of the construction and house building industry

In its early days, the building sector was typified by independent master craftsmen and regulated by a range of craft guilds. In the 19th century, a modern 'capitalist' industry emerged based on the general contracting system and involving large scale businesses with the capacity for major building projects. Two interrelated themes stand out during this transition period: the changes in the methods of operation and business organisation, and the developing technology of the building industry (Satoh and Morton, 1995).

In the early 20th century, factory production of building components developed rapidly in Europe. Groak (1993) notes that the popularity of preassembled houses came as no surprise. He claims that the extensive system of factory-produced materials and components has changed the whole building process and increased the popularity of preassembled components. The industry started to believe that, in equal measure to the car sector, the building sector could also make use of economies of scale provided that more and more parts were prefabricated in the factory and then simply assembled on site (Gann, 1996). In fact this would not only bring advantages to the house builder himself but also to the customer. For example the latter could enjoy a broader range of choice, higher quality, quicker delivery and cost reductions. The house builder would also benefit from reduced time on site, improved business margins and more satisfied customers (Ozaki, 2003).

The importance of technical advances in the building industry is highlighted particularly by the adoption of machinery and the transfer of certain traditionally on-site operations to the factory (Cox and Ireland, 2002). The detail of this innovation can be described in the context of different building materials such as stone, wood and brick and through the development of certain on-site machinery including pumps, pile drivers, cranes and scaffolding. Although the industry originally retained a very large number of small building firms and employed workers with more traditional skills, it is argued that it was the large builders who eventually initiated the new forms of business and who were responsible for driving innovation (Sato and Morton, 1995). This development inevitably led to the appearance of more capital intensive methods of production. This opened up economies of scale to the larger firms that were able to invest in new technology and thereby benefit from the improving production efficiency. This development however, was only possible because of the parallel changes in business organisation and contracting accompanied it (Groak, 1993).

Until mid-20th century, a house was built on-site with the supply chain being centred around the geographical location of the building. This made the process very complex and required exact planning and good project management. As early as 1956, Coy and Goodman identified a major problem in logistics as: "The physical substance of a house

is a pile of materials assembled from widely scattered sources. They undergo different kinds of and degrees of processing in a large number of places, require many types of handling over periods that vary greatly in length, and use the services of a multitude of people organized into many different sorts of business entity.” (p. 36). The identification of this problem of complexity over the years led to a number of initiatives and improvement ideas which ultimately were aimed at simplifying processes on site. One of these ideas, although not really new, is to preassemble the complete house in a factory and reduce the activities on site to a minimum. The first serious attempts at a manufacturing approach for housing can actually be traced back to the 18th century when Georgian architecture arose from the disciplines of ‘design for manufacture’. During the 20th century, the attempts to preassemble in the factory became more serious. In particular, the need to provide homes following The Second World War combined with the available capacities (i.e. unused armament factories), really started the production of houses in a factory environment (Phillipson, 2001). Groak (1993) anticipated this change when he stated that he is perplexed “by the changing problem of how we mesh, perceive, describe, adjust, redefine or operate for practical purposes the jangling mixtures of building design, building technologies, building science, building production, building use.” (p. 5). He continues and writes that he believes that their relationship will continue to change, but in ways which give greater priority to the making of built forms and to the services they offer.

The change of manufacturing strategies in the house building sector has mainly been stimulated by increasing customer demands in terms of design, time and costs. This suddenly required the house builders to be responsive “to customer need within a winning time” (Towill, 2001, p. 287). One can argue that there were other factors which supported the development such as shortages of skilled labour on-site but, the customer really is the most powerful figure in demand-driven business (Piller, 2004). If people are not interested in what a company produces or offers, there will be no sales and consequently no basis for existence for that particular company. Customer requirements have to be satisfied and this is what mainly drives house builders to increasingly adopt manufacturing approaches to building houses (Ozaki, 2003).

2.5. The concept of mass customisation

The concept of mass customisation has received much attention from researchers since it was first mentioned by Davis in *Future Perfect* in 1987 (Pine, 1993). In today's globalised markets, with fierce competition and ongoing technological innovation, companies need to be agile and able to quickly respond to differing perceived needs (Towill, 2001). It is this rising pressure that is driving companies to make use of the principles of mass customisation in order to provide individually designed products and services (Duray et al., 2000).

2.5.1. What is mass customisation?

In 1993, Pine defined the focus of mass customisation as variety and customisation through flexibility and quick responsiveness. The aim of mass customisation is to develop, produce, market and deliver affordable goods and services with enough variety and customisation so that nearly everyone finds exactly what they want. Furthermore, Pine has identified the key features of mass customisation: fragmented demand, heterogeneous niches, low-cost and high quality customised goods and services, short product development cycles, and finally short product life cycles. Pine argues that mass customisation is a synthesis of two totally different systems of management which have competed against each other for a long time: the mass production of individually customised goods or services. Pine further argues that the advantage for companies customising their products is that they are flexible, offer unique specialisations, manufacture a great variety of products and are able to meet small market niches.

Over the years, mass customisation has been given many definitions. A selection is given in the following:

- “Mass customization of markets means that the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually as in the customized markets of pre-industrial economies.” (Davis, 1989)

- “Mass customization is the cost-efficient mass production of goods and services in lot sizes of one.” (Pine, 1993)
- “The objective of mass customization is to deliver goods and services that meet individual customers' needs with near mass production efficiency.” (Tseng and Jiao, 2001)
- “Mass customization aims at providing cost-effective products and services to meet individual customer needs. An implicit assumption of mass customization is that organizations must recognize customers as individuals and understand their needs.” (Tseng and Piller, 2003)
- “Mass customization is a strategy that creates value by some form of company-customer interaction at the fabrication- /assembly stage of the operations level to create customized products with production cost and monetary price similar to those of mass-produced products.” (Kaplan and Haenlein, 2006)

All definitions, although differing in phraseology and the level of detail, essentially make the same statement, namely that mass customisation is the combination of two apparently contradictory terms: mass production and customisation.

Figure 2.2 illustrates the economic implications of mass customisation. Traditionally, mass production demonstrates an advantage in high-volume production where the actual volume can defray the costs of huge investments in equipment, tooling, engineering and training (Tseng and Jiao, 1998). On the other hand, meeting an individual customer's needs often results in higher value, but low production volume is also a consequence. Thus the large investment cannot be justified. Making it possible for companies to gain economies of scale through repetitive mass customisation can therefore reduce costs and total cycle time (Da Silveira et al., 2001). Mass customisation can therefore achieve higher margins and be more advantageous.

Figure 2.2 shows that in mass production the cost per unit decreases with higher throughput. This is because fixed costs are spread over a high production volume and make use of economies of scale (Gilmore and Pine, 2000). Mass customisation, however, makes use of economies of scope by applying a single process to produce a greater variety of products in a way that is cheaper and faster (Pine, 1993).

Furthermore, customers are often prepared to pay premium prices for their special requirements, thus giving companies extra profits. From an economic perspective, mass customisation enables a better match between the producers' capabilities and customer needs (Jiao et al., 2003).

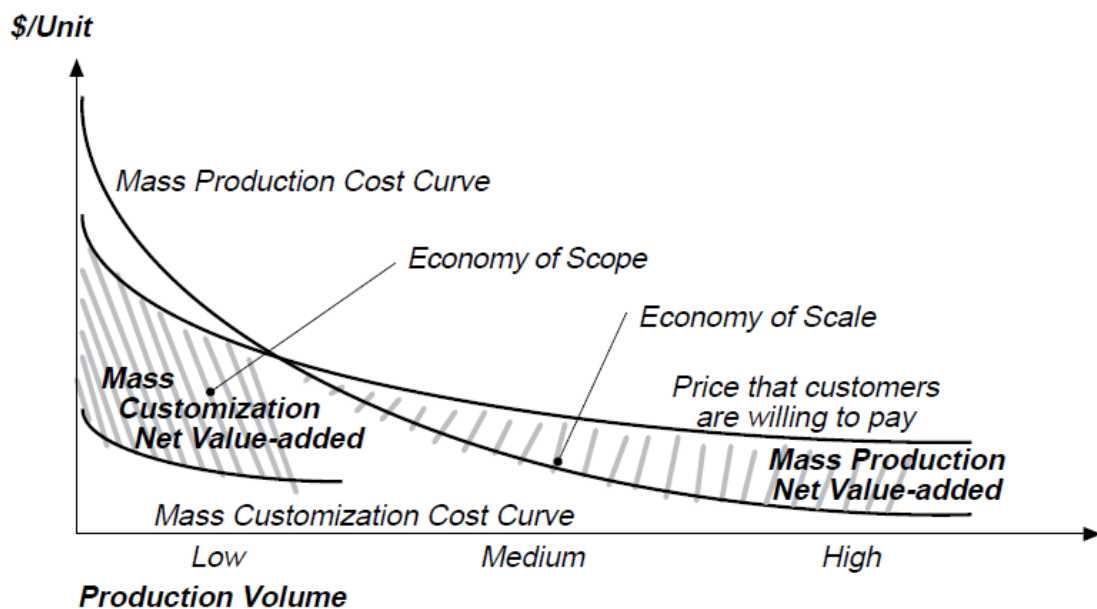


Figure 2.2: Economic implications of mass customisation (source: Tseng and Jiao, 1998)

As mentioned above, mass production is high-volume production where there is low variety. Due to the high use of machinery and energy it is capital intensive. A mass customisation strategy, however, aims to provide bespoke products that are tailor-made to reflect customer needs. The application of this concept requires a holistic approach as it affects the whole supply chain: sales, product design, production as well as delivery (Da Silveira et al., 2001). In this regard, a supply chain can be defined as a “set of three or more entities (organisations or individuals) directly involved in the upstream and

downstream flows of products, services, finances, and/or information from a source to a customer.” (Mentzer et al., 2001).

A mass customisation strategy demands flexibility and responsiveness from a company’s supply chain (Duray et al., 2000). Furthermore, a close supplier-/buyer relationship is needed to ensure that the customer’s specific requirements are met. Thus, in contrast to mass production, the customer plays a major role in the mass customisation concept. Individual requirements need to be captured and then directed through the supply chain so that the customised product can be delivered in an acceptable lead time. Depending on the nature and the complexity of the product, information technology can support the capture of these requirements through so-called product configurators (Piroozfar and Piller, 2013). A product configurator can combine the various components with the help of rules that define which components can be combined (Hvam et al., 2013). As well as having a set of well-defined components and constraints on how these components can be assembled, there is also a need for a supporting IT system that is able to process the many different component combinations. The advantage to this is that if the configurator is made available to the public then customers can configure products themselves thus not producing any costs for the company (Bechthold, 2013). A good example for this is the online configurator from Audi (see: configurator.audi.com). Here, one can configure a car online and once the process has been completed a code is generated that can be forwarded to the local car dealer who can then retrieve the individual configuration and prepare the quote. Hence, good supply chain management will provide the level of coordination needed for successful application of a mass customisation concept (Alford et al., 2000).

Proops (1996) points out that the most obvious advantage of mass customisation is that it “gives consumers the freedom to purchase individualised or tailored products” (p. 1). He writes that on the other side of the coin it helps suppliers to reap the benefits of economies of scale while at the same time having the freedom to provide the customers with what they really want.

Koth and Wiegman (2000) remind us that a few hundred years ago every single product was customised as mass production had yet to be invented. The development towards mass production in order to save costs, they argue, widened the gap between manufacturer and customer – “...it had the effect of slowing down the feedback loop between producers and customers” (p. 4). In their opinion, customisation has always held potential value for customers but companies were often prevented to customise because operations were too rigid and economies of scale precluded variation.

Berger and Piller (2003) present an example from the sport shoe industry, namely Adidas Salomon, where the company decided to change from made-to-stock to made-to-order in order to manage the cost of broad product assortments. A convenient side effect of this shift is that customers believe that it is valuable. Berger and Piller (2003) are able to identify the following benefits of mass customisation: postponement/negative cash flow, increase in flexibility and scalability, open innovation and innovation leadership.

Five basic logistical configurations for supply chains were suggested by Hoekstra and Romme in 1992: Buy-to-order (BTO), Make-to-order (MTO), Assemble-to-order (ATO), Make-to-stock (MTS), and Ship-to-stock (STS). At an aggregate product architecture level, these configurations determine the position of the Customer Order Decoupling Point (CODP). This is the point of customer involvement in the supply chain. The CODP is a useful tool in defining the right combination of standardisation versus customisation.

Lampel and Mintzberg (1996) also develop a comprehensive model showing the different degrees of customisation, moving upstream in the supply chain as shown in Figure 2.3. They point out that customisation and standardisation do not represent “alternative models of strategic action but, rather, poles of continuum of real world strategies.” (Lampel and Mintzberg, 1996, p. 21). The model depicted in Figure 2.3 shows this continuum using four stages of a manufacturing firm’s value chain: design, fabrication, assembly, and distribution. On the left hand side there is ‘pure standardisation’ which means that the product is not individualised but is instead manufactured without considering individual customer needs. Increasing customisation gradually from the left hand towards the right hand side then gives rise to five supply

chain strategies: pure standardisation, segmented standardisation, customized standardisation, tailored customisation and pure customisation. Lampel and Mintzberg (1996) point out that within manufacturing companies there often is a conflict of interest between the production manager and the sales manager. Whereas the production manager sees aggregation or standardisation as the best way to increase efficiency, it is the sales manager who considers individualisation as the surest way to increase sales. Furthermore, Lampel and Mintzberg point out that since the cost of customisation tends to increase in proportion to the number of production changes, it makes sense to customise downstream activities first.

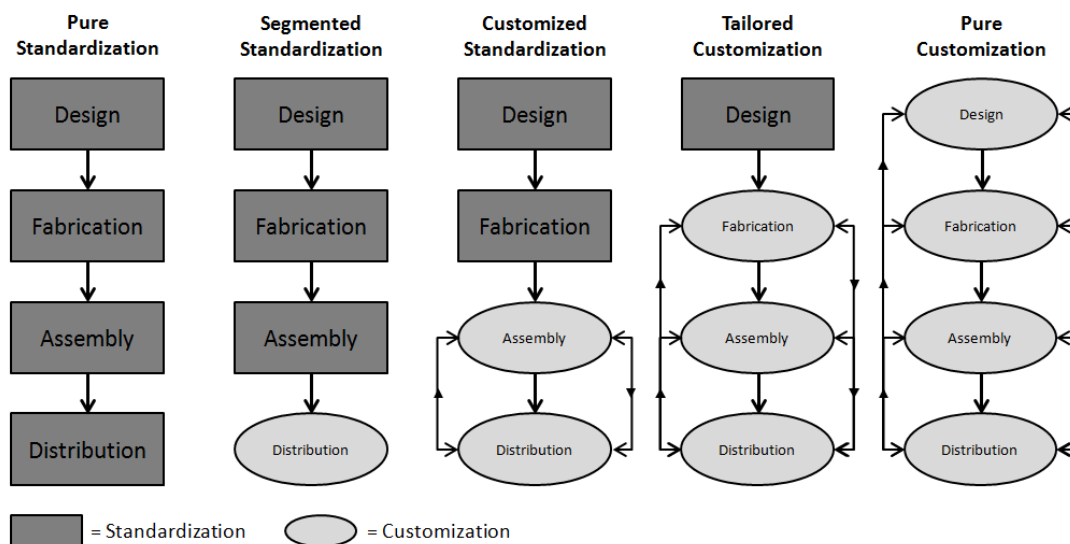


Figure 2.3: Generic customisation strategies (source: Lampel and Mintzberg, 1996)

Customisation requires a clear connection between product design and manufacture (Spring and Dalrymple, 2000). Furthermore, they criticise some manufacturing strategy authors (e.g. Hayes et al., 1988; Wheelwright and Clark, 1992) who address design issues by focussing on product development but still treat it as a distraction from the ‘true’ operations task of converting material.

Spring and Dalrymple (2000) continue by issuing a warning that “mass customisation taken to an extreme can position the firm as trying to be all things to all people” (p. 447). This means that apart from attempting to add huge value to customers, there are also certain problems when adopting customisation strategies, including increasing

complexity in the business' operations. This warning is picked up by Blecker et al. (2004) who state that a certain complexity is inevitably required and should simply be accepted when adopting a customisation strategy. They further write that "an immediate effect of mass customization is high product variety that triggers high production program complexity, as well as high configuration complexity for customers considered as a sub-system of the enter-prise system." (p. 900). Blecker at al. (2004) discuss flexible manufacturing and say that adopting a mass customisation strategy makes it obligatory to implement flexible manufacturing systems on the shop floor.

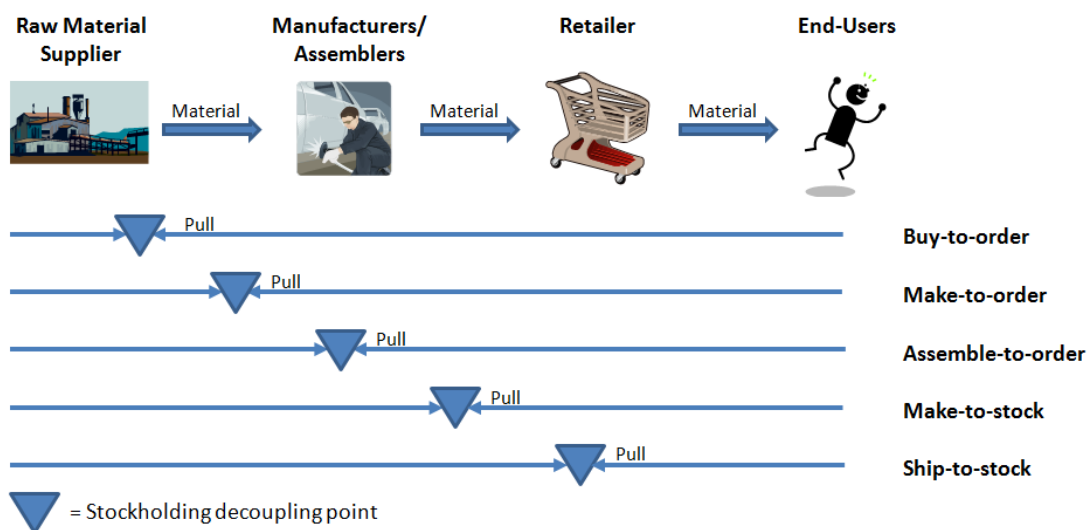


Figure 2.4: Supply chain strategies with decoupling point (source: Hoekstra and Romme, 1992)

Naylor et al. (1999) link the two recent popular paradigms: lean thinking and agile manufacturing. Furthermore, the authors use the CODP which "separates the part of the supply chain that responds directly to the customer from the part of the supply chain that uses forward planning and a strategic stock to buffer against the variability in the demand of the supply chain" (p. 112). Figure 2.4 shows different supply chain structures which build on the basis of the five configurations originally presented by Hoekstra and Romme in 1992. For each supply chain configuration in the figure, it is clear where the CODP is positioned and where strategic stock needs to be held in order to be able to respond to customer enquiries.

2.5.2. Application of mass customisation principles to the house building industry

As already mentioned in Chapter 1, the house building industry is very important for any economy as it provides employment on many different levels (Groak, 1993). However, it is a complex and difficult sector composed of a variety of people, plants, materials, locations, new technology and knowledge of the law and regulations. In a traditional building process, a house was erected on site with the supply chain aligned to accommodate this. Good project management and precise planning was required to be able to cope with such a complex process.

Simplification of on-site processes was sought as this complexity resulted in increased construction costs (Gibb, 2001). One of the approaches was to try and prefabricate houses or parts of the house in an off-site factory environment using the car manufacturing sector as an example. At the beginning this received heavy criticism: "... [this interest in the car analogy] probably appealed to those who prefer walking around in a warm, dry factory to struggling across a building site on a cold damp evening" (Groak, 1996, p. 137). Other researchers (Gann, 1996; Green, 1998; Winch, 2003) agreed with this view and issued a warning because, from their perspectives, there are clear limitations to which manufacturing systems derived from the car industry can be applied to assemble complex customised buildings.

But there were also researchers who believed in the application of car manufacturing ideas in the house building sector. In 1998, the so-called 'Egan Report' (Department of Trade and Industry, 1998) was published by an industry task force in order to drive improvements in the UK construction sector. The authors of the report state that clearly construction can learn from other sectors. The task force visited the Nissan UK manufacturing facilities in order to scrutinise Nissan's approach to manufacturing. Following this visit one task force member wrote: "We see that construction has two choices: ignore all this in the belief that construction is so unique that there are no lessons to be learned; or seek improvement through re-engineering construction, learning as much as possible from those who have done it elsewhere." (p. 18). Further recommendations for the construction sector include: focus on the end product, production of components, implementation of lean principles and standardisation.

Gibb (2001) echoes the contents of the Egan report and states that there are indeed lessons to be learnt by house builders from much of the manufacturing sector. He identifies several issues from the car manufacturing sector which he believes will improve the status of the house building industry.

In 2013 a report from the Department for Business Innovation and Skills focussed on a supply chain analysis into the construction industry. In the first part of the report the 'Egan Report' and its effects on the industry are reviewed before cost saving potential is identified and actions are recommended that can be taken to improve competitiveness of UK construction companies. Although the report does not explicitly mention the potential of knowledge transfer from other industries, it does provide evidence of outstanding examples of companies that successfully adopted off-site manufacturing strategies (Department for Business Innovation and Skills, 2013).

Japanese companies have successfully implemented manufacturing principles derived from the car industry in order to produce attractive, affordable and above all customised houses which are clearly aimed at the self-build market (Towill, 2001). They have managed to achieve a trade-off between the need for economies of scale (i.e. production of standardised parts) to increase profit margins and economies of scope in order to give the customer enough choice to get full satisfaction. In this regard, clever product architecture is vital and can give the impression of a fully customised house but by using the standard processes in the production as demanded by Gibb (2001).

Cuperus (2003) delivers evidence from the Netherlands which says that the housing industry in particular is shifting from a seller to a buyer market. Consequently, in order to meet customer needs, house builders shift from mass housing to mass customisation.

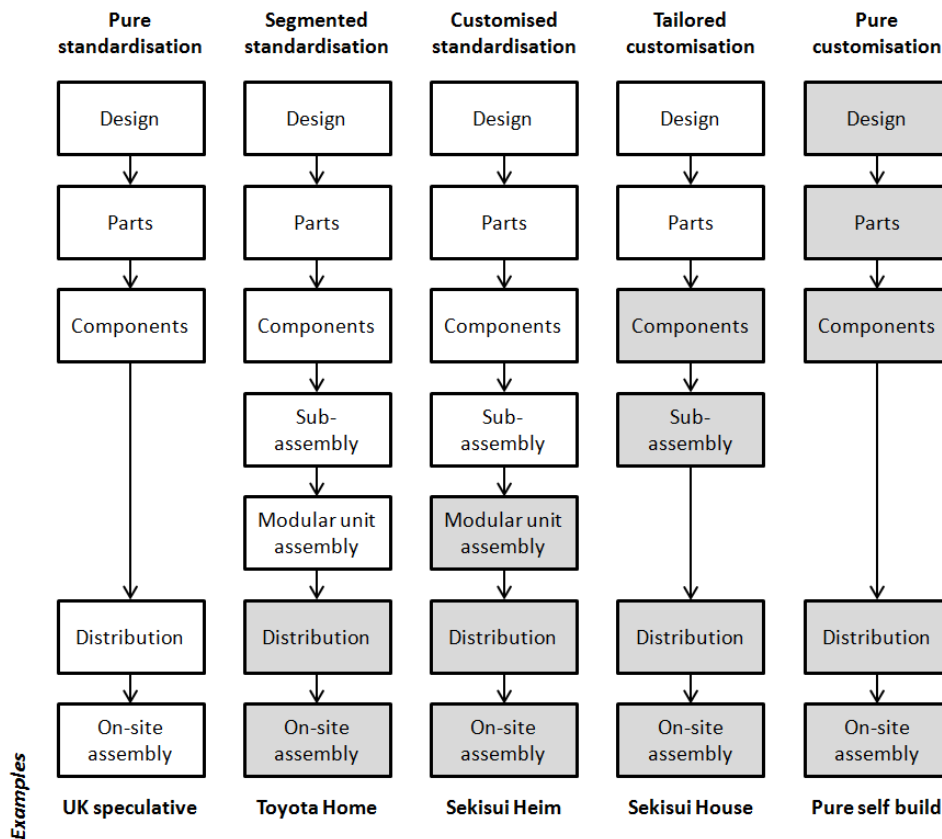


Figure 2.5: Generic customisation strategies applied to the house building industry (source: Barlow et al., 2003 based on Lampel and Mintzberg, 1996)

In 2003, Barlow et al. build on the generic manufacturing research of Lampel and Mintzberg (1996), which developed a continuum with four stages in a value chain shown in Figure 2.3, yielding five supply chain strategies from pure customisation through to pure standardisation as given in Figure 2.5. Barlow et al. (2003) exploit this approach in a house building context but focus their research on demonstrating that mass customisation in house building can be supported by several generic supply chain types. In their study, they report on various Japanese house builders who all work in the off-site manufacture based industry and supply customised homes which are preassembled from standardised components or modular systems. The fields highlighted by grey shading represent the extent of access customers have to configure the product according to their requirements. Fields without shading represent the parts of the supply chains that cannot be influenced by customers. Examples are given for each supply chain strategy on the x-axis of the diagram. On the left hand side there is the pure

standardisation supply chain that is applied in the speculative building sector. This is where companies build standard shells without involving the end customer. These houses are then sold on to customers but do not necessarily fully meet their requirements. On the right hand side, there is the other extreme. The pure customisation supply chain relates to the self-build model where the end customer configures and builds the house himself or with the help of contractors. However, the house fully meets the requirements and ideas of the customer. Barlow et al. (2003) also describe an example of one particular Japanese house builder, Sekisui Heim, who follows a ‘customised standardisation’ approach and uses standardised components and subassemblies which are then configured on-site according to customer requirements.

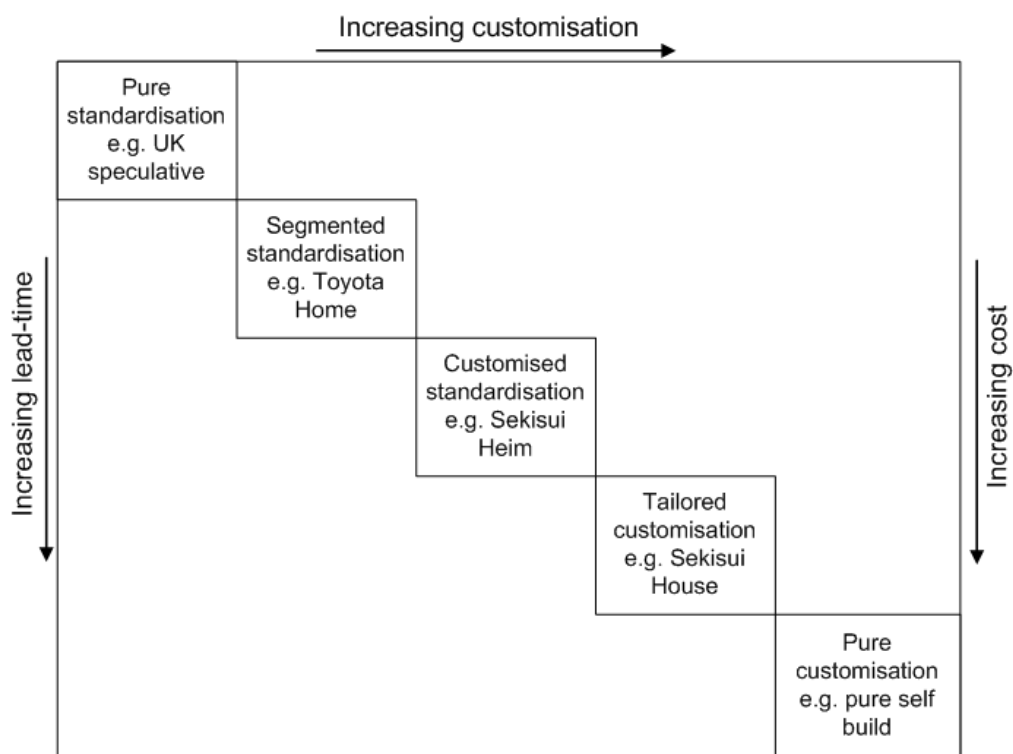


Figure 2.6: Supply chain strategy identification matrix (source: Barlow et al., 2003)

Barlow et al. (2003) further developed the above concept with the model depicted in Figure 2.6. Here, they set the different supply chain strategies in relation to the degree of customisation required, lead time, and cost requirements. In particular, they suggest that with a rising level of customisation there is also an increase of cost and lead time. The Sekisui Heim case is an example of the application of a mass customisation strategy in the house building industry. The company attempts to achieve a degree of

customisation while minimising cost and lead-time. This cost effective customisation approach is done by offering a range of modular units to customers. These can then be assembled according to customer specification. The cost effective advantage, however, is that the modular units are assembled from standard components and sub-assemblies (Barlow et al., 2003).

Year	Author(s)	Title	Country	Focus	Concept	Conclusion
1992	Koskela	Application of the new production philosophy to construction	n.a.	Whole process	One-of-a-kind-product	Improve production process + organisation with help of automation and computer-integrated solutions
1996	Gann	Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan	Japan	Manufacturing process	Management of whole production system	Study illustrates the value in cross-industry learning, and just as construction has adopted techniques from other manufacturing industries, so too can knowledge, particularly about project-based management and engineering, be of value in a wide range of manufacturing firms.
1998	Barlow	From craft production to mass customisation	UK	Increase choice in housing supply	Lean and agile paradigm	Total production system needs to be re-organised
1999	Naim et al.	Developing Lean and Agile Supply Chains in the UK Housebuilding Industry	UK	Presentation of new concept including description of similarities and differences	'Leagility' – combination of lean and agile principles	By drawing the analogy between house building and PC production the potential for a standardised component approach that not only requires a careful consideration of the technology but also an assessment of the best supply chain strategy is highlighted. The challenge is to determine the practical requirements that distinguish different house building supply chain structures.
2001	Gibb	Standardization and pre-assembly – distinguishing myth from reality using case study research	UK	Definition of standardisation and pre-assembly in the light of new management practices	Case study	Case studies found that clients' perception of the prevailing design culture has led to their demand for customized solutions, and they will accept that these can be achieved using standardised products and processes combined with pre-assembly. Lessons can be learned from the manufacturing sector, but houses are not cars and close comparisons should be treated with caution.

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Year	Author(s)	Title	Country	Focus	Concept	Conclusion
2003	Childerhouse et al.	House building supply chain strategies	UK	Supply chain strategies for house building	Fit out to order, shell fit out to order	Choice is required and companies to offer it become market leader
2003	Cuperus	Mass customization in house building	The Netherlands	Develop guidelines for consumer oriented building	Open building	Level of consumer influence on building needs to be determined
2003	Barlow et al.	Choice and delivery in house-building: lessons from Japan for UK house builders	UK and Japan	Japan's factory based housing industry	Standardisation vs customisation	Mass customisation can be supported by generic supply chain models.
2003	Ozaki	Customer-focused approaches to innovation in housebuilding	UK	Exploration on how key aspects in customer focus are dealt with in UK speculative house building.	Empirical study	Three key aspects of customer focus have been identified: good service, customised house design and good information flows. House builders' positive attitudes towards bringing customers into the house building process and reflecting their views from design and production to delivery and after-care can change the whole situation.
2006	Hofman et al.	Variation in Housing Design: Identifying Customer Preferences	The Netherlands	This paper presents the findings of a vignette-based survey about the requirements for customisation among potential buyers of new houses in the Netherlands. Based on the survey, a list of priority housing attributes is derived.	Preference measurement with vignette-based survey	One main outcome of this study is the priority listing of housing attributes. This priority listing will help building developers in their decision making about the right balance between the variety (such as different types of bathrooms, kitchens and roof types) to be offered versus the need to standardise and produce at acceptable cost.
2006	Leishman and Warren	Private housing design customization through house type substitution	UK	This research focuses on the role of planning and building regulations in permitting the house building industry to respond in this way.	Conjoint questionnaire	This research strongly suggests that volume house builders could widen the appeal of the housing choices offered on a given site by employing house type substitution. This would result in a wider range of internal options, broadly holding constant external appearance or specification.

Table 2.1: Categorisation of house building specific mass customisation literature (source: author)

Table 2.1 summarises the literature which focuses on the implementation of mass customisation in the house building industry. Looking at the various publications, it becomes apparent that before 2006 researchers were interested in how mass customisation could be achieved. However, in 2006 the first two publications appeared that were interested in finding out what customer preferences and requirements prefabricated house builders need to fulfil. It can therefore be concluded that it was during the early 21st century that mass customisation in prefabricated house building established itself.

Each of the above mentioned publications is briefly discussed and its meaning for this research is highlighted. In 1992, Lauri Koskela published a technical report with the title 'Application of the new production philosophy to construction'. In this report, Koskela discusses the problems of the construction sector. He then explains why the traditional philosophies in construction are no longer suitable from his point of view. He states that the new production philosophy (also known as lean production) needs to be introduced to the construction sector. If the new production philosophy is adopted by the sector then there is also the potential of customised production as seen in the car manufacturing sector. Koskela (1992) was the first to see the potential that strategies from other sectors offer and he calls upon his fellow researchers to acknowledge this potential and address the challenges posed by the new philosophy. Koskela's research was therefore the starting point of a more academic interest in the application of new production philosophies in the construction sector.

Gann (1996) specified the meaning of new production philosophies for the construction sector. In particular, he suggests that a wider range of choice can be delivered through the proper management of the whole production system, thereby trying to achieve a trade-off between the use of standard components and flexibility in assembly. Providing insights from Japanese prefabricated house builders, Gann (1996) argues that these case companies have learnt from other manufacturing processes, in particular with regard to customisation. He specifically points out that selective methods are not sufficient to achieve more of a customisation strategy. Instead, there needs to be a holistic approach involving the whole production system.

Two years later, in 1998, Barlow et al. criticised the UK house building industry for its lack of customer focus. They outline a bleak future for the sector if the concept of mass customisation is not adopted. Barlow et al. give principal recommendations on how mass customisation can be achieved and also report on potential barriers to the adoption. Their research concludes that one possible model is a component-based approach thus giving the opportunity to use standardised parts which can be configured in different arrangements. This highlights the importance of being aware of the product's architecture and configures the list of options according to customer requirements.

Naim et al. (1999) present the concept of 'leagility' which combines the well-established concepts 'lean' and 'agile'. Using the 'decoupling point', their research shows the potential for a standardised components approach that not only requires a careful consideration of the technology but also an assessment of the appropriate supply chain strategy (Naim et al., 1999). It is also highlighted that a house, like a PC, is a system consisting of elements and components that interconnect to create the whole.

In 2001, Gibb states that there are lessons for construction that can be drawn from the manufacturing sector. He clearly states that mass customisation must replace mass production because technology can now deliver the choice that clients demand. Furthermore, Gibb demands that customer needs must be identified and addressed. He further specifies this and states that this includes not only the need for customisation in general but also the offer of choice. In other words, Gibb (2001) ascertains that customer preferences need to be determined in order to be able to provide customised products.

One of the first papers giving specific recommendations for the set-up of a supply chain delivering mass customised houses was published by Childerhouse et al. in 2003. In the study, general principles of lean and agile are presented and the position of the decoupling point is used to determine four construction specific alternative supply chain strategies: make-to-stock, fit-out-to-order, shell-and-fit-out-to-order and design-to-order.

Cuperus (2003) provides evidence from the Netherlands which states that the housing industry is shifting from a seller to a buyer market. Having presented case study results, Cuperus concludes that growing consumer influence will direct the building process in future. Hence, the impact of customer choice needs to be minimised as this will result in a minimisation of uncertainty. Cuperus' research shows that customer oriented construction is not a UK specific problem. It is, rather, a European problem and needs to be treated accordingly.

Barlow et al. (2003) present examples of the Japanese house building industry and use these examples to develop generic supply chain models which can support various degrees of customisation. These supply chain models make it possible to meet customer requirements and market segments more effectively without the costs associated with full customisation. The suggested generic customisation strategies have been used as a basis for this research and the case company was placed within the model suggested by Barlow et al. (2003).

In 2003, Ozaki confirmed that there exists an opportunity to enhance customer satisfaction and increase market penetration to better satisfy the expectations and needs of customers. Furthermore the study names three key aspects that need to be applied in the house building industry: good service, customised house design on top of quality products, and good information flow between customers and the house builder, and within the company. The importance of these aspects has been confirmed through two empirical studies which state that only a holistic customer-focused innovation combined with long-term sustainable strategies will result in better customer relationships and consequently increased customer satisfaction. This is important for this research as only this combination will have a positive impact on the business, as Ozaki (2003) writes.

Leishman and Warren (2006) and Hofman et al. (2006) analysed the consumers' housing choice processes when configuring a house. Leishman and Warren (2006) use a conjoint questionnaire to determine customer requirements and Hofman et al. (2006) apply a vignette-based questionnaire. The latter study even prioritises the listing of housing

attributes which is of great importance to all house building companies that offer customised houses. Hence, it is important to not only determine what customers want but to also find out how these requirements are prioritised.

Those considered to be the most important and influential contributions for this research have been discussed above. It is evident that only a few studies to date provide comparisons to the modus operandi in other countries. This is questionable as the past teaches that there is enormous potential in cross-fertilisation via the exchange of ideas. For example, the automotive industry would not be as advanced as today without support from Japanese methodologies. It is therefore worthwhile to identify 'best practice' cases and research these in-depth. This can potentially lead to new findings and it may be possible to benchmark results to highlight relevant practices for the application of mass customisation strategies in the prefabricated house building industry (Jaafari, 2000).

2.5.3. Enablers of mass customisation in the house building industry

Gibb (2001) argues that there are two main drivers for the emergence of preassembled houses: pragmatism – industry response to an urgent need combined with a lack of resource; and perception – client and public reaction to prevailing design philosophy. Because of the latter's positive attribute, customers now demand maximum choice and preassembled and customised (but as far as possible standardised) buildings which has led to a new trend in housing. This was first mentioned by Koskela in 1992 and then further refined by Gann (1996), Barlow (1998) and Naim et al. (1999). Gibb supports this trend by showing that the construction industry can benefit by learning from the manufacturing sector. Gibb quotes an example from the Japanese, saying that they are the leaders in manufacturing standardised preassembled houses. This statement cannot be underpinned as there is a lack of evidence from other countries. However, he states that the challenge for house builders is to standardise and preassemble units which, when installed on site, cannot be recognised as being preassembled or even standardised. Thus Gibb writes, the whole product design, although consisting of standardised components, must provide variation: i.e. "customised solutions from standardised components" (p. 312). In his studies he also looked at the benefits of

preassembly and found that “because preassembly brought the construction site into the factory where the environment was more controllable, safety, productivity and quality could all be improved. There should also be less waste and less impact on the environment” (p. 313). Barlow (1998) points out that waste elimination and less impact on the environment is a result of applying lean production principles. Therefore, it is not merely the move from site into a factory environment that reduces waste levels and the impact on environment as there must also be a production strategy in place to optimise the processes even further. Gibb also points out that “... even though preassembly changed the site processes and could actually increase the hazards in some cases (for example it possibly increases risk of injuries), the installation processes, by their very nature, had to be thoroughly planned. It was claimed that this reduced the need for on-site problem solving and enabled site activities to be managed more effectively” (p. 313).

Prior to this, in 1996, Gann issued a warning saying that there are limits to which techniques from other sectors can be applied to the construction sectors. Even earlier, Groak (1992) emphasised that houses are not like cars and that the manufacturing or building process is fundamentally different.

2.5.4. The concept of the Customer Order Decoupling Point (CODP) and its application to the house building industry

One of the key issues in manufacturing mass customised products is to specify the position of the Customer Order Decoupling Point (CODP). The CODP is an important consideration in structuring and configuring supply chains so that total value can be delivered to the end-customer (Naim et al, 1999). The exact position of the CODP is a balancing process between market, inherent product properties and process related factors (Olhager, 2003). Influencing factors for the positioning are demand volume and volatility, and the relationship between required delivery times and possible production lead times (Mather, 1988).

In this regard, it is important for companies to align their own supply chains with the needs of their customers to achieve customer satisfaction. Lampel and Mintzberg (1996)

state that it is vital that companies locate their strategies along the continuum between standardisation and customisation and are aware of the implications of the chosen supply chain strategy. Otherwise, there is a risk of mismatch which can ultimately result in processes being inefficient or simply not meeting customer satisfaction.

In 1999, Naim et al. introduced the idea to apply the CODP, which determines the location within the supply chain at which a product is customized, to the house building industry. This notion was refined by Childerhouse et al. in 2003 just before Naim and Barlow (2003) used the CODP to design a more formalised model that connects the lean and agile paradigm. This model was then tested by Barlow et al. in 2003 against cases of Japanese house building companies and finally resulted in several generic supply chain models.

The CODP in general is a concept that decouples operations into two parts: forecast (upstream) and customer order (downstream). Further definitions are as follows:

- The CODP separates that part of the supply chain geared towards directly satisfying customers' orders from the part of the supply chain based on planning (Hoekstra and Romme, 1992).
- The CODP is the strategic stock that separates the demand side of the supply chain (focused on delivery to the end customer) from the supply side (based on logistics planning) (Naim et al., 1999).
- The CODP is defined as the point in the value-adding material flow that separates decisions made under uncertainty from decisions made under certainty concerning customer demand (Rudberg and Wikner, 2004).
- The CODP represents the point where a supply chain stops producing to forecast and instead starts producing directly to order (Hedenstierna and Amos, 2011).
- The CODP is traditionally defined as the point in the value chain for a product where the product is linked to a specific customer order (Olhager, 2003).

For the application of a more detailed definition of the CODP in this study, the Olhager (2003) definition is favoured; i. e. the decoupling point is defined to be the point in the supply chain where the product is linked to a specific customer order. This is believed to

be a simple but accurate definition of the CODP. It limits the CODP to strategic stock or inventory issues and also appreciates information flow. However, it needs to be mentioned that the differences between the aforementioned definitions are not that significant. Nevertheless, a commitment to one definition needs to be made as this will be the basis for the research presented in this study.

From the quantity of research in this particular concept, it can be suggested that the CODP is an important element in structuring and configuring the supply chain so that total value can be delivered to the end customer (Naim et al., 1999). The exact position of the CODP is a balancing process between market, inherent product properties and process related factors (Olhager 2003). Influencing factors for the positioning are demand, volume and volatility, and the relationship between required delivery times and possible production lead times (Mather, 1988).

The degree to which clients may influence the design is dependent on the point of entry in the supply chain and the CODP is a powerful tool in defining the right combination of efficiency. The positioning of the CODP resulted in the proposal of five basic logistical configurations of the supply chain (Hoekstra and Romme, 1992): Buy-to-order (BTO), Make-to-order (MTO), Assemble-to-order (ATO), Make-to-stock (MTS), and Ship-to-stock (STS). Subsequently Engineer-to-order (ETO) which relates to the situation that a product needs to be engineered before it is produced due to its high degree of customisation has been added to the aforementioned supply chain structures (Naylor et al., 1999; Olhager, 2003; Wikner and Rudberg, 2005a; Gosling and Naim, 2009).

Wikner and Rudberg (2005a) state that all CODP definitions are based on the fundamental concept of the P:D ratio. The P:D ratio of an operation is the ration of the time it takes to manufacture the product (production lead-time) and the time it takes to deliver the product to the customer (delivery lead-time). Both variables are independent as P is completely under the control of the company whereas D reflects the requirements of the market or the offering of the company. Figure 2.7 shows the aforementioned configurations based on the result of the P:D ratio. As can be seen the MTS situation as one extreme yields a P:D ratio that is a lot higher than 1, which means

that most of the P is based on speculation. On the other hand, looking at ETO it can be deduced that all activities are only started when there is an actual customer order, hence, when $P:D < 1$.

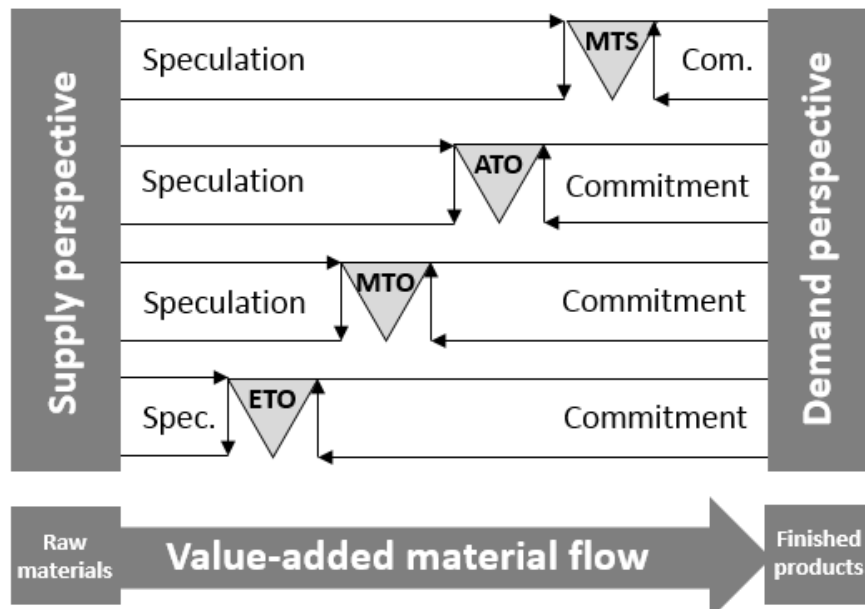


Figure 2.7: Supply chain configurations based on P:D ratio (adapted from Wikner and Rudberg, 2005a)

However, all of the aforementioned configurations are at an aggregate level, as is most of the research and literature in this area. This means that most of the research concentrates on the product itself rather than on the product architecture consisting of many different components and sub-components. This can lead to incorrect conclusions with regard to the set-up of the supply chain. It is therefore important to be aware of the practical implications of the multitude of CODPs within a supply chain for products with a complex product architecture.

A definition of product architecture is given by Ulrich (1995, p. 419): “Product architecture is the scheme by which the function of a product is allocated to physical components.” It can therefore be deduced that the product architecture, once itemised, indicates how many components the product consists of and how these components work together. Furthermore, as Fixson (2005) points out, it is vital to match supply chain processes to the product architecture as this has the potential to coordinate all the

decisions that need to be made when trying to satisfy diverse customer needs. A potential risk of only looking at the CODP position on an aggregate level is that mismatches between customer choice and a company's categorisation of such choice will not be identified. On the other hand, however, it needs to be appreciated that the aim of the above mentioned research is to highlight the implications that result from the decoupling point concept.

In this research it is thus hypothesised that a positioning of the CODP on an aggregate product level is too simplistic and that there exist multiple CODPs in a supply network. Although there is some research on complexity issues in connection with the CODP concept (Wikner and Rudberg, 2005; Van der Vorst, 2000), the existence of multiple CODPs and, most importantly, the resulting consequences for the supply chain management, has not been discussed sufficiently and there are few empirical studies on the topic.

Some authors, however, appreciate, that it is indeed difficult to identify one single CODP in a supply chain. Wikner and Rudberg (2005), for example, argue that increasing product variety can lead to an overlap in engineering and production activities, thus recognising the multiple dimensions relevant for the CODP. Nevertheless they concentrate on the positioning of one single but feasible CODP. In another study Wikner and Rudberg (2005) find that it is difficult to find that single point in the supply chain where there is a separation between certainty and uncertainty. Hence, they come up with the idea of a customer order decoupling zone (CODZ) because the traditional concept of the CODP does not give sufficient guidance on the positioning of the decoupling point. In the CODZ, the degree of certainty increases gradually (Wikner and Rudberg, 2005).

Gosling et al. (2007) conducted an empirical study in the construction sector and highlighted the diversity of operations that feed into a construction project as well as the variability that exists within the different order-to-delivery pipelines. As an approach to solve this problem, they suggest the application of a flexible and agile supply chain

strategy to enable the order-to-delivery pipeline for a range of different supply chain structures to feed into an ETO project environment.

Wong et al. (2009) also find a strong argument against concentrating on the positioning of the CODP on an aggregate level. They clarify the concept of form postponement in that delaying the product differentiation in postponement does not necessarily suggest that the differentiation is only processed after customer orders are received.

Although all of the research stated above acknowledges that the original view of the CODP concept does not appreciate the complexity of supply chain processes, it does not explicitly state that multiple CODPs exist and can be used to optimise the supply chain. This is mainly due to the fact that these studies discuss the CODP in a serial supply chain and not in a supply network consisting of many different components and sub-components which can be supplied by different suppliers (Sun et al., 2008).

Few authors specifically research the existence of multiple CODPs (Verdouw et al., 2006; Sun et al., 2008; Graman and Magazine, 2002; Banerjee, 2012). Verdouw et al. (2006) for example argue that in reality, companies have multiple CODPs for each individual product, product-market combination, product component, level of customer commitment and interface in the supply chain. They also highlight that once these different dimensions of diversity have been taken into account there emerge a number of possible CODP positions and due to this, many different supply chain configurations. In demand-driven supply chain networks, there is a particular need for the company to be able to “take part in different of these configurations concurrently in order to deliver customer or customer segment specific products.” (Verdouw et al., 2006, p. 2).

Sun et al. (2008) argue that in reality, a product consists of many different parts and components thus forming a supply network. They continue to say that quite simply this means that there exist multiple CODPs: one for each supplier. In their study, a mathematical model is developed in order to find the various decoupling points which they coin as a “partition line”. However, Sun et al. do not discuss how these multiple CODPs can be used to improve and optimise the operations of a company.

Graman and Magazine (2002) identify an order fulfilment process with two CODP and differentiate between mid-process and finished stock thus recognising that many products consist of a number of components and sub-components which can be delivered as partly finished products into the production process. They present a manufacturing system which produces one single item that results in multiple products. Hence, there is a similarity to the case presented in this thesis in so far as there is considerable product variety.

Banerjee et al. (2012) postulate that “it is imperative to look at the overall product chain rather than focusing on any single supply chain entity.” (p. 3051). They highlight that it is increasingly difficult to identify a single strategic CODP in the supply chain due to the following developments: increasing costs, uncertainty, margin pressure, globalisation, modularity, complexity and competition. Therefore, they establish different types of decoupling points such as the product structure decoupling point, supply structure decoupling point and demand transfer decoupling point. This partitioning of the supply chain into multiple, preferably lean and agile systems, Banerjee et al. (2012) claim, helps create flexibility and responsiveness.

One of the challenges for the supply chains of customised products in general is to ensure quick response to customer demand. This requires an exact knowledge of the various CODP in the supply chain and its relevance to the stakeholders. It is this balance between efficiency and responsiveness that can the CODP attempts to address (Naylor et al., 1999).

CODP in the house building industry

Some researchers have postulated how construction, and more specifically house building, may make use of the CODP. Naim and Barlow (2003) focused on the material flow principles upstream and downstream of the CODP in house building in order to include purchasing, inbound logistics, production, shipments and build. Inherent in their model is a predesigned product which can be mass customised, i.e. assembled as late as possible and configured to client requirements.

By refining the standardisation–customisation continuum model of Lampel and Mintzberg (1996) and utilizing the concept of the CODP, Barlow et al. (2003) developed the housing-specific suite of supply chains which embraces not only material flows but also the design function, as given in Figure 2.5. When client’s requirements penetrate all the way through to the concept stage, the project is a purely customised ETO supply chain (Gosling and Naim, 2009) and is synonymous with traditional self-build in the housing sector where there is infinite choice. That is, the client is starting with a blank sheet of paper for the design and even the location of the build.

At the other end of the spectrum, there is the traditional mode of operation for MTS speculative build where the design all the way through to the build location is predefined – the customer has no choice. The trade-off between the two ends of the spectrum has been the level of choice in ETO versus price in the MTS situation. Hence, the mass customised approach to self-build, as per a number of Japanese house builders (Winch, 2003; Barlow et al., 2003), is an attempt to maintain as high a level of choice as possible without the associated increase in cost. Although the model as shown in Figure 2.5 provides a good conceptual overview of the characteristics of house building specific supply chains, it is on an aggregate level and therefore does not sufficiently reflect the interactions between the multitude of components and customer choice.

Table 2.2 shows a structured synthesis of the generic and house building specific literature which the authors believe to be most relevant with regard to the CODP concept. The first column identifies the level of aggregation of the CODP concept the research concentrates on. The second and third columns define whether the study is conceptual or empirical and the fourth column indicates what industry the research is based on if it is an empirical study. The fifth column indicates the main limitations of the respective research. The table suggests that there is a gap of nearly 10 years during which the house building industry has not been in the focus of CODP research. Furthermore, there are few empirical studies on this topic and only two studies that discuss the existence of multiple CODPs in a supply chain. But none of the studies highlight the practical implications of being aware of the multitude of CODPs within the

supply chain and their importance in identifying mismatches between customer choice and a company's categorisation of such choice.

Level of aggregation	Research approach			
	Predominantly conceptual	Predominantly empirical	Industry/product	Limitations
Single		Naim, M. and Barlow, J. (2003)	House building industry	Aggregate level
Single		Barlow, J., Childerhouse, P., Gann, D., Hong-Minh, S., Naim, M. and Ozaki, R. (2003)	House building industry	Aggregate level
Single	Olhager, J. (2003)		Generic	Conceptual
Single	Wikner, J. and Rudberg, M. (2005a)		Generic	Conceptual
Single	Wikner, J. and Rudberg, M. (2005b)		Generic	Conceptual
Single		Olhager, J. (2010)	Telecommunication industry	Aggregate level
Single	Hedenstierna, P. and Amos H.C. (2011)		Generic	Conceptual
Single	Olhager, J. (2012)		Generic	Conceptual
Multiple		Graman and Magazine (2002)	Non-durable household products	No CODP focus
Multiple		Verdouw, C.N., A.J.M. Beulens, Bouwmeester, D. and Trienekens, J.H. (2006)	Dairy industry	No product architecture
Multiple	Sun, X. Y., Ji, P. J., Sun, L. Y. and Wang, Y. L. (2008)		Generic	Conceptual
Multiple		Banerjee et al. (2012)	Industrial equipment manufacturer	No product architecture

Table 2.2: Synthesis of generic and housing specific literature on CODP (source: author)

2.6. Customer preferences – importance and measurement

As mentioned above, one of the challenges for companies manufacturing customised products in general is to ensure quick response to customer demand. This requires an exact knowledge of the various CODPs and their relevance to the stakeholders. It is exactly this balance between efficiency and responsiveness that can be clarified through the positioning of the CODP (Naylor et al, 1999). Furthermore, it is vital that companies locate their strategies along the continuum between standardisation and customisation

and are aware of the implications for the product and processes. There is the need to aim for a match between the product and processes. It is only when the customer requirements are fulfilled in relation to the degree of choice and the level of customisation, that the company will be able to deliver real value to customers (Fisher, 1997). The CODP is a powerful tool that can be used to achieve this and helps in finding the right balance between product or component standardisation and customisation.

In marketing literature customer preference is defined as the underlying principle of demand (Jobber, 2004). To develop an understanding of how customers behave and make buying decisions is one of the primary aims of the marketing discipline (Peppers and Rogers, 1997). Jobber (2004) identifies three major influences on consumer behaviour:

- the buying situation,
- personal influences, and
- social influences

The buying situation is defined by the type of problem that needs solving by the product that the customer desires. Personal influences include information processing, motivation, beliefs and attitudes, personality, lifestyle and life cycle, while social influences are culture, social class, geodemographics and reference groups. Customer preferences are a complex combination of individual characteristics and it is a challenging task to determine preferences when customising products.

Historically, researchers have aimed to explain consumer behaviour so that trends can be predicted. In mass customisation, however, “the focus has to be shifted from passive to proactive analysis.” (Du et al., 2003). The difficulty with mass customisation is trying to capture individual data for each customer and configure the product accordingly. Du et al. (2003) identify two methods that can be applied to understand customer preferences in mass customisation. Firstly, preferences can be captured through data mining and profiling, thereby targeting the results of customisation. Secondly, marketing theories can be extended to the customisation and personalisation situation by conducting empirical research into the decision-making process when customising

products. Blecker et al. (2004) recommend that customer preferences should ideally be determined by applying both methods. This recommendation has stimulated the approach taken in this study.

In general, various studies have confirmed that a large variety of products is required to fulfil customer needs (Kahn, 1998; Stalk and Hout, 1990; Halman et al., 2003). With this increasing product variety, companies are also challenged to keep costs at an economical level. Nevertheless, creating a more customer-centric strategy has become number one priority in many industries such as, for example, the car and fashion industries (Tseng and Piller, 2003).

Furthermore, general customisation practice has already shown that customers are willing to pay a premium for a product that has been made according to their preferences or individual needs (Tseng and Piller, 2003). It is therefore a critical question to ask whether house builders can also achieve customer satisfaction by offering choice. In the last century, the decision to limit choice in order to achieve economies of scale proved to be a success. It was not until the 1990s, however, that the idea of efficient individualisation (i.e. use of economies of scope) was considered appropriate for the house building industry. Since then, a number of studies have confirmed that there exists an opportunity to enhance customer satisfaction and increase market penetration if houses meet expectations and the needs of customers more closely (e. g. Barlow, 1993; Gann, 1996; Barlow et al., 2003; Hofman et al., 2006).

As houses are complex products being constructed of many different elements and parts, there potentially exist a number of attributes that are customisable for the client. The aforementioned complexity problem by Cox and Goodman (1956) may have an influence on customers and their purchase decision. Offering an overly high degree of choice can cause confusion rather than satisfaction (Huffman and Kahn, 1998). And as a house is a complex product consisting of many components and sub-components, the risk of confusion is evident and choice in itself may not be beneficial. The appropriate degree of choice must be offered to ultimately achieve customer satisfaction. And for this purpose, it is vital to know which attributes are critical to customers.

This is not a specific house building issue but rather a general problem for products with a complex product architecture. Similar problems have been found in the automotive industry. Hu et al. (2008) for example present a case from the automotive industry and state that as a result of increased product variety there is an increase in product complexity as well. They report that for example the BMW Series reaches 10^{17} possible automobile variations.

Pil and Holweg (2004) present evidence from the key European, American and Japanese car manufacturers. Collected company material enabled them to measure the variations and combinations customers can actually order. Table 2.3 shows the appropriate results where it can be seen that total actual product variation is high for some car models.

Model	Bodies	Power trains	Paint-and-trim-combinations	Factory-fitted options	Total number of variations	European sales in 2002 (units)
Peugeot 206	3	8	70	5	1,739	596,531
VW Golf	3	16	221	26	1,999,813,504	595,465
Ford Focus	4	11	64	19	366,901,933	523,356
Renault Clio	2	10	57	9	81,588	502,497
Peugeot 307	3	8	70	9	41,590	441,468
GM Astra	3	11	83	14	27,088,176	440,567
GM Corsa	2	9	77	17	36,690,436	420,296
Fiat Punto	2	5	51	8	39,364	416,843
VW Polo	2	9	195	27	52,612,300,800	357,539
BMW 3-Series	3	18	280	45	64,081,043,660,000,000	350,723
Ford Fiesta	2	5	57	13	1,190,784	294,360
Renault Megane	2	6	52	14	3,451,968	261,383
Mercedes C-Class	2	16	312	59	1,131,454,740,000,000,000,000	254,836
Toyota Yaris	2	6	30	8	34,320	194,256
Fiat Stilo	3	7	93	25	10,854,698,500	173,453
Mercedes E-Class	2	15	285	70	3,347,807,348,000,000,000,000,000	157,584
Toyota Corolla	4	5	24	6	162,752	139,837
Nissan Micra	2	6	30	4	676	106,428
Mini (BMW)	1	5	418	44	50,977,207,350,000,000	105,617
Nissan Almera	3	5	30	5	3,036	87,474

Table 2.3: Overview of total number of variations offered by major automotive manufacturers (source: Pil and Holweg, 2004)

Linking the aforementioned findings from the automotive industry to the generic supply chain strategies specifically applied to the house building industry (see Figure 2.5) indicates that the available product combinations increase from pure standardisation, that is speculative house building, to pure customisation which is a supply chain strategy applied in the pure self build market.

Pil and Holweg (2004) point out that although reducing variety decreases manufacturing and logistics costs, it also reduces the company revenue because the offerings to the market place are limited. In order to reduce excessive variety companies should continuously ask the following question: For which product attributes might a broader array of choices deliver real value to customers (Zipkin, 2001)? The challenge is to identify the way in which customers make choices and how they prioritise their preferences.

Research in the automotive or clothing industry show how important it is to exactly know clients' preferences in order to deliver new product variety at a price that is acceptable to house buyers (Hofman et al., 2006 and Stäblein et al., 2011). To successfully compete in the long term, a company has to make sure that customers are satisfied (Torbica and Stroh, 2001). One way of achieving customer satisfaction in the house building industry is to build houses that reflect the personal preferences of the buyer.

Ozaki (2003) presents two empirical studies in the UK speculative house building industry. Her conclusion starts with the sentence: "Overall, UK housing customers do not seem to be very satisfied customers." (p. 562). She continues and states that the industry lacks customer-focus and that customer requirements are not sufficiently considered.

Japanese companies have successfully implemented manufacturing principles derived from the car industry in order to produce attractive, affordable and, above all, customised houses through prefabrication (Towill, 2001). In this regard, clever product architecture is vital and can give the impression of a fully customised house although in reality it involves standard operating procedures in production (Halman et al., 2008). More specifically, as Gibb (2001) writes, the whole product design, although consisting of standardized components, must provide variation: i.e. 'customized solutions from standardized components' (p. 312).

There are a number of techniques that have been used to measure customer preferences, for example: Quality Function Deployment (QFD), Analytic Hierarchy Process (AHP) and Conjoint Analysis (CA). Recently, Scholz et al. (2010) recommended the paired comparison-based preference measurement (PCPM) as a preference measurement tool for complex products. An in-depth overview and analysis of the aforementioned techniques is given in chapter three.

2.7. How to build what buyers want – product, process and customer preferences alignment in prefabricated house building

Marketing and operations management need to work hand in hand in order to achieve customer satisfaction. Marketing is an external-focused discipline and needs to continuously monitor the market so that new customer requirements for products or services can be identified at an early stage (Jobber, 2004). Operations management, however, focuses on internal processes and ensures that the products or services required by the market can be delivered in a competitive time (Tang, 2010). Many researchers therefore highlight the importance of a careful management of the marketing and operations interface as this will ultimately align these two key disciplines towards common goals (e.g. Walters, 1999; Mollenkopf et al., 2010; Tang, 2010). In this regard, Weir et al. (2000) present results from a two-stage survey targeted at manufacturers of capital equipment and industrial products based in the UK. They asked the companies what their strategy for aligning marketing and operations discipline is. The results show that the competitive advantages of building a strategic link between marketing and manufacturing are not used in practice. Hence, the conclusion is that “there is an urgent need for a methodology to aid integration between marketing and manufacturing at a strategic level which can easily be adopted by manufacturing companies during their strategic planning process.” (Weir et al., p. 843). A similar conclusion can be found in Slack and Lewis (2008) but the word choice is more dramatic: “... most organizations are as mortal as the people who create and run them. The obvious explanation is that firms fail to reconcile market requirements and operations resources because it is all too easy either to misinterpret customer requirements or fail to develop the requisite operational capabilities.” (p. 233).

There are, however, conflicts in the marketing and operations interface because of different interests. A reflection on the interaction between identifying customer needs and operational performance enables the organisation to develop effective strategies to overcome these barriers. The reward for a successful alignment will be an improvement of the competitive performance of organisations (Zanon et al. 2012).

Figure 2.7 provides a detailed insight into the intersection of marketing management, operations management and construction management as depicted in Figure 2.1. The basis for Figure 2.7 has been provided by the framework for reflecting operations strategy issues in corporate decisions as presented by Hill and Hill (2012). In the original framework, which is shown in Table 2.4, it is argued that businesses must set up processes and infrastructures that are aligned with market order-winners and qualifiers. It is important to note that there is an element of dynamics influencing the framework. These dynamics can have multiple sources. However, it is vital for a business to develop a strategy that deals with these dynamics. This is what Figure 2.7 highlights specifically for the house building industry.

Corporate objectives	Marketing strategy	How do you qualify and win orders?	Operations strategy	
			Process choice	Infrastructure choice
Sales revenue	Product/service markets and segments	Price	Process choice	Functional support
Survival	Range	Quality conformance	Trade-offs embodied in these choices	Operations planning and control systems
Profit	Mix	Delivery (speed, reliability)	Make or buy	Systems engineering
Return on Investment	Volumes	Demand increases	Capacity (size, timing, location)	Clerical procedures
Other financial measures	Standardization versus customization	Product/service range	Role of inventory in the process	Payment and reward systems
Environmental targets	Innovation level	Design leadership		Work structuring
	Leader versus follower	Technical support		Organizational structure
		Brand name		
		New product and services (time-to-market)		

Table 2.4: Framework for reflecting operations strategy issues in corporate decisions (source: Hill and Hill, 2012)

In Figure 2.7 on the bottom left hand side, there is marketing, or the demand side. With regard to this thesis, the tasks of marketing management that are of interest are to:

- Identify target customers.
- Measure preferences of these target customers.
- Prioritise customer preferences in order to set up option lists accordingly.

The operations side is on the right hand side and indicates how the findings from the marketing management can be operationalised. Hence, the relevant tasks for this thesis that operations management should consider are to:

- Design the products for customer preference.
- Standardise components, operations and processes.
- Consider technical and production constraints.

However, from experience the author can state that for the prefabricated house building sector, the interface is much more complex as the product as such consists of many different product levels and components. As depicted in Figure 2.8, the customisation process feeds the product specification, in this case the specification of the prefabricated house, directly into the interface. However, the circular process as shown in Figure 2.8 needs to be completed as otherwise, operations department does not have a final product specification, and consequently the production process cannot be started. The client collaborates with the designer and expresses his or her requirements and wishes. The designer needs to be aware of the product specific design rules which determine the possibilities of the building system. The prefabricated house manufacturer applies and submits draft drawings to the technical department then checks the drawings with regard to technical and structural constraints before forwarding it to the production manager who checks for producibility. The production manager is then the one to feed all the changes required back to the designer who finally consults the client and ideally lets him sign off the drawings so that the project can start. This describes the ideal situation without any delays. However, often there are problems with determining the customer preferences or the preferences could be determined but the building system or the option list does not satisfy the requirements. Moreover, there can be problems with the constraints. Every time there is a problem, the customer needs

to be involved again as the required changes may influence the design or the layout of the house. Hence the configuration process of a prefabricated house can be lengthy, thereby transferring a high degree of uncertainty onto the operations side (Hofman et al., 2009). This critical situation was highlighted by Wortmann et al. (1997). They were concerned with setting up a typology for customer-driven manufacturing and emphasise that customer involvement means that the customer's influence on the product "can range from the definition of some delivery-related product specifications in advanced phases in the product life cycle (i.e., packaging, transportation) to a modification of the ultimate functions of the product in the very early product life cycle phases (i.e. customer-related product specifications)." (p. 42). Therefore, Wortmann et al. conclude that a systematic approach is needed and appropriate organisational structures and production systems need to be set up so that customer orientation can be controlled.

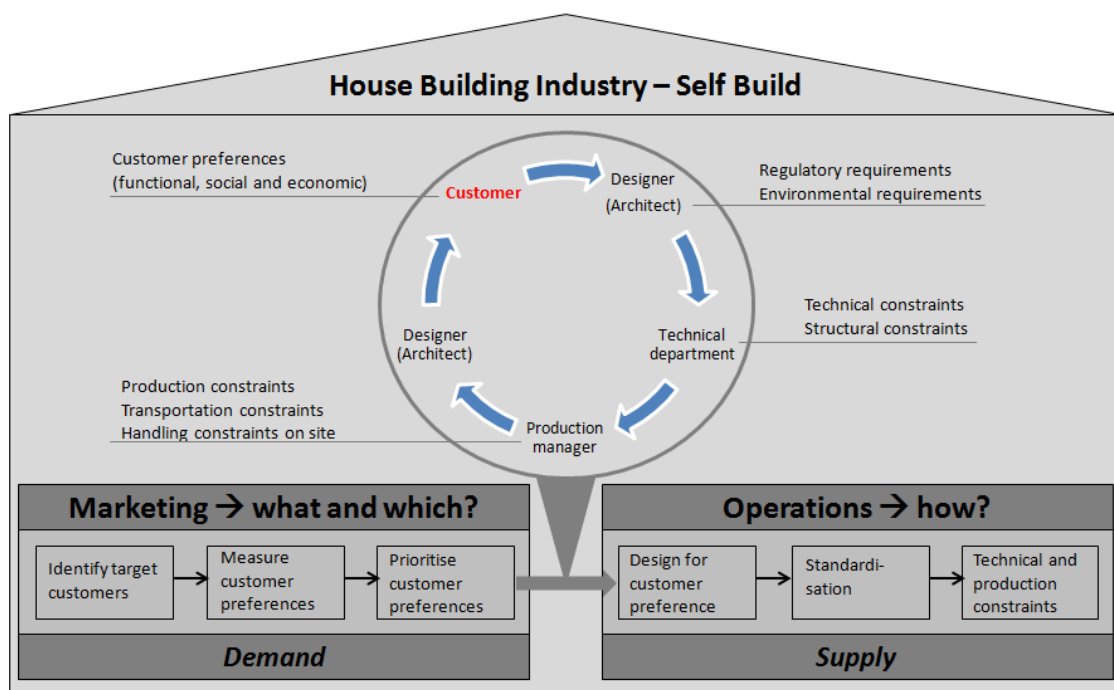


Figure 2.8: Marketing and operations interface in prefabricated house building (source: author, synthesised from: Walters, 1999; Jobber, 2004; Hofman et al., 2009; Mollenkopf et al., 2010; Tang, 2010; Hill and Hill, 2012)

In the foreword of Joseph Pine's well-known book *Mass Customization – The New Frontier in Business Competition* (1993), Stan Davis points out that mass customisation does not occur in isolation. Mass customisation is instead an array of concepts and

strategies which all need to be aligned to a greater or lesser degree. Only if this awareness exists, can mass customisation become a competitive advantage (Pine II., 1993).

It is often argued that customer satisfaction can only be achieved if the degree of choice offered matches customer requirements. This is the reason why customisation is such a powerful strategy (Peppers and Rogers, 1997). As mentioned before, if customers are offered too much choice there is a risk of confusion rather than satisfaction (Huffman and Kahn, 1998). But if too few options are offered to customers, they may decide to buy a different product as they cannot find the product or model they require. Hence, customers do not want a lot of options per se. They only want the options that meet their requirements and needs (Stäblein et al., 2011; Peppers and Rogers, 1997).

For the house building industry, a number of studies confirm that there exists an opportunity to enhance customer satisfaction and increase market penetration if houses meet the expectations and needs of customers more closely (Barlow, 1993; Gann, 1996; Barlow et al., 2003; Naim and Barlow, 2003; Ozaki, 2003; Hofman et al., 2006). However, the majority of these approaches concentrate on the building level rather than on the component or even attribute level. If customer choice penetrates on all levels, this over-simplifies the analysis considerably, links marketing and operations on a superficial level, and finally leads to mismatches between products and processes (Schoenwitz et al., 2012).

Leishman and Warren (2006) present research on housing design customisation. They highlight the importance of capturing user requirements and suggest that wider choice of internal specification is associated with greater consumer demand. The multiple components and sub-components of a house are partially available in many different attributes which increases the options that can potentially be offered to a customer. Therefore, companies opting to provide houses that are built according to customers' needs must develop strategies on how to identify customer preferences and consequently configure the products and processes in a way that can cope with the degree of choice that needs to be provided (Barlow et al., 2003). In this regard, it is also

important to know how customers prioritise their preferences. Only then will it be possible to identify elements with the need and degree of variety.

Payne and Holt (2001) propose a framework that is aimed at determining a total organizational value proposition. The value process involves four sequential activities: value determination, value creation, value delivery and value assessment. The underlying principle of the value process is that a value needs to be identified before it can be created, delivered and communicated to the customer. Critical in the process presented by Payne and Holt (2001) is the consideration of a value assessment in which it is assessed whether real value has been delivered to the customer.

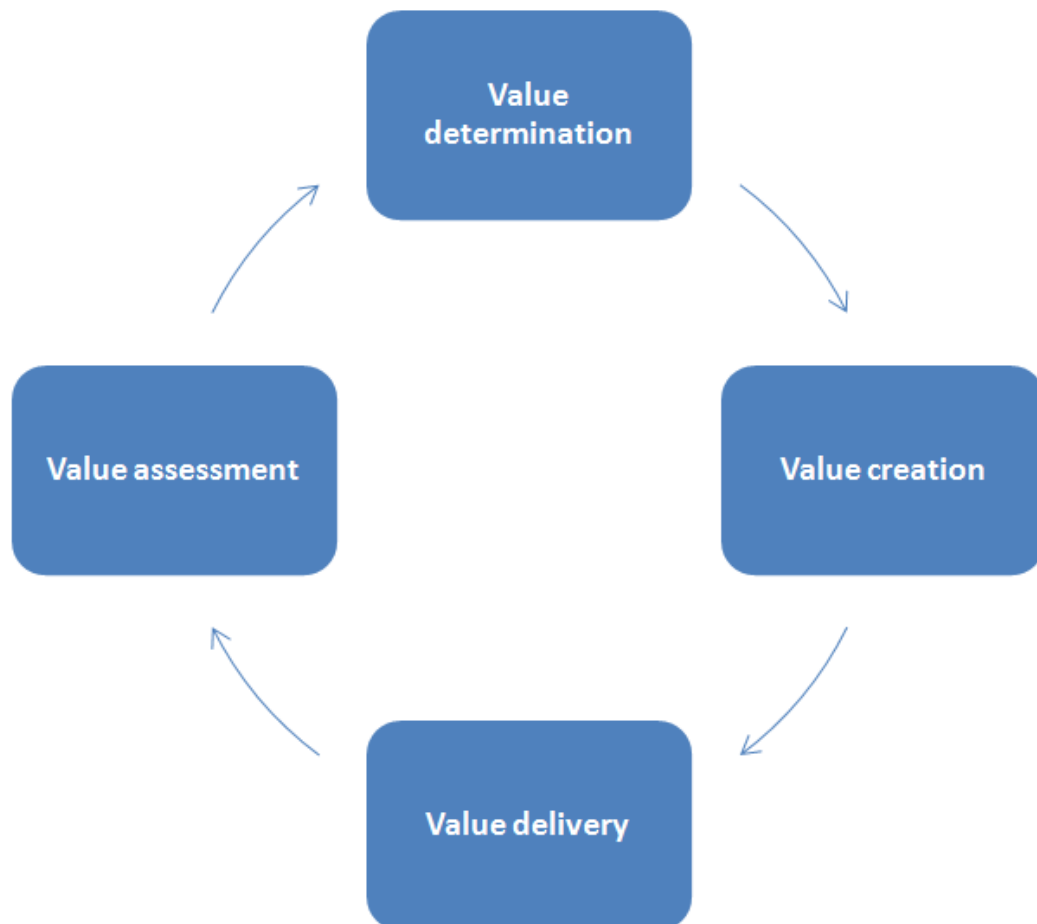


Figure 2.9: The value process (source: Payne and Holt, 2001)

Figure 2.9 shows the value process. The value determination for example is achieved by completing a customer preference measurement. As pointed out by Payne and Holt (2001) this activity needs to be completed in order to identify what is driving customers when “trading off the benefits and sacrifices, both when they are purchasing and when they are using or consuming products” (p. 174).

In the second activity value is created. This can be done by aligning products or services on offer with the requirements identified during the value determination activity. Following value creation decisions need to be made with regard to how the value is delivered. Hence, the operational capabilities need to be aligned accordingly. In the final activity it is assessed whether value has been delivered to the customer. Payne and Holt (2001) suggest customer satisfaction surveys or service quality measures as value assessment methods.

2.7.1. The role of concurrent engineering in operationalising a mass customisation approach

As mentioned in chapter 2.5.1., the mass customisation system focuses on the customer with simultaneous product development activities. Therefore, if a company applies a mass customisation strategy, then the traditional order of product development, production and distribution activities needs to be realigned so that the process is not linear anymore but more concurrent (Kincade et al., 2007). Many authors identify concurrent engineering (CE) to have the ability to convert a linear process to a more integrated and simultaneous one (Fine, 2000; Balasubramanian, 2001; Kincade et al., 2007). This means that activities are not performed in a sequential way but mostly at the same time. If this is done properly, then the reward is a compressed time-to-market of the product, which means that customer preferences can be fulfilled faster, and more accurately (Balasubramanian, 2001).

As Swink (1997) points out there are two aspects of CE that makes the approach different compared to conventional approaches to product development: cross-functional integration and concurrency. It can therefore be defined as “the simultaneous design and development of all the processes and information needed to manufacture a

product, to sell it, to distribute it, and to service it.” (Swink, 1997, p. 104). Hence, it is claimed that if CE is applied properly then it improves design quality while reducing time and cost of product development. Swink (1997) states that some companies have reported savings in product development costs of 20% as well as a reduction of 50% of the development time. Hence, he concludes: “effective CE processes can provide fundamental sources of competitive advantage.” (Swink, 1997, p. 115).

Fine (2000) acknowledges that CE was responsible for developing the understanding that there is a need to simultaneously design the product and manufacturing process. However, he claims that due to the demonstrated benefits of the concept, the application of CE techniques has become very popular which resulted in it no longer being a source of competitive advantage (Fine, 2000). Therefore, he extends the concept “from product and manufacturing to the concurrent design and development of capabilities chains.” (Fine, 2000, p. 218). The new concept is presented as three-dimensional concurrent engineering (3-DCE) and considers the many different connections between the product, process and the design of the supply chain. Figure 2.10 shows some of these connections as presented by Ellram et al. (2007). Linkages between the three areas are highlighted by the overlapping areas.

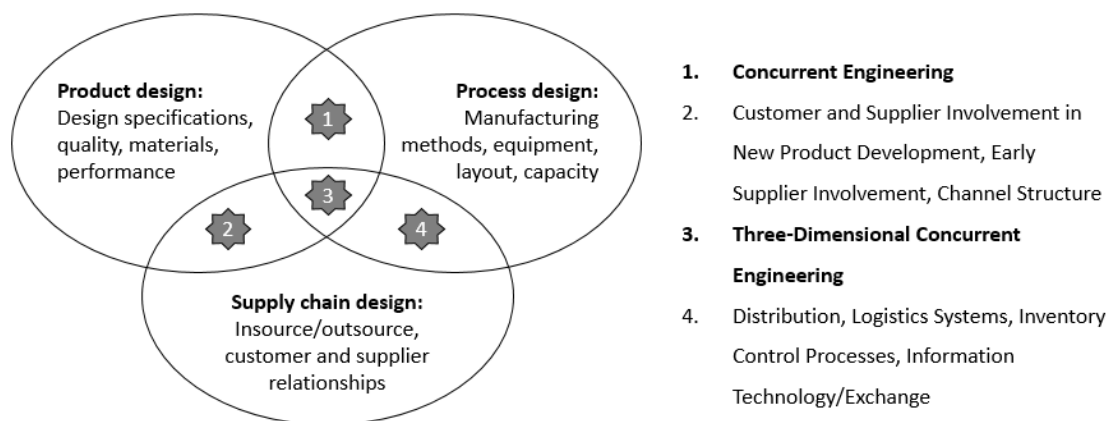


Figure 2.10: Three-dimensional concurrent engineering (adapted from: Ellram et al., 2007)

According to Fine (2000) product design is divided into activities of architectural choices and detailed design choices whereas process design is divided into the development of processes and manufacturing systems. Supply chain design is defined as activity [64]

concerned with supply chain architecture and logistics/coordination system decisions. This thesis is limited to researching the product and process interface with an awareness of the impact on the supply chain design. Hence, there is considerable scope for future research as will be discussed in the concluding chapter.

As mentioned before, Fisher (1997) realised that the supply chain needs to be in alignment with the processes and abilities of the manufacturer as only this enables the company to meet customer requirements. Fine (2000) uses the 3DCE concept to provide a detailed understanding on how this can be achieved. The 3DCE thus takes a “holistic viewpoint that considers the key functional interfaces within the organization and includes suppliers and customers, and how the product, process and supply chain work together to efficiently and effectively meet the customer’s needs.” (Ellram et al., 2007, p. 320).

Piller (2013) translates the above in a house building specific context and names solution space development, robust process design and choice navigation as the fundamental groups of capabilities which determine the ability of a company to fulfil customer requirements. Solution space means that the company needs to be able to define exactly what it is going to offer. To be able to do this the business must have an understanding of “product attributes along which customer needs diverge the most.” (Piller, 2013, p. 18). The adequate combination of organisational and value chain resources in order to efficiently and reliably deliver customised solutions is defined as robust process design. Finally, Piller (2013) points out that a company needs to be able to simplify the navigation through the options on sale. This is defined as choice navigation. Piller claims that successful mass customization demands a combination of these capabilities in a “meaningful and integrated way, to design a value chain that creates value from serving individual customers differently.” (Piller, 2013, p. 18). In contrast to Fine (2000) and Lambert and Cooper (2000) Piller does not mention supply chain design as a separate area to consider. However, like the aforementioned authors he states that the appropriate design of the supply chain is a result of the product and process combination.

The need to be able to satisfy varying customers' needs resulted in creating flexibility not only in manufacturing but also in the architecture of the product. Modularity and platform concepts were applied in order to increase responsiveness (ElMaraghy and Mahmoudi, 2008). Robertson and Ulrich (1998) suggested the use of product platforms and stated that this must include considerations of marketing, design and manufacturing issues. Tseng and Jiao (1998) developed the idea of the product family architecture model in order to handle the diverse customer requirements, reusability of design and process capabilities.

All of the aforementioned ideas have one thing in common: in order to be able to apply the concepts, the constitution of the product, also known as product architecture, needs to be known. Ulrich (1995) defines product architecture as the "scheme by which the function of a product is allocated to physical components." He specifies further that a product architecture is:

1. the arrangement of functional elements;
2. the mapping from functional elements to physical components; and
3. the specification of the interfaces among interacting physical components.

Fujita (2002) reports that products are complicated and "have systematic structures in various aspects such as physical functions, manufacturing units, etc. in order to accomplish integrated superior functions apart from native tools." (p. 945).

The goal of developing and constantly refining the product architecture is to maximise the profit potential for the company. However, the complexity of setting up the product architecture is even increased by the dynamics of customer requirements, technological changes and competitor responses (Martin and Ishii, 2002).

2.8. Gaining competitive advantage through better alignment with customer preferences

Competitive advantage is described as the key to superior performance. Jobber (2004) identifies two means for gaining competitive advantage: product differentiation and managing for lowest delivered cost. Furthermore, a combination with the competitive

scope of activities enables Jobber (2004) to identify four generic strategies with which competitive advantage can be gained:

- Differentiation – the company offering gives customers a reason to prefer the product over another. The aim is to differentiate in a way that leads to a price premium.
- Cost leadership – cost leaders often sell standard products for which there is a broad customer base. The aim is to achieve the lowest cost position in the industry.
- Differentiation focus – differentiation focusers target customers with special needs and aim to differentiate their offerings within a target market.
- Cost focus – a basic product offering is provided and a cost advantage is gained within a target market.

Only if companies commit themselves to one of the above mentioned strategies will they gain an advantage over their competition. However, when aiming to gain a competitive advantage it is also important to understand where the competitive advantage comes from, i. e. what are the sources of competitive advantage and where exactly are they located. Jobber (2004) names three different sources:

- Superior skills – unique capabilities of personnel.
- Superior resources – tangible ingredients which enable a company to show its skills: financial resources, sales promotion, etc.
- Core competencies – the combination of skills and resources results in core competencies.

It is important to note that apart from being aware of the sources of competitive advantage it is also important to understand that customer value needs to be delivered as otherwise, although skills and resources are in place, there is a risk of not meeting customer requirements (Payne and Holt, 2001). Hence, resources and skills need to be married with customer value (Woodruff, 1997).

Strategic and managerial guidance to achieve competitive advantage based on the above explanations is provided by the resource-based view theory (RBV). Barney

presented the first serious framework linking resources to sustained competitive advantage and superior performance in 1991. In 1992 when the RBV was still an emerging framework, Mahoney and Pandian point out that the concept provides an “illuminating generalizable theory of the growth of the firm.” (p. 373).

In general, the RBV is used to theorise linkages between causes (e. g. resources) and effects (e. g. competitive advantage, performance). It is a model that regards resources as key to superior company performance. Supporters of this view argue that companies find the sources of sustained competitive advantage inside the business rather than in the competitive environment (Wernerfelt, 1984).

Under the RBV there are four conditions which must be met in order to be able to transfer short-term competitive advantage into sustained competitive advantage (Peteraf, 1993):

- Resource heterogeneity – the resource bundles and capabilities underlying production are heterogeneous and thus create Ricardian or monopoly rents.
- Ex post limits to competition – prevent the rents from being competed away. There are two critical factors which limit ex post competition: imperfect imitability and imperfect substitutability.
- Imperfect resource mobility – resources are perfectly immobile if they cannot be traded. This ensures that valuable resources remain within the company.
- Ex ante limits to competition – prior to any company’s establishing a superior resource position there must be limited competition for this position.

Although the above conditions are critical in achieving competitive advantage, these are not sufficient to enable the company to sustain it. In 1991 Barney proposed the VRIN framework which tests whether resources and skills are valuable, rare, costly to imitate and non-substitutable. Those resources and skills that fulfil the aforementioned traits are the sustained competitive advantage (Barney, 1991; Peteraf, 1993). Barney was the first who extended the VRIN framework because he realised that a company needs to be organised to exploit and deploy the resources and skills. Hence, the new framework

was coined VRIO: valuable, rare, costly to imitate and organised to capture the value of the resources ('non-substitutable' was integrated into 'costly to imitate').

More recently Hinterhuber (2013) criticises that none of the adaptations of the RBV following the seminal work of Barney was actually able to address the biggest problem of the concept: "its lack of future orientation and its inability to differentiate, ex ante, between valuable and less valuable resources and skills:" (p. 799). Hence, Hinterhuber (2013) proposes a market-oriented version of the RBV. This extension builds on the VRIO framework as suggested by Barney (1991), however, Hinterhuber adds two further dimensions: customer needs and size of addressable market segments. Consequently, resources and skills that enable the company to gain competitive advantage must have to following properties:

- Valuable
- Rare
- Imperfectly imitable and non-substitutable
- Company is organised to exploit the resources and capabilities
- Sufficiently large – market segments are addressed that are sufficiently large to cover the fixed costs of the business.
- Resources and capabilities enable the company to address customers' unmet needs

Hinterhuber (2013) emphasises that the new framework, which he calls VRIOLU, is no criticism of the RBV but as a value-adding extension to the current framework. And indeed the VRIOLU framework resolves one of the biggest problems of the RBV: the lack of practical applicability. With the new framework, the resources and capabilities, which lead to competitive advantage, can be identified ex ante. Hence, managers will now be able to distinguish more valuable resources and capabilities from less valuable ones (Hinterhuber, 2013).

This links in with the work of Fine (2000) and Lambert and Cooper (2000) who insist that competitive advantage is achieved by combining product, process and supply chain in a way that creates value by meeting customer needs.

2.9. Summary – synthesis of key literature and summary of research gaps

The literature review has denoted that there exists only some limited understanding of what customers prefer when configuring a house. Moreover, there seems to be no research that links the identification of customer preferences with the required alignment of the product and processes.

Author(s)	Year of publication	Title of research	Research in:						
			Mass customisation	Supply chain management	Multiple CODP	Customer preferences	Product architecture	Alignment	House Building
Pine II, J.	1993	Mass Customization: The New Frontier in Business Competition	X	X					
Gann, D. M.	1996	Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan	X	X					X
Lampel and Mintzberg	1996	Customizing customization	X	X					
Fisher M. L.	1997	What is the right supply chain for your product?		X				X	
Huffman and Kahn	1998	Variety for sale: mass customization or mass confusion?	X			X			
Naim et al	1999	Developing lean and agile supply chains in the UK house building industry	X	X				X	X
Towill, D. R.	2001	The idea of building business process: the responsive housebuilder	X	X					
Barlow et al	2003	Choice and delivery in housebuilding: lessons from Japan for UK housebuilders	X	X				X	X
Naim and Barlow	2003	An innovative supply chain strategy for customized housing	X	X				X	X
Ozaki, R.	2003	Customer-focused approaches to innovation in housebuilding	X	X					X
Hofman et al	2006	Variation in housing design: identifying customer preferences	X			X	X		X
Leishman and Warren	2006	Private housing design customization through house type substitution	X			X			X
Schoenwitz et al	2012	The nature of choice in mass customized house building	X			X	X		X

Table 2.5: Synthesis of key literature (source: author)

The few studies looking at customer preferences in the house building industry concentrate on the upper level of the product architecture, that is, the whole house, which does not appreciate the complexity of the product. However, if customer choice can penetrate on all levels of the product architecture, then it is important that the operational capabilities reflect this degree of choice.

Table 2.5 shows the key literature for this research. The shaded boxes with an “X” show which area the appropriate publication covers. Overall, it can be deduced from the table that there is no research that considers all of the first six generic research areas which are important for the successful application of a mass customisation strategy. And the

seventh column also indicates a gap specific to the house building industry. It can be noted though that the frequency of house building specific mass customisation research has increased during the last ten years. Therefore, it is the aim of this study to provide an understanding of the importance of all the six areas as well as their interrelations. The identification of the above gaps and shortcomings has generated the four research questions as stated in Chapter 1.3 of the thesis. These are restated in the following in order to highlight the relation between the gap identification and the formulation of the research questions:

RQ 1: What relevance does product architecture have for the provision of a customised product?

Gap: Lack of research in establishing the link of a product's architecture to a company's capabilities.

RQ 2: How do customers prioritise their preferences with regard to the configuration of a prefabricated house?

Gap: Not sufficient research into the measurement of customer preferences in prefabricated house building. Furthermore only few studies look at the prioritisation of the preferences that have been determined.

RQ 3: How can customer preferences be aligned to what is offered in terms of customisation?

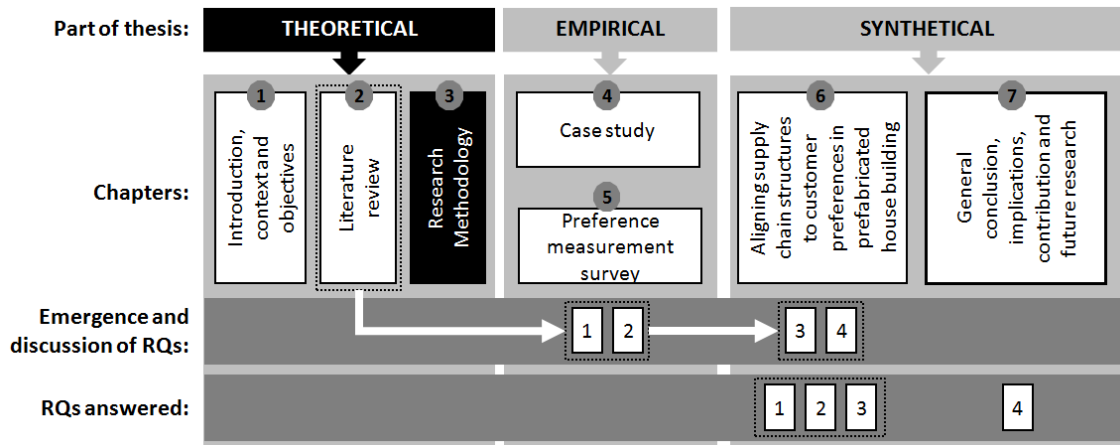
Gap: Lack of research in scrutinising the link between customer preferences, production and process development as well as alignment strategies.

RQ 4: Can lessons in aligning the product and processes with customer preferences be generalised to different industry sectors?

Gap: As the link between the product, processes and customer preferences has not yet been established in the house building industry it is assumed that the findings of this study can be relevant to industries producing products which are comparable to a prefabricated house.

Chapter 3

“Theory is good but it doesn’t prevent things from existing.” (Ian Craib)



3. Research Methodology

3.1. Introduction

The primary research aim of this thesis is to present a method of how product and processes in a house building specific product environment can be defined and aligned with customer preferences. The theoretical foundation for this research has been established in Chapter 2. The purpose of Chapter 3 is to describe which research strategy and instruments were utilised in the empirical element of the thesis. These are presented and discussed in detail.

The methodological approach this study has taken is rationalised. First, the underlying philosophy of this research is defined. This determines the belief about the way in which the data was gathered, analysed and used. The research philosophy is not to be mistaken for ethical principles which define the protection of the rights of research participants.

The four research questions as developed in Chapter 2 are revisited and it is explained how the methodology that has been adopted and leads to answers to the research questions. Furthermore, for each of the research phases, the choice of the approach is

discussed and strengths and weaknesses are assessed before giving details about the application in this thesis.

As data collection methods, a case study and an online survey were conducted. This implies that personal data is captured which means that there are a number of ethical implications that need to be considered. These are also discussed and it is stated how these implications were incorporated into this research.

3.2. Philosophical considerations

3.2.1. Different philosophical paradigms

In general, the research philosophy defines the belief about the way in which data for a research project should be gathered, analysed and used (Saunders et al., 2009). It is often described as the outer layer of the 'research onion' as coined by Saunders et al. (2012). Further layers towards the core of the onion are: approach, methodological choice, strategy, time horizon and techniques and procedures. It is argued that the development of knowledge follows these steps.

When conducting research one might be tempted to ask: "Why bother with philosophy?". Dobson (2001) refers to Collier (1994, p. 17) for an answer:

"A good part of the answer to the question 'why philosophy?' is that the alternative to philosophy is not no philosophy, but bad philosophy. The 'unphilosophical' person has an unconscious philosophy, which they apply in their practice – whether of science or politics or daily life."

This thesis was written to make a contribution to knowledge. Therefore, it seems sensible to think about knowledge in more depth. In particular, one needs to be concerned with the basic issues of how knowledge is created and how it is distinguished from opinion, belief or falsehood (Thomas, 2004).

Hence, an understanding of the existence of various and in fact different philosophical paradigms provides a good basis for the ability to justify a particular research approach.

Unfortunately, however, it appears from the extensive literature in this field that there is no consensus with regard to the classification and categorisation of different research philosophies. In a critique, Mkansi and Acheampong (2012) note that the difficulty in conducting research today is increased by the incoherency of the research philosophy classifications. They highlight a number of studies that use different descriptions, categorisations and classifications in relation to research methods with overlapping emphasis and meanings. The consequence is “tautological confusion of what is rooted where, and according to whom; but raises a critical question of whether these opposing views are enriching knowledge or subtly becoming toxic in the field?” (Mkansi and Acheampong, 2012, p. 1). The author of this thesis shares these sentiments as he has found himself in the same dilemma. Furthermore, the question needs to be asked as to why all these different views exist and whether these add any value to the research community. Certainly, the latter can at least be challenged. However, this is not the focus of this research. In order to be able to provide an insight into the positioning of the researcher in the knowledge creation process of this thesis, the definitions and explanations given by Saunders et al. (2012) have been chosen to be the basis for the following. From the author’s point of view, Saunders et al. (2012) provide a good and tangible overview of the philosophical implications of research work.

The creation of knowledge is generally based on the following underlying principles:

- Philosophy: comes from the Greek word ‘philosophia’ which means ‘love of wisdom’. It is concerned with the most fundamental questions about knowledge, reality and existence (Thomas, 2004).
- Ontology: comes from the Greek word ‘on’ and means ‘being’. Ontology is concerned with the nature of reality (Saunders et al., 2012)
- Epistemology: concerns the definition of acceptable knowledge in a particular research field.

For ontology there are two aspects that need to be mentioned: objectivism and subjectivism. Objectivism describes the position that social entities exist as an important reality outside the social actors who are concerned with their existence. Subjectivism,

on the other hand, means that the affected social actors create social phenomena through their perceptions and consequent actions.

As mentioned above, the epistemology is concerned with what is considered to be acceptable knowledge. It deals with the relationship between the researcher and the research object. Saunders (2012) gives three different approaches which can be embraced by researchers. Firstly, there is the philosophy of positivism. This is characterised by an insistence that science can deal with observable entities only. Abercrombie et al. (2000, p.269) give the following definition:

“Positivism is characterised mainly by an insistence that science can deal only with observable entities known directly to experience and is opposed to metaphysical speculation without concrete evidence.”

Therefore, positivists believe that reality can be observed and described from an objective viewpoint.

Secondly, there is realism which assumes that what we sense is reality (Saunders et al., 2012). Realists believe that the world is made meaningful by interpretation and seek to rationalise what can be observed in terms of underlying structural mechanisms (Thomas, 2004).

And finally, there is interpretivism which advocates that only through subjective interpretation of reality can that reality be understood. Interpretivists state that there exists a whole variety of interpretations of reality but believe that these interpretations in itself form a part of the knowledge creation (Saunders et al., 2012).

3.2.2. Research philosophy applied in operations management research

Traditionally, the positivism approach has been dominant in operations management research (Meredith, 1998). This involves survey research which often means that large samples are collected and statistical generalisations are made. The researcher and the respondent are considered to be independent. Most studies are limited to testing hypotheses.

However, in the early 1990s there were calls in operations management research to conduct more interpretivist oriented research as these studies were expected to establish hypotheses rather than to just test hypotheses. McCutcheon and Meredith (1993) provided a rationale for the wider use of case studies in operations management. They concluded their study with a clear statement (p. 252): "... embracing a field investigation technique such as case studies, is bound to make the individual researcher, and the field in general, richer and better prepared to solve real OM [operations management] problems." At the time the acceptance of that recommendation by the operations management research community was rather low which was highlighted by Stuart et al. (2002). Here, they state that despite the many calls for case-based research, the publication rate of such articles in top-tier journals has been less than stellar. They repeat the demand that case research deserves a stronger role in the mix of methodologies than it currently receives.

Good social science should be problem and not methodology driven (Flyvberg, 2006). The aim is to use methods that best help to find the answer to research questions. It should not be the aim to choose a method first which is then applied to solve a certain problem even though there may be a more suitable method. Often, a combination of qualitative as well as quantitative methods, of positivism, realism and interpretivism will do the task best (Flyvberg, 2006). This means that a strict separation of quantitative and qualitative methods can result in unproductive problem-solving.

3.2.3. Research philosophy adopted in this thesis

Saunders et al. (2012) suggest that it is more appropriate for a researcher undertaking a particular study to regard the research philosophy as a multidimensional set of continua rather than separate positions. This supports the statements made by Flyvberg (2006) as stated above.

In this thesis, qualitative as well as quantitative research methods are applied. Hence, a hybrid approach is taken employing more than just one particular research method. From the author's point of view, a revision of the philosophical stance always involves a review of the research problem as such. A particular philosophical position must not

preclude the researcher from investigating a particular problem only because the right methodology is inappropriate according to the philosophical stance.

However, by scrutinising the three key research paradigms it can be deduced that for this research a manifestation of the realist stance was adopted, that is, critical realism (CR). This perspective owes its popularity to the original work of Bhaskar (1978). Followers of the CR movement argue for a shift from prediction to explanation, the use of abstraction, and reliance on interpretive forms of investigation (Wikgren, 2005).

Critical realists focus on the role of replication which means that research work should be replicable across samples, populations and research methods before any generalisability of the findings can be claimed (Mir and Watson, 2001). However, more importantly, CR justifies the study of any situation, but only if the research process involves thoughtful in-depth research with the objective of understanding why things are as they are (Easton, 2010). Exactly this is what this thesis is trying to achieve. Using a two-stream research approach, combining qualitative and quantitative methods, this thesis aims to rationalise how customers assign their preferences when configuring a prefabricated house.

3.3. Ethical implications

There are a number of rules that need to be considered when conducting research involving the participation of human beings. The most important rule is that the personal rights of each participant need to be protected (Wiles, 2012). This means, for example, that in any case the participation in the research must be voluntary and people must not be coerced into participating. This was particularly relevant for the case study where interviews and focus group sessions were conducted. At the beginning of each session, participants were told that the participation is completely voluntary and that any refusal to take part would not result in any disadvantage for that particular person.

However, in the context of this study this is not really relevant, as with an online survey people have the choice to participate or not. Nevertheless on the second page of the

online survey the participants needed to actively agree (i. e. by clicking “I agree”) to the following:

The participation in this study is entirely voluntary and you can withdraw from the study at any time without giving a reason. The information provided by you will be processed and analysed using special software. However, the data will be held confidentially, securely and will only be used for the purpose of this research.

You hereby confirm that you agree with the above if it is ensured that only the researcher himself can trace the information provided back to you individually. The storage and analysis of this research related data is in accordance with the legal requirements.

If you have any queries, you can contact the responsible researcher under schoenwitm1@cardiff.ac.uk.

- I agree.

- I disagree.

As mentioned above, only when the participants clicked “I agree” was access given to the online questionnaire. This also covered the issue of informed consent according to which the participant must be fully informed about the background, procedures and potential risks of the research (Singer, 2008). Furthermore, it was explained to the participant that the data collected, which is partly identifying information, was not made available to anybody who was not involved in the study. Moreover, any data in this study is presented in aggregate form which makes the identification of an individual impossible.

Good research practice requires that there is an adherence to the above mentioned principles. Although this is a lower risk project as it only involves one online survey, this research has been conducted in close collaboration with the University’s Research Ethics Committee. The required ethical approval was given before the research involving human participants began.

3.4. Research approach and design

3.4.1. Methodological route

This study is built on two empirical pillars and the evidence drawn from these sources, plus the placing of the sector specific findings within the context of the general body of knowledge. Figure 3.1 gives the overall approach utilised in the research. This Figure follows Figures 1.1 and 1.2 and also includes the gaps as well as the research questions.

As a result of the literature review, gaps in the body of knowledge have been identified. These gaps provided the basis for the formulation of the research questions. Following the two-stream empirical research approach, the first three research questions could be answered. For the fourth research question, these findings combined with a comparison of the general body of knowledge and in particular with other product architectures, leads to findings with which research question four could be answered.

On the basis of a case study, a view of the house as a system of components and sub-components has been developed. Furthermore, the locations of multiple CODP for the components and sub-components have been identified. Meredith (1998) stresses the need in case and field studies for new theory development in operations management. These are preferred methods because the explanation of quantitative as well as the set-up of theories based on these findings will ultimately have to be predicated on qualitative understanding.

A preference measurement task applying a pairwise comparison questionnaire was conducted in order to define the level of choice expected by customers for a particular component and/or attribute. This 'ad hoc' survey was undertaken using an online questionnaire. An 'ad hoc' survey is a one-off survey which is specific in its subject matter (Saunders et al., 2003). Survey methods are often used due to their ability to represent a large population at low cost. Furthermore, the data gathering is easy and the time needed to collect the data is low compared to other research methods.

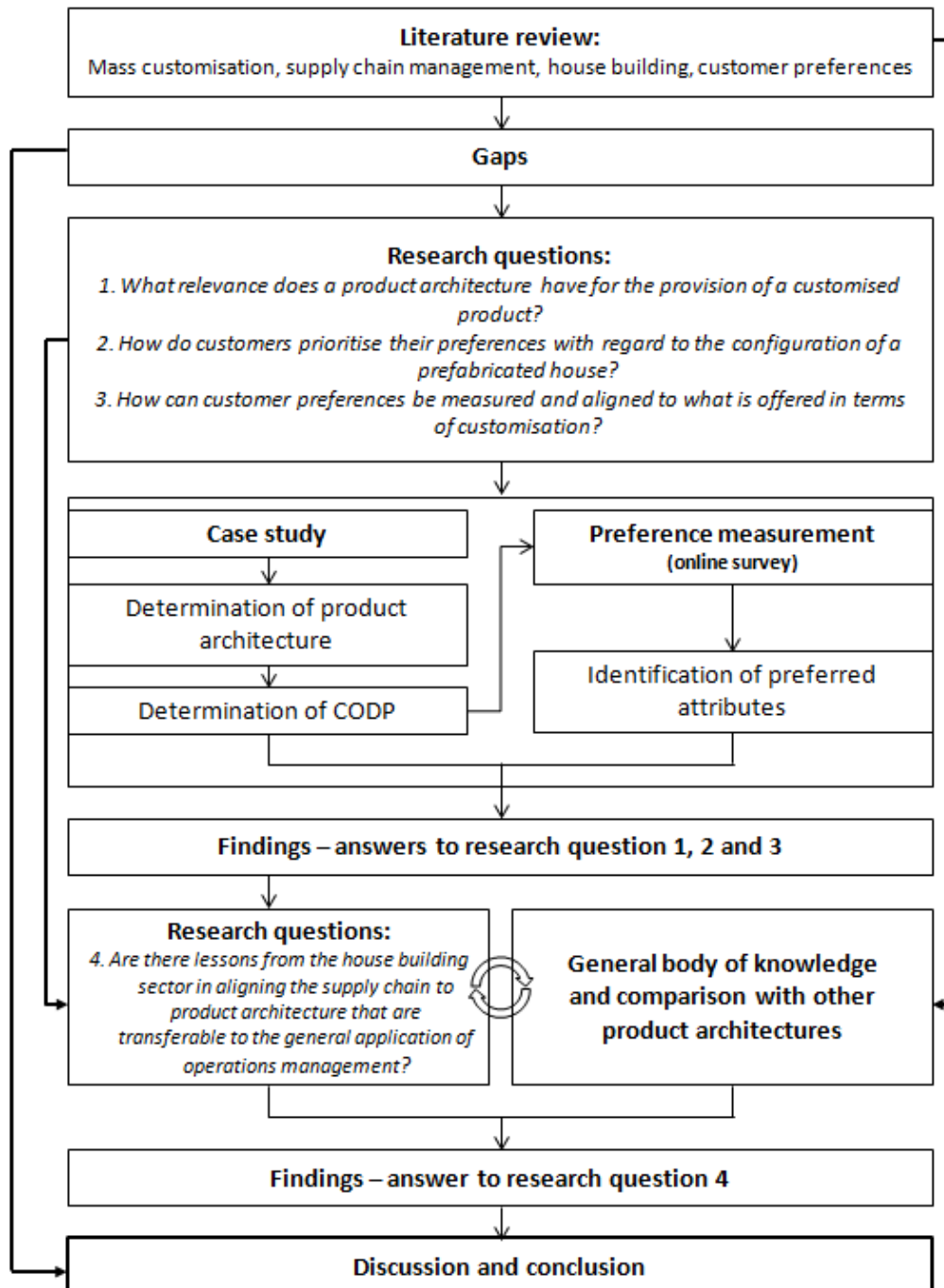


Figure 3.1: Schematic description of methodological route (source: author)

This study applies a multi-method model combining qualitative and quantitative methods. Although each method is useful and powerful on its own, the research is greatly improved when these are used in combination (Kraemer, 1991).

In particular, the combination of case study and survey research is feasible. It is this methodological mix that has been chosen for this study. Gable (1994) studied the

methodological pluralism and its superiority to a single method approach. In his study he also presents his observation that many of the strengths of one method can act as a compensation for weaknesses in the other. Therefore, the combination of qualitative and quantitative research methods not only seems logical for this study but the literature also recommends this multi-methodological approach as it provides better insights.

The case study was conducted before the survey following the recommendation by Attewell and Rule (1991): "Getting close to the phenomenon – gathering insights or discoveries about causal links, motivations, reasons why things happened – should precede verification by more objective techniques, such as surveys. Clearly it is not necessary to carry out fieldwork across an entire sample of firms, but one should study firms across a spectrum - the centre and extremes; the least and most successful as well as some typical firms, before launching a survey; indeed before deciding on instruments and questionnaires." Furthermore, for this research conducting a case study first is logical as the basis for the customer preference measurement was determined by it. Looking at several projects conducted by the case company, the case study delivers results from the past but the survey delivers insights in how things should be. The results of these two research streams when interpreted properly provide useful insights into the operational performance of a business.

The above explanations and decisions on how the research was actually conducted enabled the definition of the unit of analysis for this research. The unit of analysis is the basis for the research and it is crucial for the outcome of the study that only questions about the unit of analysis are asked including sub-units (Rowley, 2002). The sources of evidence are chosen by the boundaries that define the unit of analysis. In this regard Yin's positioning of case research design model is applied (2003). He identified four different basic case study designs which are shown in Figure 3.3.

	Holistic Case Study	Embedded Units of Analysis
Multiple Case Studies		
Single Case Study		Position of this research study

Figure 3.2: Positioning of case research design (source: adapted from Yin, 2003)

As can be seen in Figure 3.2 Yin (2003) divides case studies into holistic and embedded studies. Holistic case studies research the case from a helicopter perspective as one unit. This approach can miss changes in the unit of analysis that have an effect on the original research design. Embedded case study designs, however, explore identified sub-units of analysis individually. These results then yield in an overall picture of the case (Rowley, 2002). This study matches the latter and the appropriate position of this research is shown in Figure 3.2. One case study has been conducted with a focus on two other embedded units of analysis: product and processes.

The following sections discuss the two empirical streams as well as the research methods used in more depth.

3.4.2. Stream 1: Case study

The approach in this study is to review a specific case and determine the components of customer choice over a given time span. Hence, a longitudinal in-depth case study research method is applied. An in-depth case study is recommended in the literature for understanding complex research issues (e. g. Wacker, 1998; Stuart et al., 2002; Voss et al., 2002; Gerring, 2004; Flyvberg, 2006; Easton 2010). Flyvberg (2006) provides a clarification of what he describes as the five misunderstandings about case-study

research and concludes: "One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas 'the force of example' is underestimated" (p. 228). This is a clear statement in favour of case study research and justifies the application of a single case study approach in theory building. Case studies are therefore suitable for research involving exploratory investigations, theory building, theory testing and theory extension/refinement (Voss et al., 2002).

While case study methods have been frequently criticised with regard to methodological rigour in terms of validity and reliability, it is evident that in the past case studies have regularly provided insights into business processes (Gibbert et al., 2008). It has been repeatedly emphasised that case studies are suitable for research involving exploratory investigations, theory building, theory testing and theory extension/refinement (Voss et al., 2002). This study is a combination of exploratory study and theory extension/refinement which is why a case study approach according to Voss et al. (2002) is justified.

Furthermore, case studies have been criticised for containing a subjective bias. Supporters of this argument believe that there is a tendency to confirm the researcher's preconceived notions. Hence, the scientific value of that research is doubtful (Scapens, 1990; Voss, 2002). This criticism is valuable in that it sensitises the research community. However, as Yin (1989) points out, the case study has its own rigour which is not less strict than the rigour of quantitative methods. Furthermore, Flyvberg (2006) highlights that many researchers who conducted case study research report that their preconceived views and hypotheses were disproved by the case study. Therefore Flyvberg (2006) concludes: "The case study contains no great bias toward verification of the researcher's preconceived notions than other methods of inquiry. On the contrary, experience indicates that the case study contains a greater bias toward falsification of preconceived notions than toward verification." (p. 21).

It is also possible to draw wider conclusions even when the collected data lacks statistical generalisability (Marchington, 1996). This is due to the exploited process of logical inference as described by Mitchell (1983). Criticism mainly in the past century, however, claims that single case studies offer even less basis for scientific generalisation as they are not representative of the population or only unique to this one instance (Gable, 1994; Yin, 1989; Numagami, 1998). However, Yin (1989) and Stake (1995) state that although most experiments could be criticised in a similar way, the results are nevertheless published and generalised on a more regular basis. In general, single sources of information provide a holistic overview whereas multiple sources then enable methodological triangulation. Stake (1995) in particular, highlights that results from single case studies can be generalised because the aim of such studies is theory building followed by further research in this area and not statistical relevance.

As Ahlstrom (2007) points out qualitative research is difficult to present. However case research, if properly conducted, generates large amounts of data that eventually leads to rich insights which unfortunately can be hard to communicate to others (Ahlstrom, 2007). Hence, case research needs to show rigour and illustrate the process that lead to the conclusions. Exactly this is what this study aims to do. Therefore, a step-by-step description of the various steps taken is provided in order to build the bridge between the case (raw data) and the conclusions.

The strengths and weaknesses of case study research have been discussed above. However, case study research is often exposed to criticism with regard to validity and reliability issues. Yin (2003) presents four tests for judging the quality of research designs which are common to all social science methods: construct validity, internal validity, external validity and reliability.

Construct validity

This is concerned with establishing the correct operational measures for the studied concepts. In order to achieve this type of validity, the data should be from different sources (Riege, 2003). Furthermore, Yin (1994) recommends that key informants review transcripts or parts of the analysis and if necessary change unclear aspects. Finally,

triangulation is required in order to reach a coherent result which minimises the risk of subjective judgements. As will be seen later in this chapter all data collection methods will be triangulated in order to strengthen the rigour and trustworthiness of the findings. Multiple sources of evidence were used including archival data and focus group sessions. Furthermore, all data analysis was presented to the management of the company who then confirmed the findings.

Internal validity

This is achieved when the phenomena is established in a credible way. The researcher does not only highlight major patterns of similarities and differences between respondents, experiences or beliefs but also tries to identify what components are significant for those examined patterns and mechanisms produced them. The establishment of causal relationships have been ensured by the application of a number of different techniques. Furthermore, during focus group discussions, multiple perspectives were gathered which resulted in the cause and effect relationships being reflected in the consensus between participants. Also, multiple projects were studied over a long time span. And finally, results were also cross-checked during the data analysis phase which, according to Yin (1994) also increases the internal validity of the research.

External validity

The focus of this type of validity is on understanding and exploring constructs by comparing initially identified and developed theoretical constructs and the empirical results of single or multiple case studies (Riege, 2003). Hence, external validity is concerned with establishing the domain to which the study can be generalised. The extent to which the findings of this case study can be generalised will be discussed later. Furthermore, as will be clarified later, embedded units of analysis are used which account for depth and breadth of the analysis. Due to the application of multiple techniques there is a potential that the method outlined in this case study is generalizable.

Reliability

This refers to the proof that other researchers can repeat the approach used in the research. Hence, assuming that techniques and methods remain consistent, other researchers need to be able to achieve similar findings (Yin, 2003). To facilitate reliability, the different steps of the case study have been outlined in depth offering a protocol-like account on how the research was conducted. Furthermore, the data collection spreadsheet is attached to this study so that the process of collecting the data can be understood. Each research step was documented and a matrix was set up in which all the data were entered.

This study is based on the house building industry as an example for the application of customisation strategies. A well-known German prefabricated house builder was identified as the case company. The main criterion for this was that this business manufactures self-build homes with a high off-site content, and is commensurate with other similar house-builders with the potential for using mass-customised houses as identified in the literature (e.g. Gann, 1996; Towill, 2001; Barlow et al., 2003). However, the building system is different from the system applied by the Japanese house builders mentioned earlier. The case company offers a house which consists of pre-manufactured elements based on characteristics from the old, medieval German post and beam designs. Although the design as such is modular, the building system is panellised. This offers additional flexibility for the customer. The Japanese companies scrutinised by Barlow et al. (2003) used a modular building system.

Furthermore, the author is actually based in the collaborating company. This has provided considerable access including personnel and archival data and facilitated data collection as access to information sources was readily given. Ottoson and Bjork (2004) argue that when dealing with complex adaptive systems, such as engineering and product development projects, researchers should consider 'insider' and 'participatory' approaches to research. Thereby, researchers gain valuable insights into practical processes and the theories that result from the study will have at least some practical element.

The starting point for each house building project in a pre-fabricated environment is a standard building specification. From this, clients can tailor many elements, from the location of internal walls to fixtures and fittings. These changes then form the basis for the fit out specification, which reflects the client's actual requirements. Partly driven by demand, in recent years, the case company's sales and marketing division has started to offer customers more and more choice without due consideration of the operational implications. This has also meant an increase in costs for clients and as a consequence there is a risk of diminishing market share. This strongly contradicts the mass customisation approach and poses the question of whether clients appreciate the degree of choice given to them.

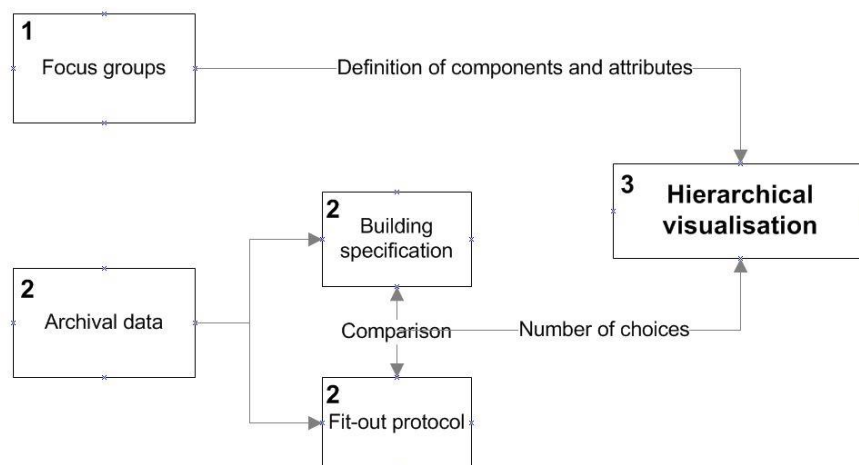


Figure 3.3: Case study research approach (source: author)

The aim of the case study was to categorise all the components in a house that can be customised. This was done to highlight the customised features that clients value and identify those that can be standardised. Figure 3.3 shows the research process that was used. This resulted in the creation of a product architecture for the case company's prefabricated houses.

Stake (1994) clarifies that case study research is not sampling research, but there exist cases that may be a better choice than others. Eisenhardt (1998) emphasises that cases are often chosen for theoretical and not statistical reasons. Furthermore, cases may replicate previous cases or extend theories. Finally, cases can be chosen in order to fill theoretical categories and provide examples of polar types (Eisenhardt, 1998). In this

study the case company was chosen due to the fact that the author is actually based in the company. The multiple house building cases were selected on fulfilment of three criteria: accessibility, suitability and completeness of data. Apart from these three there were, however, no particular selection criteria, which is why the sample can be described as random. Accessibility means that the data needed to be accessible and readable. As will be explained later a lot of the data was retrieved from an archive and in particular some of the contents of the old project folders were barely readable. Hence, these were excluded from the case selection process. Furthermore, only suitable projects were chosen. This means that only 'standard' projects were included in the data set. Special projects were excluded as these had a special fit-out as well. This would have biased the data set in particular with regard to the deviation from the standard fit-out. And, finally, completeness of the data was an important selection criterion. Many project folders were excluded from the data collection process because the required data, that is, fit-out protocol and cost sheets, could not be retrieved.

Step 1 – focus groups

To determine the different components and more importantly the nature and extent of choice allowed, a focus group discussion was conducted with all the major stakeholders: sales manager, production manager, fit-out manager, purchaser and technical manager. This particular technique was chosen in order to capture the hard facts that could potentially be retrieved from building specification and fit-out protocol. It also captured the soft facts, essentially, the options that are not on the option list but are offered to customers. A focus group discussion then generated data and insights that one would not have access to without the characteristic interaction of the group setting (Patton, 2002 and Sanchez-Rodrigues et al., 2010). Once the discussion had started, comments and statements from others encouraged the other participants to share their experiences and ideas. This is the advantage compared to one-to-one interviews. However, skilled moderation is required as a few dominant focus group participants can easily distort the results of the session (Krueger, 1998).

After a brief introduction, the participants were given 10 minutes to brainstorm all the components of a house they believed to be influential in customisation. The idea behind

this was to capture the first ideas and thoughts of the participants. This exercise resulted in a mélange of components and sub-components which were then categorised in terms of the main structural elements of a house, for example, internal design, construction design and facade. Following this, each of the named components was listed on a separate sheet of paper and the corresponding sub-components were allocated. Then the sheets were displayed on a white board and discussed. This further stimulated the participants to delete, confirm or extend the list of sub-components.

The categorisation and prioritisation exercises were formally structured and resulted in a matrix that showed categories, components and sub-components. This matrix was later verified in a presentation of the results to senior management at the company who confirmed its credibility.

The exercise was important for determining the specification options that are available to clients. Furthermore, the aim was to establish whether there is any difference between what is perceived by a focus group as being a specification option and what really can be influenced by the client as set out in the building specification. It has to be emphasised, though, that a product's architecture will change over time. This is mainly due to product and production development. Hence, it is vital that the structure that has been established is revised on a regular basis.

Step 2 – archival data

To show the long term development of the choice offered by the house builder, the author used data from a number of house building projects collected over a 35 year period. The study can therefore be described as being longitudinal. The collection of data was hindered by the fact that it had been stored in a traditional paper based archive and files were not being organised and structured in a systematic way. This required a thorough examination of each file before the necessary data could be captured. The files contained all the relevant project information from drawings to delivery notes of ordered materials. For this research, however, only the project specific fit-out protocol and the building specification that was relevant at the time were retrieved. On average, data collection for each project took approximately nine working hours.

Because the company started to manufacture houses in the 1970s the first project dataset is from 1975. Data was then collected from house building projects every fifth year until 2009. To exclude any anomalies, two project datasets per year were collected. In total, 16 datasets were collected and a stratified random sampling method was utilised ensuring that the data was first structured before a random sample was taken. The sample of projects was limited to Germany as this is where the company has had the longest presence in the market. This also avoids any regional or national biases that may exist. As Ball (2003) highlights, clients' wants and needs can vary considerably between countries.

The extent of choice has been determined by comparing the standard building specification of the appropriate house style with the additional individual fit-out specification chosen by the client. The standard building specification defines the fit-out of the house for a fixed price. It is a document that lists the different categories of a house (for example: construction, external walls, internal walls) and next to this describes what the appropriate components are made of or what they look like. It was a challenge to source the standard building specifications that were relevant for the projects that were built in the 1970s. In general, it was necessary to source the standard building specification that was valid when the projects were built. Otherwise, the comparison would have been biased, as a customer specification could have been recorded as choice even though this option was still within the degree of choice offered in the standard building specification.

Eventually, the folders in which all the old standard building specifications were filed were located thus giving the correct basis of comparison for each project.

As mentioned above, the standard building specification is the basis for the customisation process. Once the sales contract has been duly signed, the clients are in possession of the chosen house type with the fit-out as described in the building specification. From this, the so-called fit-out specification will be completed. This is a list of all items that have been changed and then customised. Comparing the building specification with the results of the focus group showed that the company allows a far

greater degree of customisation than they formally declared at the outset to clients in marketing material.

A comparison of the building specification and the fit-out specification for each project enabled the author to determine exactly which items were customised. In order to structure the data for further analysis, a matrix was created which can be seen in Appendix 1. This includes all the items that can be customised, determined from and structured around the focus group findings, as well as the choices made by each client. As mentioned before, the customised items were derived from the fit-out specification that lists all the variances from the building specification.

As the fit-out specification is the final building specification and includes all the extras the clients wanted, it was possible to extract the aggregated costs for the customised options. This made it possible to determine the difference between the standard and fit-out price for each project, and therefore an average cost per option can be calculated.

The study includes many several projects that were invoiced before the Euro conversion so, prices were converted from Deutsche Mark into Euro, applying the official conversion rate published by the Deutsche Bundesbank at the introduction of the Euro in 1999. Furthermore, the costs have been adjusted to a current level.

Step 3 – Hierarchical representation of choice

In Step 3, the data acquired was visualised and analysed. It turned out that it was necessary to differentiate between component and sub-component. For example, an external wall is a component of the house but made of several sub-components which can be changed by the client, for example, the cladding or its colour. The data collected was grouped into categories, components and sub-components. Furthermore, the attributes for each item that could be influenced by the customer were determined. This created a complex hierarchical structure as can be seen in Figure 3.3.

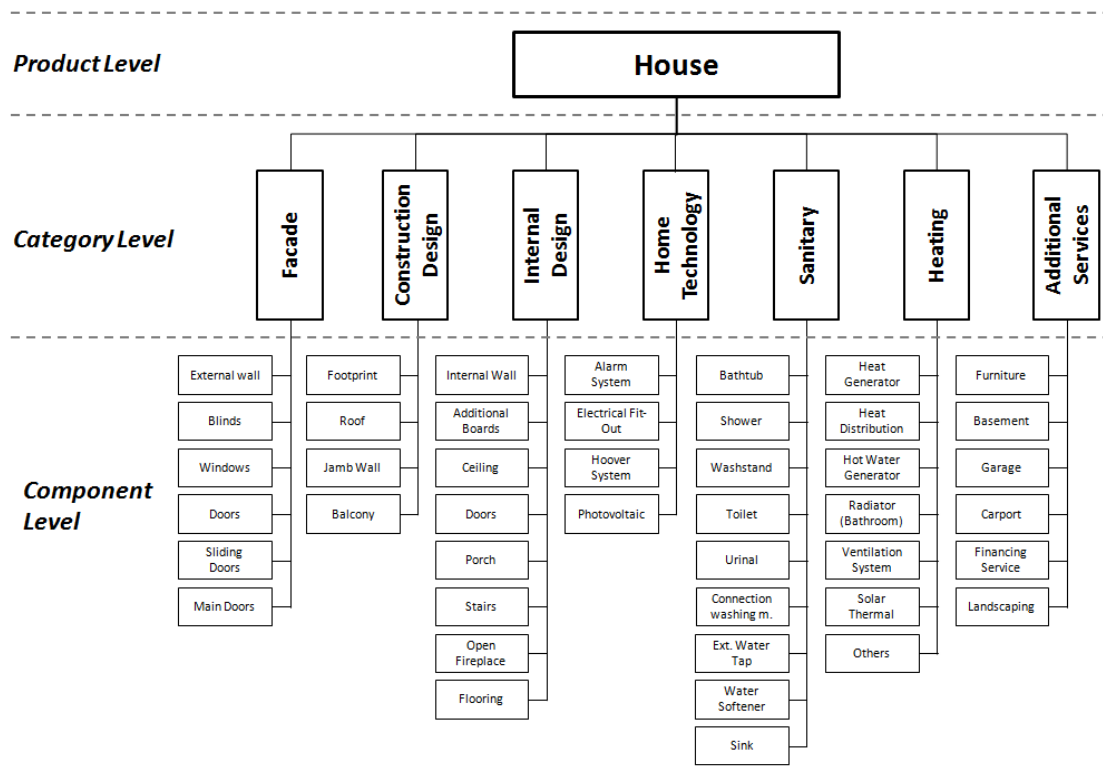


Figure 3.4: Product architecture matrix of prefabricated house (source: author)

In order not to increase the complexity further, the sub-components were not shown in Figure 3.4. However, the definition of the product architecture – usually determined by decomposition of a complex system into subsystems as suggested by Ulrich (1995) – is vital in order to help understand the complexity of product design. The determination of the product’s architecture is a finding from a rational definition point of view. Nevertheless the author believes it is important to present it here already as it is essential for the readers’ understanding of the research.

In order to deliver a compact, space-constrained visualisation of the collected data a treemap was chosen (Shneiderman, 1998). Treemaps are very useful in structuring hierarchical data whereby the data is displayed in a two-dimensional rectangular map using both colour and size to visualise different data sets. The data is presented in rectangles whereby each represents a component, sub-component or attribute. One advantage of structuring data in a treemap is that data to be neglected can be spotted quickly and easily. A second advantage is the treemap’s efficient use of space. This type of visualisation can display numerous components or items on the screen simultaneously. An evaluation of treemaps is provided in Asahi et al. (1995), which

highlights a positive perception by a small group of users. While treemaps have seen applications in fields such as information technology (Wood and Dykes, 2008) and knowledge management (Twietmeyer et al., 2008), there appears to be no published applications in recognised construction and operations management journals.

As mentioned in the literature review chapter, one of the key issues in manufacturing mass customised products is to specify the position of the CODP. This is important in order to structure and configure the operations so that total value can be delivered to the end customer (Naim et al., 1999). Using the case study results generated by the steps as described above, it was possible to determine the position of various CODPs.

Step 4 – triangulating data in steps 1-3

When using more than one information source, there is a need to triangulate the data to strengthen the rigour and trustworthiness of the findings (Golafshani, 2003). Patton (2002) highlights the importance of triangulating research: “... triangulation strengthens a study by combining methods. This can mean using several kinds of methods or data, including using both quantitative and qualitative approaches.” (p. 247). Therefore, in order to complete the positioning of the CODP exercise it was important to triangulate the data of steps 1-3. The overall method adopted for this exercise is visualised in Figure 3.5.

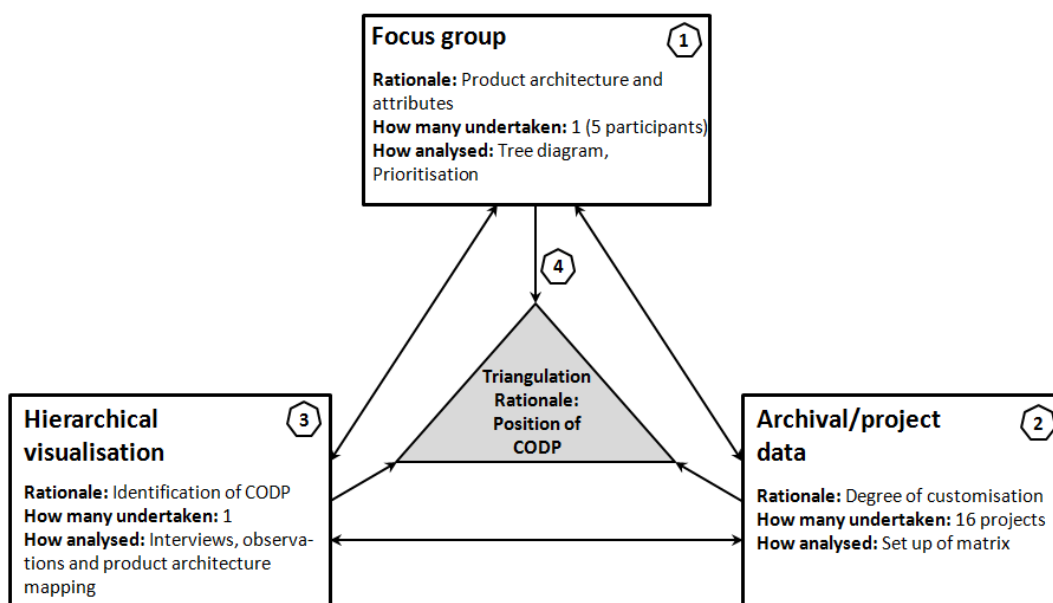


Figure 3.5: Visualisation of method (source: author)

It was important to analyse different perspectives in order to gain a better understanding of the supply network and increase confidence in the research data. Thus, the approach enabled a triangulation of the results from the focus group discussions, hierarchical visualisation by interviews and observations, and archival data which, although time-consuming, was important in order to establish validity of the findings (Golafshani, 2003). Figure 3.5 also highlights the rationale, number of data sets and analysis tools of each step in the process. Steps 1 and 2 are pure data collection exercises whereas in steps 3 and 4 the collected data is analysed.

The triangulation of the information output delivered by steps 1 to 3 also enabled the determination of mismatches which could consequently be clarified in meetings with senior management before refining the positioning of the CODP for each relevant component.

3.4.3. Stream 2: Online preference measurement survey

In order to determine customer preferences and find out how the identified attributes are prioritised by potential home buyers configuring a house, it was decided to conduct a customer preference measurement based on the results of stream 1 (i. e. the case study). In general a preference measurement is complex and difficult as many customers are not able to exactly specify the importance of product attributes. Moreover, the perception of an attribute independent from others may be completely different compared to the perception of the same attribute in combination with others (Hofman et al., 2006).

Eggers and Sattler (2011) categorise preference measurement techniques as:

- Compositional approaches. Evaluation of product attributes and levels separately. The perceived utility of the entire product is then composed of the importance allocated to its specific attributes and levels.
- Decompositional approaches. Evaluation of products by considering the attributes and levels jointly. Preferences can then be decomposed using statistical methods.

- Hybrid approaches. Combination of compositional and decompositional approaches.

There are a number of techniques within these categories that have been used to measure customer preferences, for example: Quality Functional Deployment, Analytic Hierarchy Process and Conjoint Analysis. Table 3.1 shows a comparison of the aforementioned techniques in order to highlight why the PCPM method is particularly suitable for this kind of research.

Attributes	Conjoint Analysis (CA)	Analytic Hierarchy Process (AHP)	Quality Function Deployment (QFD)	Paired Comparison-Based Preference Measurement (PCPM)
Pre-condition	Preferential independence of attributes	Preferential independence of attributes	Preferential independence of attributes	Preferential independence of attributes
Survey form	Decompositional	Compositional	Decompositional	Compositional
Application range	Selection problems	Selection problems and/or design problems	Selection problems and/or design problems	Selection problems and/or design problems
Attribute importance elicitation	Directly stated importances are updated by differences in partworth utilities between the most and the least preferred levels of each attribute	Derived from pairwise comparisons of attributes.	Directly stated for each attribute	Derived from pairwise comparisons of attributes. In addition differences in the desirabilities between the most and the least preferred levels contribute to attribute importances.
Levels of measurement	Interval scales	Ratio scales	Interval scales	Ratio scales
Utility model	Linear additive partworth utility model	Weighted additive utility model	Weighted average utility model	Linear additive utility model
Applicability	Up to 6 attributes with 2-4 levels	Many attributes possible with up to 8 levels	Up to 6 attributes with 2-4 levels	Many attributes and many levels possible
Major strengths	Measures preferences at the individual level	Prioritisation in a structured setting is achieved	Simple-to-use tool giving detailed results	Number of level effect is applied
Major weaknesses	Study design can be complex	Not suitable for very complex hierarchies	Not suitable for very complex hierarchies	Not applicable without suitable software
Content adapted from	Helm et al. (2004)	Helm et al. (2004)	Cherif et al. (2010); Pullman et al. (2002)	Scholz et al. (2010)

Table 3.1: Comparison of customer preference measurement methods (source: author)

Although there is no clear recommendation in the literature, Conjoint Analysis (CA) has been identified as being the most frequently used method for measuring customer preferences. However, this decompositional approach uses a ranking procedure to assign customer priorities to product attributes. This means that the CA cannot be first choice when it comes to measuring customer preferences for complex products as the questionnaire length increases considerably with growing numbers of attributes and attribute levels which results in information overload for respondents (Green and Srinivasan, 1990). Recently, however, compositional tools have experienced a

renaissance. This is mainly due to the fact that these approaches are cognitively less demanding than decompositional tools.

The analytic hierarchy process (AHP) has also been used as a customer preference measurement tool (Scholl et al., 2005). Although this is an effective method to identify respondents' priorities for products with a normal architecture, as the number of attributes increases, more comparisons become necessary thus risking that the respondents are overburdened. The quality function deployment (QFD) is problematic for preference measurements involving many attributes as the attribute importance is stated directly for each attribute. Thereby the measurement task can become very complex for the respondent (Cherif, 2010).

Recently Scholz et al. (2010) recommended the paired comparison-based preference measurement (PCPM) as a preference measurement tool for complex products. Essentially, PCPM is a modified version of the AHP method but differs from the latter in some important aspects (Meißner et al., 2010). PCPM uses paired comparisons where the respondent indicates a preference of an element over another element. It has a simple three layer hierarchy which means that the product hierarchy is limited to three levels. Furthermore, static two-cyclic designs are used to reduce the number of paired comparisons needed in the data collection process. Two-cyclic designs give a simple but that the same time efficient method for data pair selection from a whole set of pairs of n objects. Thereby the number $n(n-1)/2$ of paired comparisons is reduced to $m = 2n$ (Miyake et al., 2003). Furthermore, a bipolar equidistant scale is shown.

One advantage of the PCPM approach is that it takes into account the Number-of-Levels Effect. In PCPM, the average preference weight is reduced when further attributes are included in the sub-problem. With increasing numbers of attribute levels, the range in the preference weights between the most and the least preferred levels is thus reduced. The PCPM approach tries to balance this effect by multiplying the respective preference weights with the number of attributes being compared. As a consequence, the average preference weights stay constant even if additional elements are included (Scholz et al., 2010).

The PCPM is used in this study as it has a proven track record of successful application in complex product environments (e.g. Scholz et al., 2010). Moreover it is critical for the success of a preference measurement that in addition to the actual method there is also a comprehensive data collection method applied. In particular, for products with a complex product architecture resulting in many different comparative decisions for the respondent, it is important that the questionnaire is appealing. Furthermore, the amount of data that is generated requires that the data is captured in a structured way which facilitates a further analysis. For this study, an appropriate software tool was readily available to conduct the online survey.

Questionnaire design and data collection

Online surveys for data collection have become very popular due to the ever-increasing number of internet users and the availability of improved and more sophisticated online survey software. The latter was decisive for this study as it is important for a preference measurement using pairwise comparisons to have software that visualises the questions effectively. This is to ensure a user-friendly design, which does not discourage participants from taking part in the survey. The survey method applied involves low costs and enables the researcher to collect many data within a short period of time (Brandenburg and Thielsch, 2009). The advantages and disadvantages of online surveys are illustrated in Table 3.2.

A further advantage is that with an online survey, additional data that could be relevant for a business can be captured. Furthermore, it is possible to include a demographical question, which helps to extract the results from participants that represent the company's target market. Therefore, the design of the questionnaire needs careful consideration, as it should be the aim to gain as much relevant information as possible from this one online survey without overburdening the participant.

Step 3 of the case study yielded a product architecture overview showing all the components and attributes that typically belong to a house, as shown in Figure 3.3. The set-up of the questionnaire followed this product architecture but not all components and subcomponents were included as otherwise the questionnaire would have been too

long. The above mentioned case study identified subcomponent options taken up by customers on a regular basis. The highest ranked subcomponents for each component have been considered in the preference measurement task.

Advantages	Disadvantages
Time efficiency during data collection, analysis and presentation of data.	The programming of the online questionnaire needs more time. There may be a dependency on third parties
Time and effort as well as expenses for print, distribution and coding of questionnaire do not apply. No interviewee and data transfer is needed.	Additional training on the software may be necessary.
Automation and with this increased objectiveness: no error sources through data transfer, no test supervisor effects, no group effects.	The conditions of the data collection cannot be controlled, which results in problems with the objectivity.
More heterogeneous sample formation compared to offline studies. Online surveys will never be able to represent the total population.	Online surveys will never be able to represent the total population.
Availability of the medium: some groups of people can be better reached online.	Not all target groups go online and not all computers are up to date with current soft- and hardware.
Higher data quality, well programmed online questionnaires avoid "missing data" and consistency checks through time protocols are possible.	Multiple participation cannot be ruled out completely. Questions a respondent may have can only be answered asynchronously and on the initiative of the respondent.
Higher acceptance due to voluntariness, flexibility and anonymity.	Problems with acceptance if the respondents suspect a marketing campaign or data abuse.
Ethical transparency: online surveys are much more transparent as they are more accessible than offline surveys.	The database of the online survey needs to be protected against unauthorized access. Data protection in general is more difficult.

Table 3.2: Methodological advantages and disadvantages of online surveys (source: translated from German in Brandenburg and Thielsch, 2009).

In order to set up the online questionnaire and conduct the survey, a software tool, AHPlab version 2.2.6©, was used. This tool supports the data input and weights preferences according to the PCPM approach. Furthermore, the questionnaire can be designed in a way that appeals to respondents. As the survey was conducted in Germany, the questionnaire was set up in the German language.

As is good practice in questionnaire design, easy introductory questions were asked first and the most important questions were positioned in the first half of the questionnaire when concentration and focus is still high (Burns and Bush, 2008). In total, the respondents had to answer twenty questions. Some were dual- and others multiple-choice. The expected time to complete the questionnaire was twenty minutes which was indicated on the start page so that each respondent knew exactly what the associated expenditure of time was.

As mentioned before, once the decision has been made to conduct a preference measurement, an opportunity is offered to capture additional relevant data. However, one needs to be careful with the extent of the questionnaire as the concentration of the participants decreases over time and therefore too many additional questions could potentially result in participants feeling overburdened. The consequence would be that participants would leave the questionnaire and this particular source of information would be lost.

A systematic approach to survey data analysis is needed as otherwise there is a risk that key findings can be overlooked and data subsets with clear findings remain uncovered. In this study, the data analysis was started with the Initial Data Analysis (IDA). Silver (1997) clarifies that an IDA includes processing the data into a suitable form for analysis. This has been done by converting the data input from the software into verbal and/or numerical information. Furthermore, during an IDA the quality of the data is checked as well. This is an important step as it removes any risk of biased data sets being considered in the data analysis. Errors can, for example, be identified by looking at the consistency of the data. In this survey the following questions were asked:

- How old are you?
- How often have you built a house before?

If the answer to the first question is '17 years old' and the answer to the second question is 'six times', then it can be assumed that this data set is biased. Furthermore, the data set were checked for answer patterns. An answer pattern is the result of one participant activating the same fields. Sometimes this is a reaction of a participant who is

overburdened. The data set needs to be removed as it does not deliver usable information.

The risk of making errors for example when '3.0' is typed when the answer was meant to be '30', was reduced considerably as the software enabled the appropriate text fields to be pre-defined. This means that for text fields where a numerical entry was required, the range could be pre-set and limited to specific numerical values.

The data was also checked with regard to extreme values and outliers. However, although the statistical literature sometimes recommends that these are removed (e. g. Puhani, 2001), it was decided to include the appropriate data sets in the analysis. This is primarily because the main motivation for the survey is the preference measurement. The PCPM method, however, does not allow extreme values as it is a measurement of preferences. With regard to the additional questions there were only a few fields where text or numerical values could be entered. All other questions were list, category and rating questions where a set of answers was given and no text entry was required. Only three questions were self-coded meaning that the data collected from these questions could be analysed without any decoding being necessary. Usually these questions involve, for example, years and post codes.

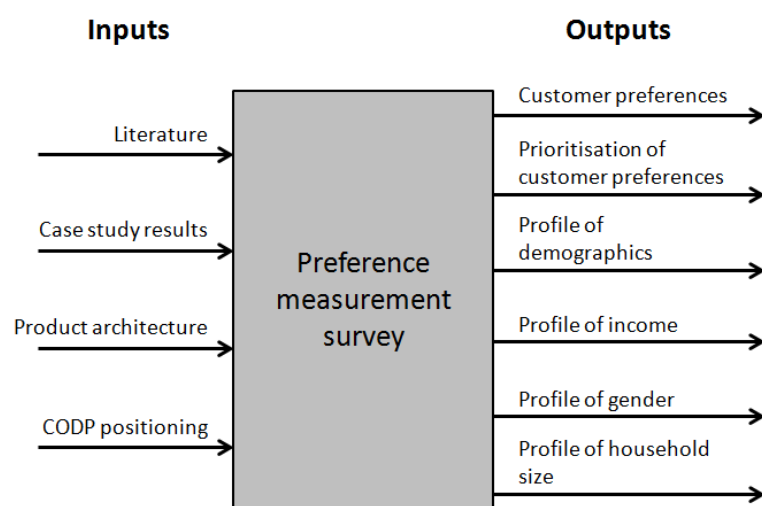


Figure 3.6: Inputs and outputs of preference measurement survey (source: author)

Figure 3.6 shows an input and output diagram for the preference measurement. Inputs stem from the literature, case study results, product architecture and CODP positioning. These provided the basis that enabled the set-up of the online questionnaire as a tool for the preference measurement. Once conducted the preference measurement is to provide a determination and prioritisation of the customer preferences, profile of the respondent demographics, a profile of their income, gender and the household size. All these information can be used to retrieve target group specific information from the data.

Appendix 2 shows the translated online questionnaire. The first page gives an overview of the study's objectives. Moreover, in order to motivate people to participate, it was stated that the final page of the survey gives a brief summary of the data input including an overview of the preferences that were determined by the preference measurement. Finally the deadline to complete the survey was mentioned so that participants could consider this in their time management. The following text appeared on the first page of the online questionnaire:

Welcome to the online survey on preferences and customisation in the house building industry. The aim of this survey is to determine your preferences and choice requirements with regard to prefabricated houses.

On the final page of this survey we show you a brief summary of your data input which highlights the components which you defined to be important when configuring a prefabricated house.

The completion of this survey will take around 20 minutes. Many thanks for your support with this study.

This page was followed by the data protection regulations where the participant had to confirm that he read and understood how his data is treated.

Furthermore, it was explained to respondents how a 'prefabricated house' is defined in the context of this study. The sentence preceding the first question in the questionnaire was therefore the following:

For this study a prefabricated house is defined as a product that consists of many different standard components. A prefabricated house is a building that is erected using modules which are usually manufactured off-site. The house building company usually offers a turnkey solution for the clients and different possibilities to specify the product (i. e. house) – some offer a high degree of choice, others a rather low degree.

Thereby it was ensured that the meaning of 'prefabricated house' was the same for all respondents.

As previously explained, in order to increase the number of responses, it was specifically mentioned in the accompanying text that the link could be forwarded to other recipients. Using this snowball sampling (Bradley, 1999), the sample frame was increased considerably. In the following, a calculation is provided that shows the desired sample size if using a certain degree of accuracy. Even by using a snowball approach it was not possible to achieve the required sample size. Therefore, a smaller sample size was traded off against less accuracy. Nevertheless, the results add to a better understanding of customer preferences in the prefabricated house building industry.

At the heart of the preference measurement were the paired comparisons where the respondent had to rate the preference for an attribute or component over another on a 9-point rating scale. In contrast to the AHP, where two scales are normally used to measure the preference and preference strength, in PCPM a bipolar scale is used which measures both the direction and the strength of the preference at the same time (Scholz et al., 2010). Typically these are equidistant which is why a change to the neighbouring scale level corresponds to a geometric increase or decrease in the measured preferences. Figure 3.6 gives an example of a paired comparison question.

If you think about the facade of a house: in which of the mentioned categories below would choice be more important to you?

	Absolutely preferred	Strongly preferred	Considerably preferred	Weakly preferred	Equal	Weakly preferred	Considerably preferred	Strongly preferred	Absolutely preferred	
Material of main door handle (handle or knob)	0	0	0	0	0	0	0	0	0	Locks with normal or higher security
Material of window and door handles (stainless steel or plastic)	0	0	0	0	0	0	0	0	0	Material of main door handle (handle or knob)
Material of window and door handles (stainless steel or plastic)	0	0	0	0	0	0	0	0	0	Manual or automatic window or door opener
Material of window and door handles (stainless steel or plastic)	0	0	0	0	0	0	0	0	0	Locks with normal or higher security
Manual or automatic window or door opener	0	0	0	0	0	0	0	0	0	Locks with normal or higher security
Scale level	1	2	3	4	5	6	7	8	9	
Preference value	9.00	5.20	3.00	1.73	1.00	1/1.73	1/3.00	1/5.20	1/9.00	

Figure 3.7: Paired comparison question in questionnaire (source: author)

The 9-point bipolar scale with the appropriate values for the determination of the preference weighting is illustrated in Figure 3.7. In this particular example, the weighting determines the preference for window attributes in the facade of a house.

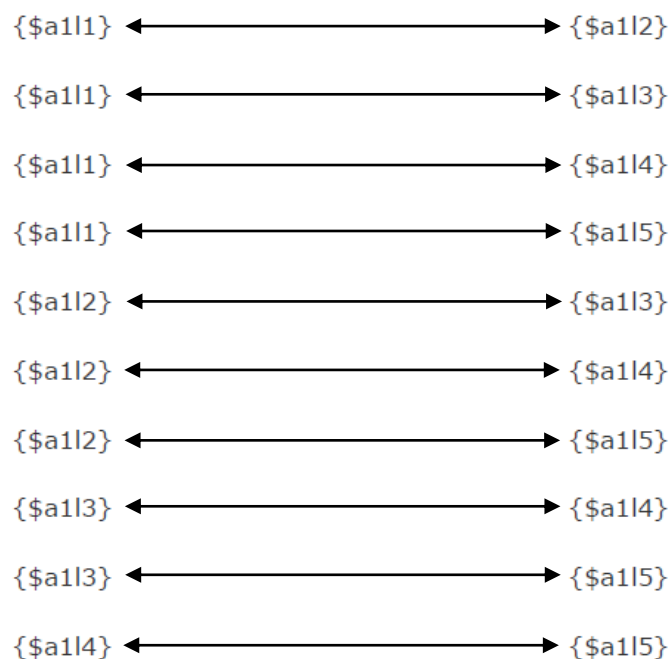


Figure 3.8: Coded paired comparisons of facade components (source: author)

The paired comparisons for the preference measurement were set up using this software and following the determination of a three layer product hierarchy, as will be shown in the findings section. The subcomponent level has not been considered in the

preference measurement as this would have resulted in too many pairwise comparisons, thus, overburdening participants. Furthermore, the content and design of the questionnaire was informed by the findings of the case study. Figure 3.8 shows a coded version of paired comparisons in the facade category. The codes were generated by the software and decoding was necessary once the data was entered into the database.

The data in Figure 3.8 is decoded as follows:

- {S_{a1} = denotes the category; in this example it the facade category
- {S_{a1}|1} = denotes the category as well as the component (facade, locks with normal or high security)
- {S_{a1}|2} = denotes the category as well as the component (facade, manual or automatic window or door opener)
- {S_{a1}|3} = denotes the category as well as the component (facade, material of window and door handles)
- {S_{a1}|4} = denotes the category as well as the component (facade, material of main door handle)
- {S_{a1}|5} = denotes the category as well as the component (facade, design of main door)

Hence every component in this category is compared to another component.

Having finalised a draft version of the questionnaire, a pilot was tested with a group of three experts and two non-experts. The latter were members of the public who were selected randomly. One expert is the Head of Technics of The Association of German Prefabricated Building Manufacturers (BDF). The second expert is a Senior Lecturer in Marketing at a well-know university in Germany and the third expert works as an engineer for a German prefabricated house builder. This testing was important to ensure that the questionnaire was suitable for people with and without specific knowledge of the house building industry. The group was asked to evaluate each question and pairwise compare attributes with regard to clarity, relevance and

preciseness. Following this, small improvements were made before the questionnaire was finalised.

The final version of the questionnaire can be found in the Appendix (Appendix 2). As the survey was conducted in Germany and, hence, the questionnaire was in German language, screenshots from the online version of the questionnaire cannot be displayed here. However, the contents of the questionnaire were copied and translated so that the reader can follow and understand the questions asked.

Initially, people particularly interested in prefabricated housing were targeted for data collection. The Association of German Premanufactured Building Manufacturers (BDF) represents nearly 90% of the German prefabrication industry (BDF, 2013) and runs over 20 show home 'villages', which are usually the first contact points for those interested in such houses. Hence, the BDF was contacted to enquire whether a survey could be conducted in one of the aforementioned centres. A new show house centre in Cologne was chosen as it had an average of 5,228 visitors per month between January and July 2012, making it the most frequently visited centre. Two computer stations were set up for one day (Saturday) for visitors to complete the questionnaire. Although the centre was well visited, only five respondents agreed to complete the questionnaire in over eight hours. A reason for this very low participation was that most visitors on that day were families or groups who wanted to visit the show house centre together, and none of these visitors were prepared to complete the questionnaire and delay the whole group. Furthermore, it was difficult to convince people that the survey was for academic purposes. Given this low completion rate, the sampling method was reviewed and changed.

A non-probability sampling method was then applied due to its cost effectiveness. In general, non-probability sampling is an alternative to the random sampling method when the research is aimed at making exploratory inferences or interpretations (Schillewaert et al., 1998). But a bias is introduced when applying the non-probability method as the results cannot be representative of a particular population. However, for the determination of customer needs this is not a limitation as data from real and true

potential customers is gathered. From the known non-probability sampling methods, that is, convenience, judgement and snowball, the judgement sampling strategy was chosen. This method is also known as purposeful sampling and is the most common sampling technique (Marshall, 1996). Hence, with the motive to maximise the response rate, the author actively selected the most productive sample consisting of friends, professionals, colleagues and family members. Thus, all of the subjects are known to the researcher and were selected from a list of available email addresses. In total 34 email respondents were identified and this was done on the basis of the researcher's judgement of the subject's helpfulness and accessibility. This kind of sampling strategy is problematic, as the respondents are not selected randomly. Hence, there is no attempt to claim that the results are in any way generalizable. The interpretation of the data must consider this limitation although there is at first no reason to believe that the population's view is different (de Rezende and de Avelar, 2012).

In order to increase the number of responses, it was specifically mentioned in the accompanying text that the link could be forwarded to other recipients. Using this snowball sampling (Bradley, 1999), the sample frame was increased considerably. After four weeks, 62 responses were received and a reminder was sent to other potential respondents. Following another four weeks, the survey was closed and the link was deactivated. Unfortunately, 33 responses had to be removed from the results spreadsheet as they were biased. These included unrealistic responses to questions for example when postcodes or figures were not indicated in a correct way. Furthermore, data sets were removed where a response pattern was identifiable. This happens when respondents always activate the same field and do not specifically respond to the question. In total 87 responses were identified as being suitable for further analysis.

The software used recorded the respondents' input in a data format that enabled an export of the data into an Excel spreadsheet. This facilitated further analysis of the data. First, the biased data sets were removed. Following this, the raw data was formatted and decoded so that figures could be derived from the data. These activities involved mainly the conversion of the system data into usable information.

3.5. Summary

This chapter has presented the methodology applied in this research. Furthermore, three main research philosophies have been defined and their meaning has been discussed. This discussion resulted in the identification of the philosophical stance, namely, critical realism, that has been adopted in this thesis.

As this research involved an online survey with human participants, the ethical implications of such a research method were highlighted and discussed. It has been shown that the major ethical principles (i. e. protection of personal rights, informed consent and anonymity) have been adhered to in this research.

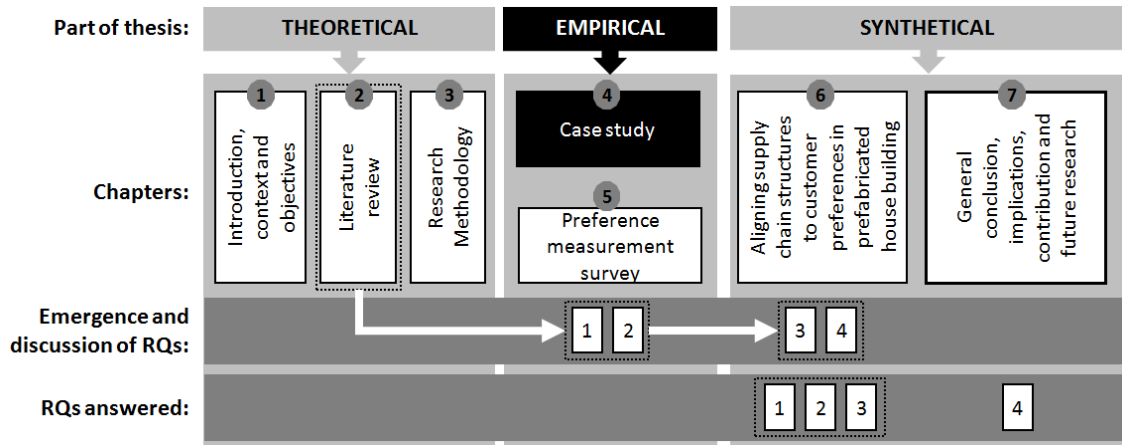
The use of the methodology as depicted in Figure 3.1 has been justified. A methodological pluralism was chosen as a research approach with a qualitative element delivering the basis for the quantitative study. In particular, the use of a multi-methodological approach has been discussed and this originates from the objective of the research and consequently the research questions.

This chapter has also given a detailed description of the two research streams: case study and online survey. The strengths and weaknesses of both approaches have been addressed and discussed. Furthermore, a detailed protocol of both approaches has been given so that the reader can follow the methodological process. The case study involved multiple data collection techniques and each of these techniques have been discussed and described in depth. Furthermore, validity and reliability of the case study was discussed and the four key validity and reliability concerns were addressed in order to provide proof on the validity and reliability of the study.

With regard to the online survey, different preference measurement techniques have been discussed and the decision to apply a PCPM survey has been justified. Furthermore, the design issues of the online questionnaire have been discussed and a detailed description of the data collection process has been delivered. Finally, a brief preview of the data analysis has been given which will be discussed in more depth in chapter 5.

Chapter 4

“What is the general? The single case. What is the specific? Millions of cases.” (Johann Wolfgang von Goethe)



4. Findings of stream 1 (case study)

This chapter begins with a brief introduction followed by an overview of the modus operandi of the case study research. Furthermore, the case company is presented in more depth before the findings are presented and discussed. The key contribution of this chapter is the positioning of the CODP which formed the basis of the online survey.

4.1. Introduction

The case study has been conducted in an industry that produces highly complex products with multiple product architecture levels. Due to market and company access the house building industry and more specifically a German ‘self-build’ house manufacturer was chosen as the case company. The European house building industry in general is currently facing an increasing demand for choice from customers with the competing pressure to keep prices low. The challenge then is to respond to these requirements and look at customisation strategies in more depth (Schoenwitz et al., 2012). In this regard, it is important for companies to align their own operational capabilities with the needs of their customers, thereby achieving customer satisfaction. It is vital that companies locate their strategies along the continuum between standardisation and customisation and are aware of the implications of the chosen

customisation strategy (Lampel and Mintzberg, 1996). Otherwise there is a risk of mismatch which can ultimately result in processes that are inefficient or simply do not achieve customer satisfaction.

4.2. Overview of modus operandi

A longitudinal study of a case house builder was made to assess the relationship over time between the level of specification options made available versus the actual take up of such options by clients. The findings of the case house builder may then be contextualised within existing scientific literature, mostly found within research on the automotive sector that highlights the challenges of satisfying the proliferation of customer choice. The approach therefore is to review a specific case and determine the components of customer choice over a given time span. All the components in a house that can be customised are categorised to highlight the customised features that clients value and those that can be standardised.

4.3. Presentation of case company

The company's headquarters and manufacturing facilities are located in Germany, servicing the European market. Germany is a leading country in Europe for self-build housing, accounting for over 50% of all new homes (Rogers, 2011). In 2010, prefabrication accounted for 30% of all self-builds with a market size of over 13,000 homes (BDF, 2011). Therefore, by studying a company operating in this sector, the opportunities in a relatively sizeable market can be considered. Furthermore, foreign exports currently account for approximately 30% of the case company's sales. Compared to the industry's average export quota of 11% in 2007 (BDF, 2008), this clearly highlights the company's international strategy.

The operation started out as craft carpentry, as per the pure customisation ETO model, evolving into a manufacturer of houses with a high degree of prefabrication, striving to a mass customisation approach. In recent years, the case company has faced the challenges of increased proliferation of offering more options as found in the automotive sector (Pil and Holweg, 2004). The case company offers self-build clients a complete package, from specification and design through to completion, including a

financing service, interior design and after sales service. This one-stop shop concept is not dissimilar to an early and well publicised “lean” house builder, Doyle Wilson in the USA (Towill, 2001; Womack and Jones, 1996). Unlike the speculative build market, which has previously been well researched (for example Hong-Minh et al., 2001 and Roy et al., 2003), the self-build market promises an extremely high degree of customisation. However, previous research shows that, in the UK at least, the market is associated with a low level of customisation and excessive costs (Barlow et al., 2003).

4.4. Findings

A focus group discussion took place to identify the components of the house that can be changed by clients. During this it became clear that, depending on the individual’s function within the company there were different degrees of awareness with regard to customisation possibilities. The sales manager listed far more items which, from his point of view, can be changed than the production manager did. This is a phenomenon which has often been experienced and reported by researchers (e.g. Konijnendijk, 1993). The reason for these different views lies within the different mindsets that are influenced by the nature of the job. In the sales manager’s world, the production process is pragmatic. He does not have detailed insights and therefore does not know which problems might occur when a client wishes to change certain components. Furthermore for the sales manager the conclusion of a contract is most important and so sometimes there is a difference between what is promised in the sales process and what can be realised in the production process. Hence a trend could be perceived of sales driving the company to offer more and more choice.

4.4.1. View of a prefabricated house as a system of components

From the focus group discussions, a hierarchy of elements within a house were identified, as depicted in Figure 4.1. The squares at the bottom of the figure represent the number of sub-components each component consists of, but are not detailed for clarity.

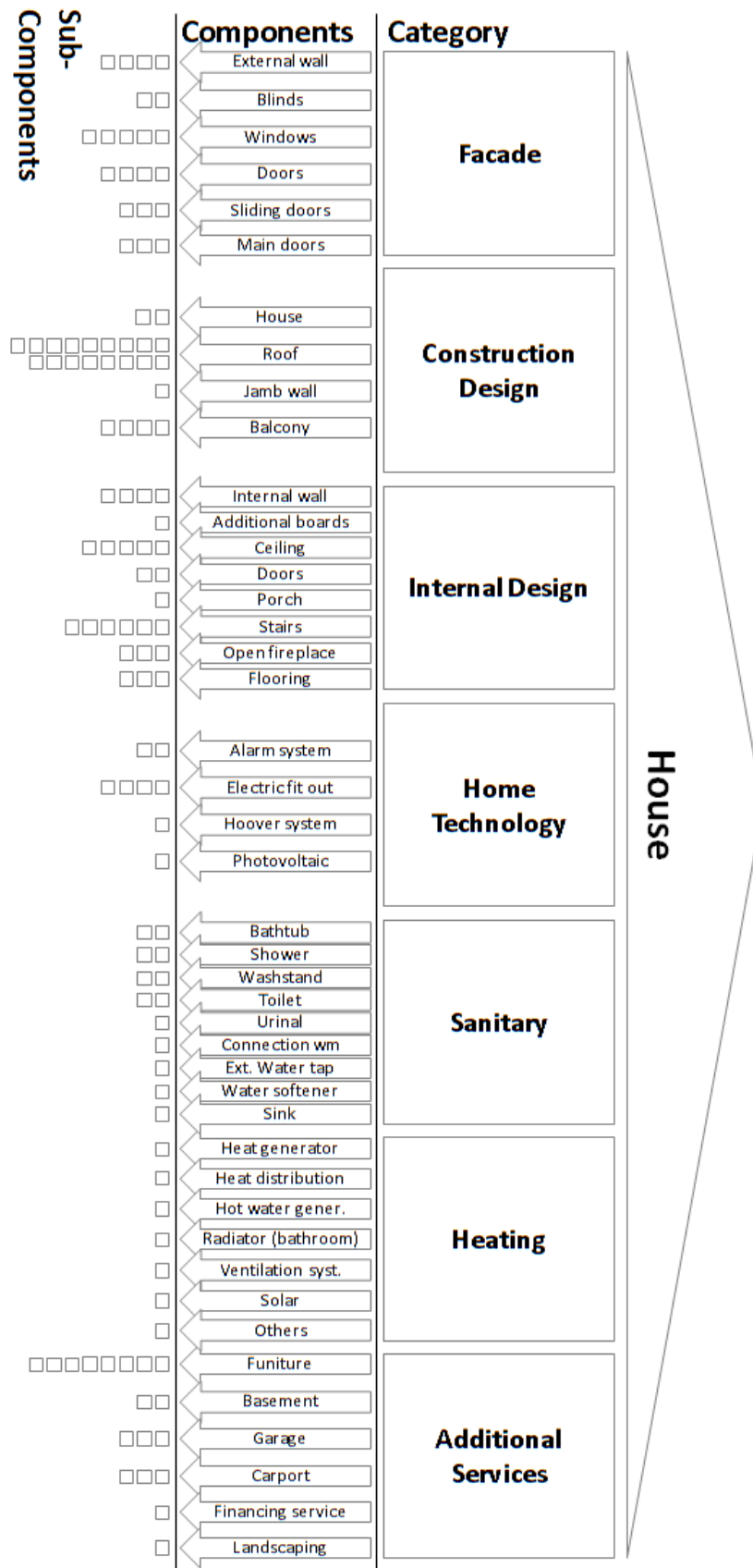


Figure 4.1: Diagram showing categories, components and sub-components (source: author)

Figure 4.1 denotes that a house consists of many different elements. It turned out that all of the items on the component level can actually be influenced by the clients. This is one of the reasons why the specification of the house (fit-out specification) takes more than two days as otherwise there is a risk of clients feeling overloaded with information. In order to make the complexity of a house more tangible for the reader, a practical example for a category breaking into component and sub-component is provided. In the facade of each house there exist doors. For this attribute, a considerable number of specifications can be made: type, colour, type of lock, type of door handle/knob, alarm secured (a yes/no question). This results in many different choices for the clients.

The product architecture presented above does have some similarities to the automotive sector. As reported by Pil and Holweg (2004) automobiles are very complex products due to the many different components that are needed to manufacture a car and the variety that is offered. The aforementioned authors present research that shows the total numbers of variations offered by the key European, American and Japanese automobile producers. Looking at the company material provided by the case company a total number of 1,786,400 variations was calculated. This, however, does only include the standard offerings. According to Pil and Holweg (2004) the case company provides thus as many variations as Ford for their Fiesta model.

In general product architecture can also be described as product breakdown structure. It details the physical components of a particular product. By breaking up the end product into its components, a clear understanding of the product and how it is set up is achieved. This method of visualisation is often used when products are designed for variety as in this case the level of complexity usually increases as well (Biren, 1998). As an example for a product architecture of a different product, a breakdown structure of a motorcycle is shown in Figure 4.2. Usually at the top the end product is shown and then further below the component and sub-component structure can be seen. This gives a good overview with regard to the product's set-up. As one can see there is a strong resemblance with the diagram as shown in Figure 4.1.

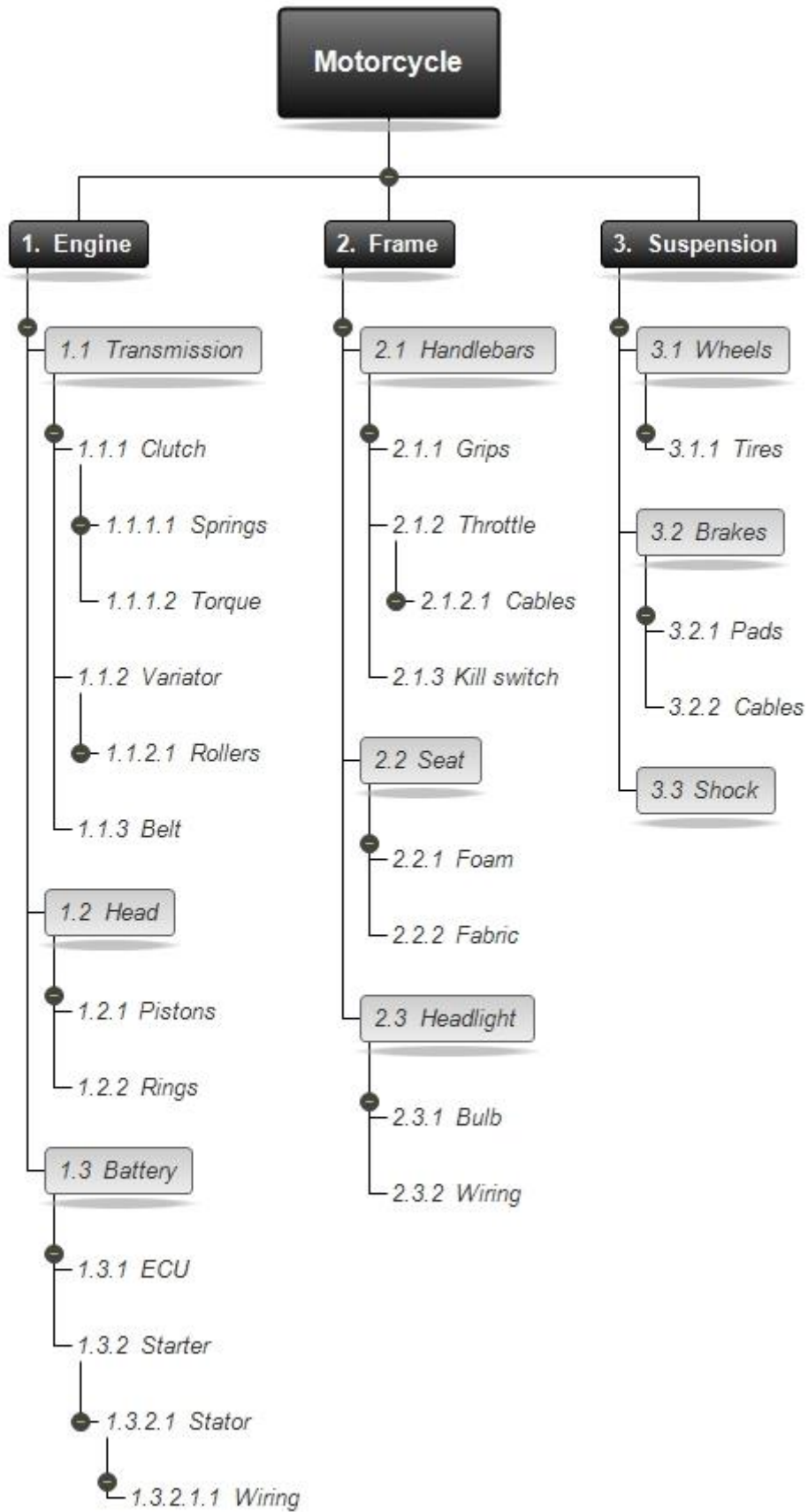


Figure 4.2: Product breakdown structure of a motorcycle (source: Productbreakdownstructure.com, 2014)

4.4.2. Analysis of degree of customisation

Figure 4.3 provides a unified treemap of the first level (i.e. category) for the projects investigated. The size dimensions are correlated to the tree structure as shown in Figure 4.1, with the shading representing the client uptake of specification options. As can be seen, the most options available are for the internal and construction design. For the internal design, the client is able to make 25 specification options and for the appropriate components within the construction design category, 24 specification options are available. However, the colour intensity shows that, for the scrutinised 16 projects, the actual take-up of options was somewhat higher for those elements that affect the appearance of the house, suggesting that this is particularly important for clients.

Furthermore, we learn that the sanitary design seems to be very important as the actual take-up of options was greatest, at 27.25% of the specification options taken up, as seen in Figure 4.3. In this instance, clients are well-prepared and have precise ideas of how the bathroom is designed and fitted. When discussing the results of the research with the internal stakeholders, it was confirmed by the fit-out managers that the fit-out of the bathrooms is easy for them to customise as most clients have their own ideas that clearly vary from the standard.

Following the tree structure and zooming into the component level, Figure 4.4 delivers a more detailed picture as it is possible to see which components were chosen by clients. In reverse, components can be identified where choice is offered but the actual take-up by clients was low (e.g. ceiling, external wall).

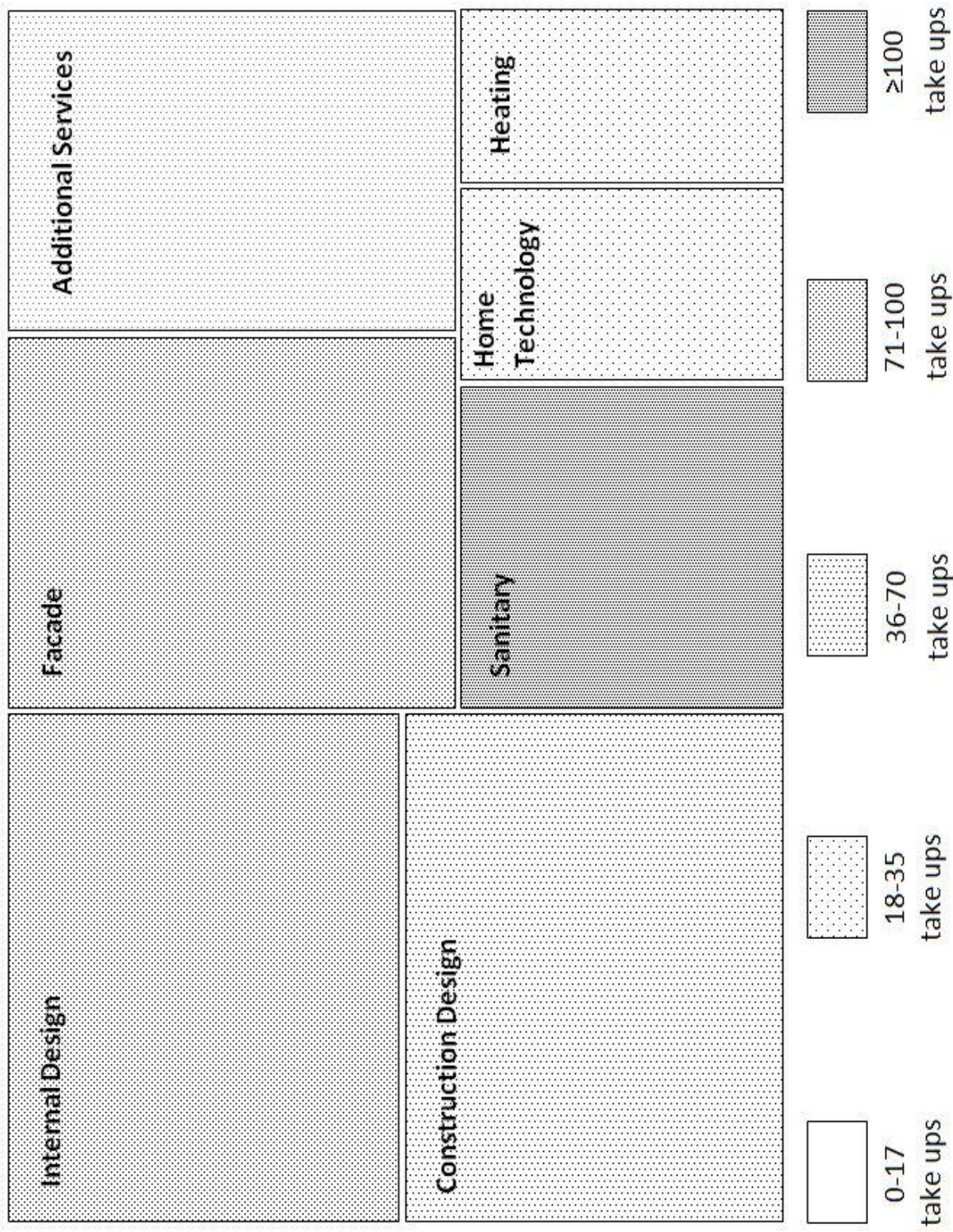


Figure 4.3: Treemap of category-level (source: author)

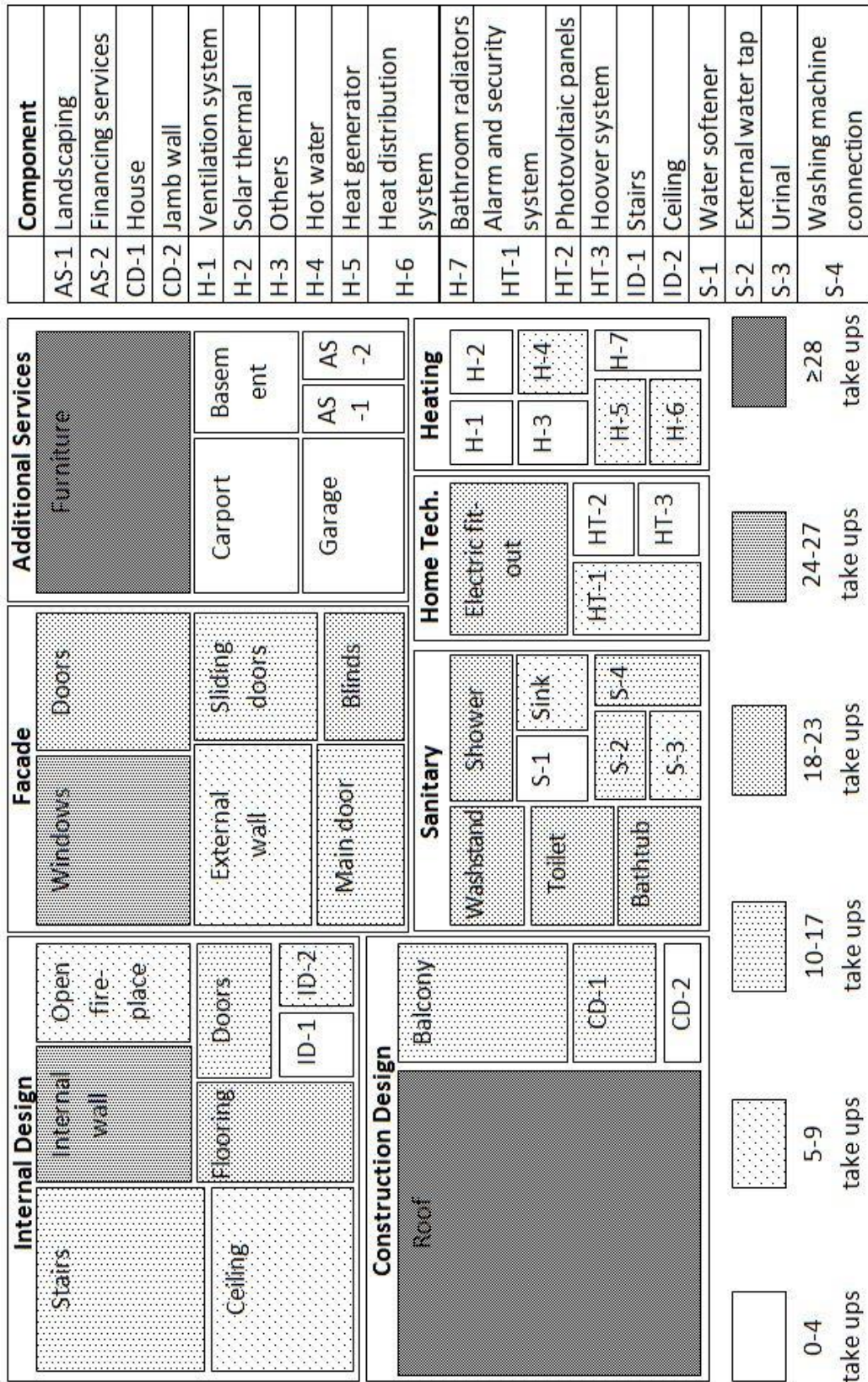


Figure 4.4: Treemap of component-level (source: author)

The analysis of Figure 4.3 shows that clients appreciate choice in the sanitary fit-out with 130 specifications made. The potential reasons for this have been discussed above but by scrutinising Figure 4.4 it becomes apparent that the main components within a bathroom that clients find important to customise are washstands, toilets, showers and bathtubs. Looking at the additional services, we see that furniture is also something that requires customisation from the client's point of view, reflecting the appearance of the house again. The roof (40 specifications made) and electric fit-out (20 specifications made) also appear with high levels of customisation and the reasoning behind this is discussed below.

Figure 4.5 provides the analysis at the sub-component level. The limitations of a treemap application become apparent here where, with the given level of detail, some elements are difficult to read.

In general, it appears as if the components which signify lifestyle and/or design of the house are important for clients as these account for over 50% of all specifications made. Clearly, choice in these categories is appreciated. Furthermore, switches and sockets in the electric fit-out category provide a pointer towards a potentially under-equipped house with regard to the electrical fit-out, or the design is not what clients want. In one project, for example, the fit-out manager registered over one-hundred variances from the building specification for sockets. Clearly this needs careful consideration by the company, as it may be that clients are customising because they can in this instance, rather than because they want to.

However, equally important as the categories in which choice is appreciated by clients are the categories and components that remain white or pale in the treemap representation of Figure 4.5 which means that there has been infrequent or no intervention by the client at all. A number of these components relate to the roof, which in Figure 4.4 was identified as a highly customised area. The reason for this is that there are a large number of subcomponents to the roof and so, when aggregated, it looks like there is customisation when in reality there may not be so much.

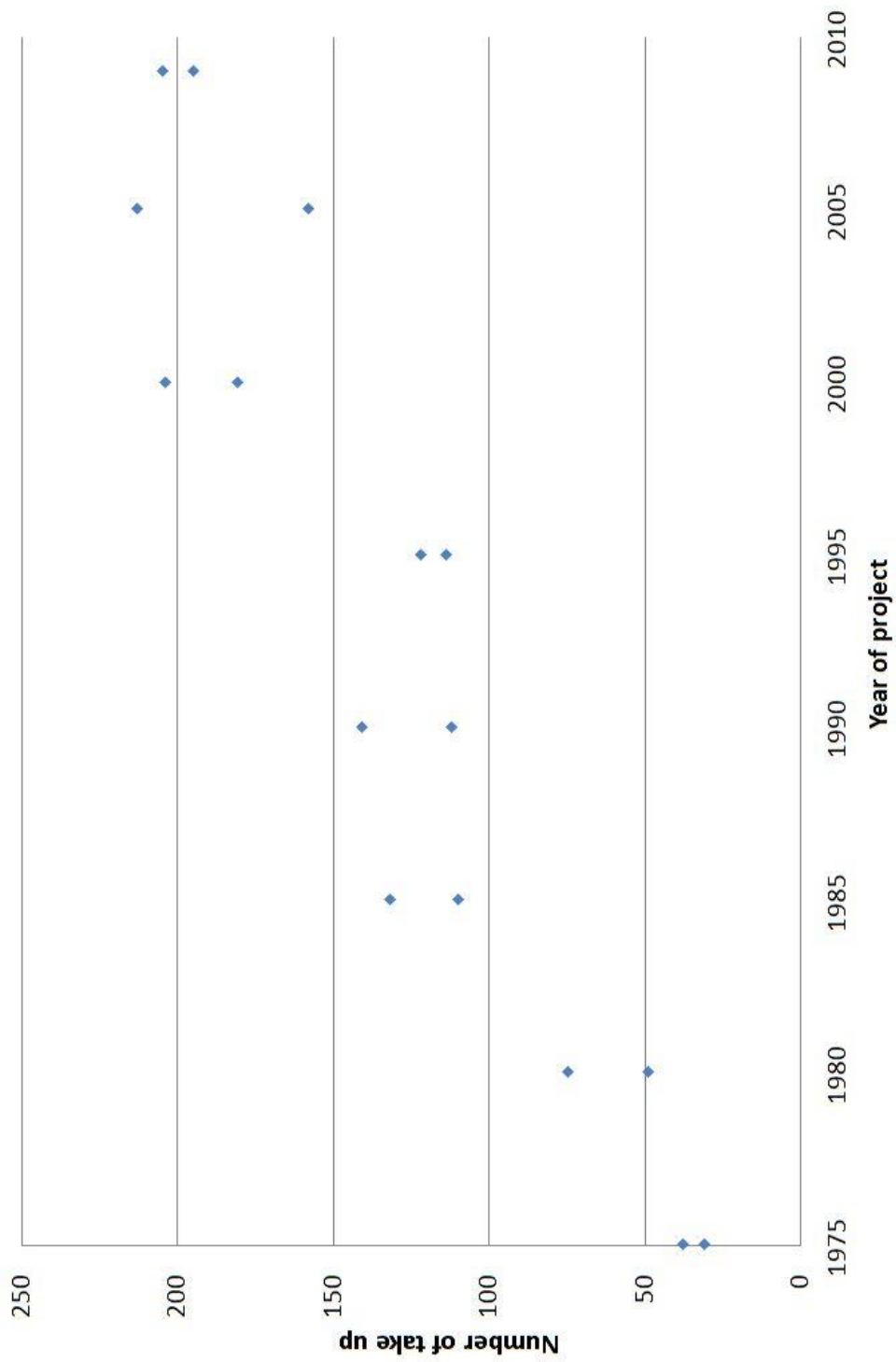


Figure 4.6: Total number of specification options taken up (source: author)

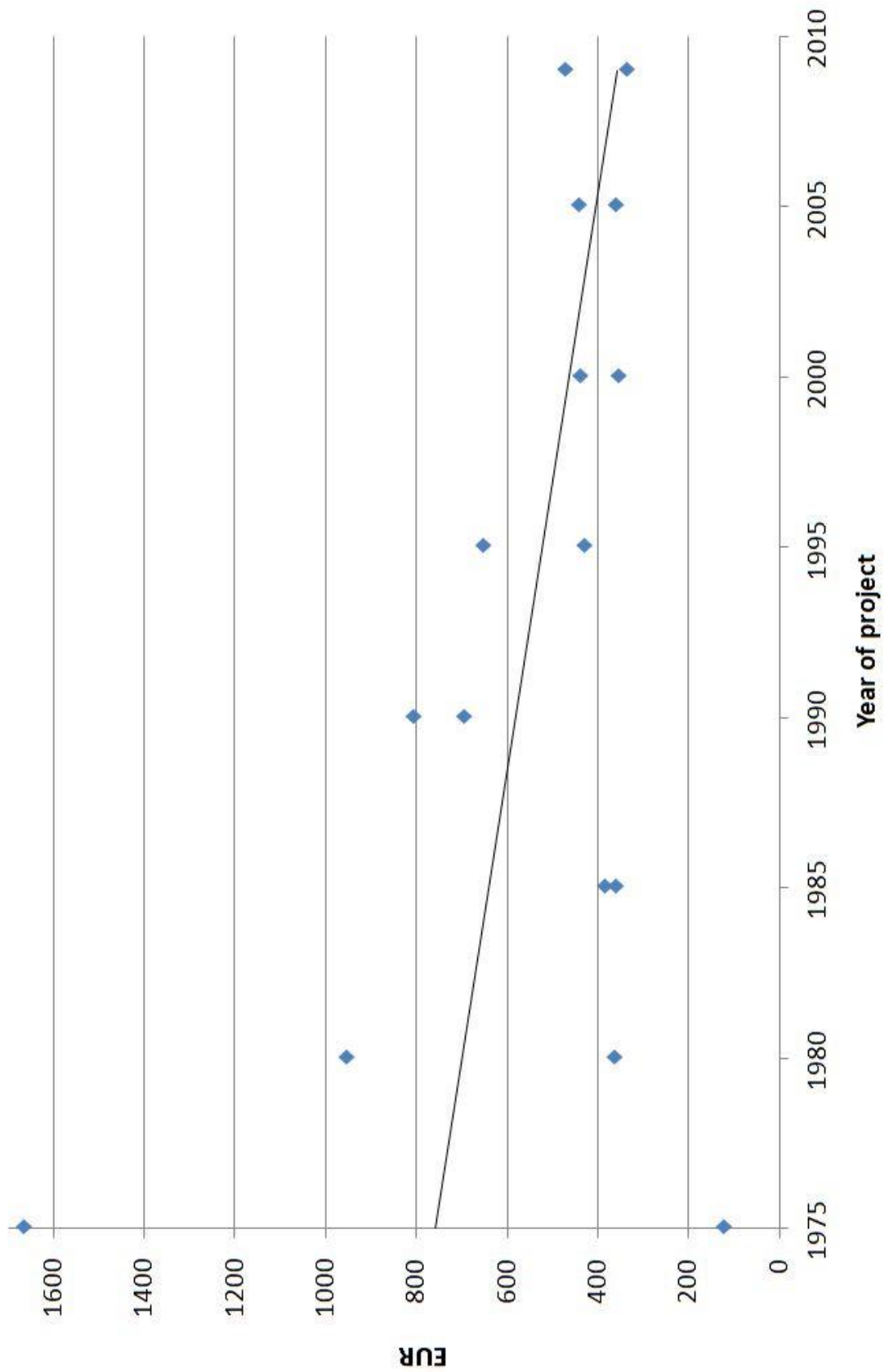


Figure 4.7: Cost per option (source: author)

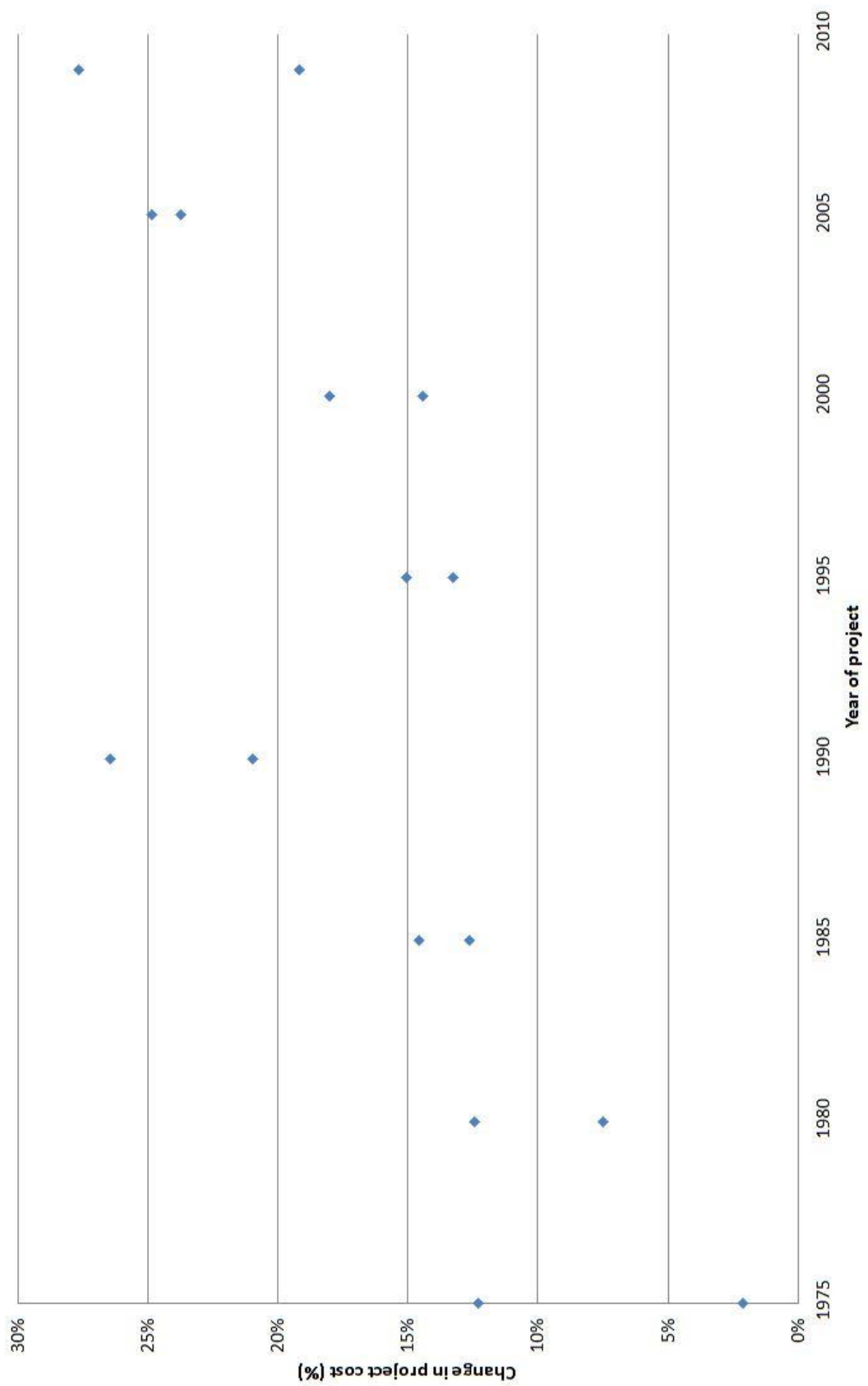


Figure 4.8: Percentage change of project cost due to customisation (source: author)

Appendix 3 provides an overview of the total uptake of each component as well as for each category thus further highlighting the complexity of the product.

While the above analysis focuses on all of the projects, the longitudinal nature of the data means that it is possible to examine some trends over time. Figure 4.6 shows the absolute number of options taken up for each project between 1975 and 2009.

When scrutinising the results, it becomes apparent that the number of changes made by the clients increased considerably over the relevant time span. However, when mapping the number of choices as a scatter diagram, as in Figure 4.6, three phases emerge. Years 1975 to 1980 (phase 1) show an increasing number of option take-ups, years 1985 to 1995 (phase 2) a more or less steady development and years 2000 to 2009 (phase 3) a steady development as well, but at a higher level. Overall, the number of take-ups of the options offered increased, from around 40 in 1975 to 200 in 2009. This can be partly explained by the development of showrooms at the company's headquarters. This meant more explicit choice offerings and therefore an increased degree of customisation.

Figure 4.7 points out that although the number of take-ups increased over the years, the trend of cost per option decreased over the same period of time. As pointed out above, the costs per option have been adjusted to inflation. Linking Figure 4.6 to Figure 4.7 shows that phase 1 and 2 see scattered cost per option; phase 3 shows steady costs at around €400 per option. This demonstrates that the company has finally been able to control the actual cost per option effectively. This has been achieved by a consistent alignment of their internal processes. Furthermore, the company has developed a more flexible building structure that allows late changes to certain items, even if the house is on site already.

By working out the percentage change of the total project cost due to customisation (Figure 4.8), it is possible to deduce that clients spent increasingly more money tailoring the building to their own specification, with a 25% increase in house construction cost

in 2009. This suggests that clients appreciate the freedom of choice, and are taking increased advantage of this.

Positioning of CODP based on above findings

Referring to the four steps presented in Chapter 3, Step 1 of the method applied delivered a complete product architecture of the case company’s product: a view of a prefabricated house as a system of components. Using the data collected in Step 2 it was possible to set up Table 4.1 which explores the actual uptake of specification options by clients in the context of the self-build housing industry. An overview of the total uptake of each component as well as for each category is given. The same components as in Schoenwitz et al. (2012) are used as their research finds that these are the most commonly customised.

Table 4.1 clarifies that customer choice can penetrate the supply network on each level for this particular product. It is therefore sensible to consider this in more depth in order to establish knowledge with regard to possible CODP positions and the appropriate chain network configuration.

Level in hierarchy	Degree of customer option take-up			
	High	Medium	Low	None
House	House			
Category	Facade	Construction design	Home technology	
	Internal design		Heating	
	Sanitary		Additional services	
Component	Bathtub	Blinds	External wall	Hoover system
	Shower	Windows	Roof	Water softener
	Washstand	Doors	Jamb wall	Basement
	Toilet	Sliding doors	Additional cover boards	
	Connection for washing machine	Main door	Ceiling	
	External water tap	Footprint	Stairs	
		Balcony	Open fireplace	
		Internal wall	Alarm / security system	
		Doors	Photovoltaic panels	
		Porch	Ventilation system	
		Flooring	Solar	
		Electric fit-out	Others	
		Urinal	Furniture	
		Sink	Garage	
		Heat generator	Carport	
		Heat distributor system	Financing service	
		Radiator	Landscape gardening	

Table 4.1: Categorisation table showing customer option take-up (source: adapted from Schoenwitz et al., 2012)

Looking at the data generated in Step 3 and merging the various data sets that have been collected in Steps 1 and 2 resulted in the finding that trying to position the CODP

on an aggregate product architecture level results in oversimplification. Looking at the tree diagram (see Figure 4.1), one can see that the product consists of seven categories and each of these categories is positioned separately with regard to the degree of customisation.

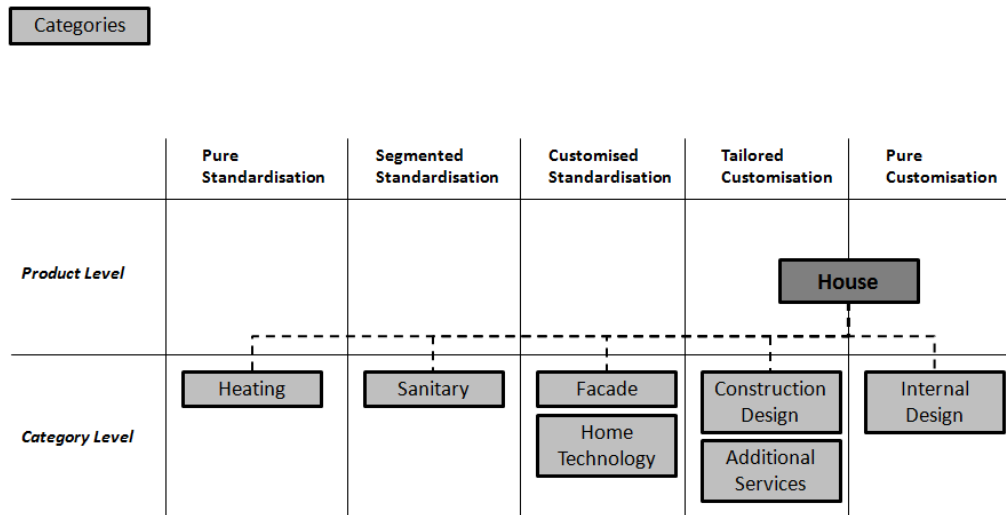


Figure 4.9: Customisation versus standardisation based on product architecture (source: author)

In Figure 4.9, the first and the second level of the product architecture has been mapped on a matrix showing the degrees of customisation/standardisation as per Lampel and Mintzberg (1996). The mapping has been done by assigning the characteristics of each customisation strategy to each category and/or component separately. As can be seen, on an aggregate level, the house was categorised to be between tailored and pure customisation. This is due to the virtually infinite choice a client has when configuring the product. However, choice is limited by the generic post and beam architecture which gives, for example, particular wall element sizes. Unfolding the product architecture and including all categories as identified in Figure 4.1 shows that on the category level there is a variety of approaches from pure standardisation (i. e. heating) to pure customisation (i. e. internal design). In this regard, pure standardisation means that the components cannot be customised and there is no choice for customers. In house building terms, this customisation strategy can be described as a speculative build. Pure customisation on the other hand, means that the customer is fully integrated in the product configuration and design process and there is infinite choice. This strategy is normally described as

self-build. Between these two extremes are segmented and customised standardisation as well as tailored customisation representing a gradually increasing degree of choice.

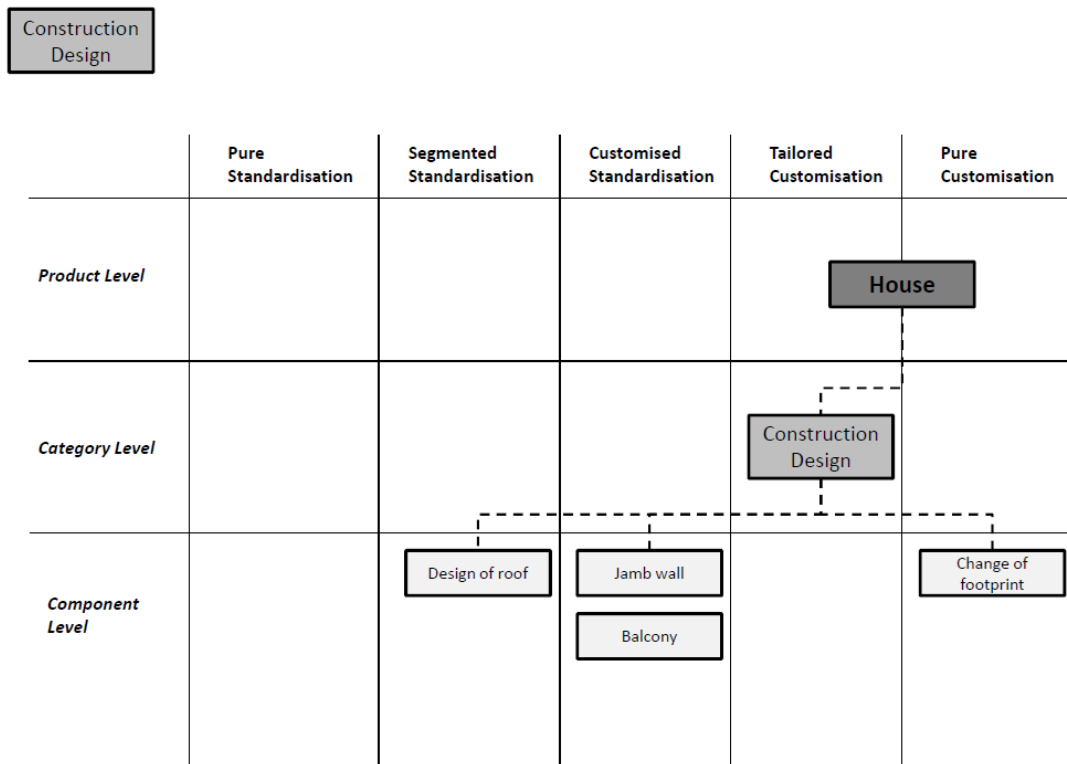


Figure 4.10: Customisation versus standardisation based on product architecture – using “Construction Design” as an example (source: author)

In Figure 4.10, one category (i. e. construction design) has been decomposed into its components. It has been categorised as being customised standardisation which means that it is assembled to order (ATO). However, due to the complexity of the product architecture and the many different levels in the hierarchy, it cannot be deduced that in this case the traditional characteristics of an ATO product are met. In fact, as can be seen in Figure 4.10, the construction design consists of a variety of components and even sub-components that itself can be categorised as completely different from the higher level aggregate. Blinds and doors, for example, are pure standardised components as choice is limited to options presented in a catalogue. These items are readily available. However, the main door can be customised but limited options are available thus making this component a customised standardisation component. Obviously, the items all have different internal and external supplier relationship interfaces and can be categorised differently depending on their degree of customisation based on the

characteristics assigned to each category. By scrutinising Figures 4.9 and 4.10 it becomes apparent that in order to position the CODP effectively the whole product architecture, including all levels, needs to be considered.

A further particularity of products with complex product architectures becomes obvious when doing this mapping exercise. Even the smallest change on the sub-component level can have a knock-on effect on all other levels. A good example in this regard is the external wall which can have a glazing or not. If the client decides that the wall will have a glazing then this has structural implications, meaning that the load of the building needs to be absorbed somehow. Hence, this one decision can potentially have consequences on the overall product and the client needs to be aware of this, especially if it influences the aggregate CODP which determines the delivery time. This can have an effect on the P:D ratio as mentioned in chapter 2.5 which then determines the amount of planning and production that needs to be based on speculation.

The decomposition of all the other categories has been attached as Appendix 4.

Relevance of CODP

As previously indicated, when determining the position of the CODP it is important to ascertain who is affected by this particular position. Multiple CODPs have different degrees of relevance to the stakeholders. From a company perspective, for example, the complete supply network is relevant, hence, all the CODPs that are positioned therein are relevant. This is because the company needs to configure the supply network in a way that it can accommodate customer requirements. The customer, however, once the product has been specified and signed off is only interested in delivery time and thus only the CODP on the aggregate level is relevant. However, both internal and external suppliers are involved in the further upstream processes which is why the CODP on an aggregate level is relevant as well as the appropriate CODP that exist within the production processes of the sub-components and components.

The aforementioned process describes the ideal situation. It has been observed, though, that the case company needed to go back to the customer and tell him that his chosen

configuration could not be built. This clearly shows that the high variety offered often leads to new configurations which have not been approved by the engineers. This is one of the downsides of the application of a high variety strategy for a complex product.

4.5. Discussion of case study findings

There are a number of implications that arise from the case study. Firstly, the results of the case study demonstrate that clients, when given the potential to do so, are increasingly looking at customising their houses. This is reflective of trends found in other industrial sectors (Piller et al., 2003). Because the house builder can charge for these changes, this also provides an additional revenue stream. This is perhaps slightly different to the automotive industry, where some customisation is possible within the list cost of the vehicle while another range of options incur an additional charge (Stäblein et al., 2011).

Despite this increase in customisation, the selection of options is limited to certain aspects of house building. Many structural areas are generally not customised. This may reflect a lack of confidence from the consumer in such areas, as they form a fundamental part of the building. The question therefore arises as to whether the house builder should actually offer choice in this area, or provide a fixed solution. By offering a more standardised product, further efficiencies in manufacturing may be achieved. As a comparison, the mass customised automotive sector does not offer the inner workings of the engine to be configured, as many consumers would not know the relative benefits or otherwise of different component types (Alford et al., 2000).

One key area for customisation relates to the fixtures and fittings. These directly affect the appearance of the house, and therefore reflect the occupier's personal style (Duffy, 2002). As a consequence, it is important for the company to be able to offer variety, and the high uptake of these options shows how important this is to the client. For other products, there will equally be a key set of components that clients need to be able to tailor to their own desires. However, with less complex products the customisation process can be controlled in a much easier way. Piller et al. (2003) provide an example of a company called AutoScout24, a European intermediary and brand-independent

seller of cars. Their website offers a configuration process that is based on questions regarding the clients' needs. Based on this profile, different cars which fit these parameters are individually pre-configured for each providing a good basis for the customisation process.

Some of the items in the additional service category are particularly related to the interior design of the property rather than the actual house building process. Therefore, the challenge is to decide whether offering these services in-house or through a third party offers greater value. In the case example, it is perceived that the value lies in offering these internally, with the exception of entertainment equipment which is offered through a preferred supplier.

Another area that is popular for customisation is the walls, doors and windows. Again, these can have a significant impact on the ambiance of a property. The question this raises is whether the standard specification includes too few of these components. While some may need to be in fixed positions from a structural perspective, additional options could be offered on a flexible basis allowing the client to position them wherever they wanted. Because the additional components would be part of the standard specification, this flexibility would have little impact on the manufacturing process.

Analysing the results of the focus group sessions, it became apparent that customer choice can actually penetrate the product architecture at different levels for different components. Starting at the attribute level the customer specification converges into sub-components, components and finally the house itself. This has been confirmed by Step 2 during which project data was analysed to identify the uptake of options by customers. Step 3 finally delivered the finding that non-standard customer requirements can actually penetrate the product architecture at any level. This supports the view that a positioning of the CODP on a pure MTS, ATO, MTO and ETO basis is overly simplistic.

Any supply chain consists of hierarchical composition relationships between materials and modules, sub-components and components (Sun et al., 2008). It is important to

identify the products' architecture and determine the appropriate classification for each of the components that can be customised in order to structure the supply chain at that particular point accordingly. If a sub-component is made MTS it must not be assumed that the complete product is made MTS. In the case study it was found that, for example, a door is MTS but becomes part of a wall element which is configured once the customer order is received. However, there are also examples where the complete component consists of order specific sub-components thus making it ETO. Hence within a complex product architecture consisting of many different components, it is not sufficient to analyse the product delivery strategy on an aggregate level.

The four step method used in this research is a feasible approach when studying products with complex product architectures. It enabled the decomposition of the product into components and sub-components. The findings, and more specifically the approach that has been developed in this study, extend the existing CODP concepts and take into consideration that there can be diversity in order fulfilment strategies for one product. The current literature presents a number of conceptual studies but there is a lack of empirical studies on this topic.

Furthermore, earlier research has solely concentrated on the degree of choice offered by house builder operations but the interaction between choice and production and processes has not been examined in depth. However, it is important for a business providing a certain degree of choice to be aware of the influence choice has on the operations so that an appropriate and efficient set up of the product and processes can be determined. This is only possible if there exist a thorough understanding of the operational processes.

However, this study extends the existing body of generic and industry specific knowledge and is relevant for both researchers and practitioners producing products with a complex ETO product architecture. Much of the previous empirical research in this field has concentrated on the spectrum of ATO – MTS products at an aggregate level.

4.6. Conclusion

The above findings and the approach developed in this paper can help house builders and manufacturers to pinpoint areas in which to focus their efforts in providing choice. A framework has been developed that enables the identification of the components. This defines the degree of customisation of a house and the relevance of such components to house builders.

The longitudinal case study undertaken provides insights into the nature of choice for a house builder's operations where some choice is made by clients. It is therefore worthwhile for house builders to not only make use of economies of scale but to also work on economy of scope strategies. The hierarchical product structure presented in this paper is consistent with other house builders who produce pre-manufactured houses (Naim and Barlow, 2003, Barlow et al., 2003). Therefore the results are generalisable within this particular industry.

This empirical research suggests that different CODPs can exist concurrently within the product architecture of one ETO product which has an effect on the product and processes. It can be deduced that the position and number of CODPs changes with the perspective. This also happens with each project, component, sub-component and attribute level. Moreover, there are CODPs on many interfaces which can be of customer-to-business or business-to-business nature. This is often neglected by researchers when positioning the CODP. However, there are dependencies between the different components and sub-components which is why the knowledge of each CODP in the supply network is vital in order to better control and organise company activities such as engineering, purchasing, inventory control and production.

However, it has to be highlighted here that the positioning of the CODP is based on the point of customer involvement which is critical to determining the degree of customisation (Rudberg and Wikner, 2004). But it could be argued that this in itself is simplistic as the CODP concept is much more complex in particular considering the P:D ratio and, hence, the time dimension. In fact it can even be argued that this research does not position CODPs but a different form of decoupling point. However, the scope

of this research is not to give in-depth guidance on single production processes for which the determination of production and delivery time would be vital. Furthermore, the CODP concept is used for positioning purposes which indicate that there is a problem rather than to reengineer production- or distribution-related activities.

The use of treemaps within the context of construction management is novel, and highlights a potentially useful technique in practice although further applied research and testing is required. Previous research has highlighted a positive user reaction. However, experience suggests that there is a learning curve that needs to be overcome to get useful insights, and a need for a logical structure within the data. For practical purposes in ensuring visual clarity, it is found that treemaps are limited to a maximum of three hierarchy levels. Furthermore, due to space constraints the labelling is not always clear. A further limitation is that the currently available software solutions do not provide consistency when visualising a dataset with two or more hierarchies.

An additional natural development of the treemap technique is analytical hierarchical process (AHP) and the application in measuring consumer preferences for ETO self-build applications. It is suggested in the literature that too much choice can cause confusion rather than satisfaction among clients but such research has concentrated on high volume manufacturing products such as automobiles, personal computers and mobile telephones. These are products where the design function is a distinctly different process in contrast to ETO.

An alternative interpretation could be that clients only decide to customise because of the choices available. The case company needs to evaluate whether the offer of choice is still necessary for those components that have had limited take-up, such as for example, the ceiling and Hoover system. This would help to simplify the customisation process for the client considerably. By offering too high a degree of choice, where it is not required, clients could become confused. Table 4.2 gives an example how to identify components for which options can be omitted. The decision for a threshold depends on the company management strategy. In Table 4.2, the threshold was defined to be 10%

which means that all components for which the uptake was below 10% of the total potential can be omitted.

Category	Component	Total take up	Potential take up	Take up in %
Facade	external wall	5	64	8%
	blinds	19	32	59%
	windows	24	80	30%
	doors	19	64	30%
	sliding doors	15	48	31%
	main door	17	48	35%
Construction design	house	13	32	41%
	roof	40	272	15%
	jamb wall	1	16	6%
	balcony	15	64	23%
Internal design	internal wall	25	64	39%
	additional cover boards	3	16	19%
	ceiling	7	80	9%
	doors	15	32	47%
	porch	7	16	44%
	stairs	11	96	11%
	open fireplace	5	48	10%
	flooring	21	48	44%
Home technology	alarm / security system	4	32	13%
	electric fit-out	20	64	31%
	hoover system	0	16	0%
	photovoltaic panels on roof	1	16	6%
Sanitary	bath tub	22	32	69%
	shower	21	32	66%
	washstand	23	32	72%
	toilet	22	32	69%
	urinal	9	16	56%
	connection for washing machine	14	16	88%
	external water tap	13	16	81%
	water softener	0	16	0%
	sink	6	16	38%
Heating	heat generator	7	16	44%
	heat distributor system	5	16	31%
	hot water generator	1	16	6%
	radiator (bathroom)	7	16	44%
	ventilation system	1	16	6%
	solar	1	16	6%
Additional services	others	2	16	13%
	furniture	28	128	22%
	basement	0	32	0%
	garage	2	48	4%
	carport	3	48	6%
	financing service	2	16	13%
landscape gardening	1	16	6%	

Table 4.2: Omit or retain – an overview (source: author)

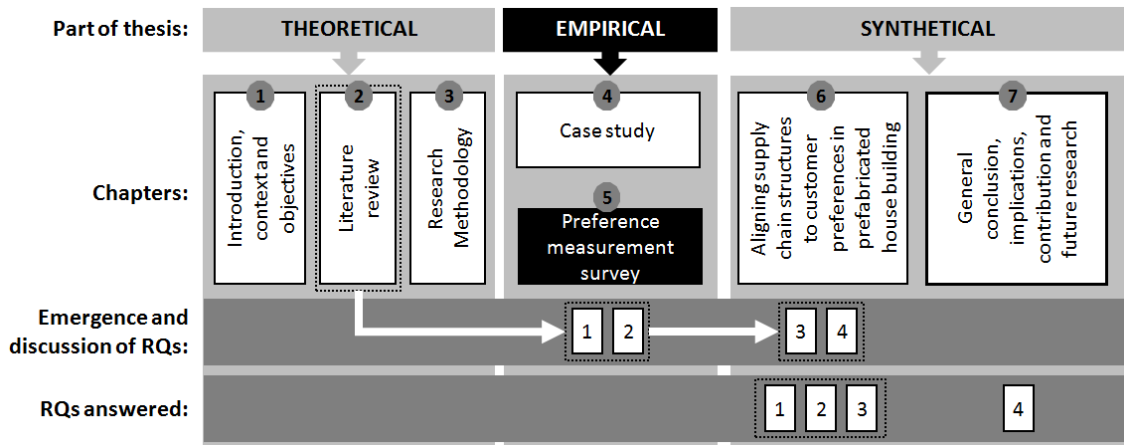
There is considerable scope for further research of this topic contributing to generic and house building specific literature. From a scholarly perspective, the findings contribute to a better understanding of the applicability of mass customisation strategies in the industrialised housing building industry. The house builder studied has evolved over time from a craft manufacturer to a mass customiser but is finding it harder to maintain the efficiencies associated with the latter given the increased pressures from clients for

more choice. Hence, there is a tendency for the house builder to revert back to a pure customised self-build strategy. This, however, is case specific as the company presented here is at the top end of the market where the demand for customisation is more prevalent.

The explanatory power of the study is limited by the fact that the findings presented are those of a single case in a particular market. Furthermore, the life cycle of certain technologies as well as the potential change in lifestyle of clients has not been considered in this study. Nevertheless, the results can be regarded as pointers for both scholars and practitioners. As the treemaps and associated analysis have shown the degree of customisation for various components of the house differ.

Chapter 5

“The sickness in our cities and residential estates today is the sad result of our failure to place basic human needs and requirements ahead of economic, business and industrial demands.” (Walter Gropius)



5. Findings of stream 2 (online preference measurement survey)

This chapter begins with a brief introduction followed by an overview of the modus operandi of the online survey research. Furthermore, a full statistical analysis of the survey results is given and the findings are presented and discussed. The key contribution of this chapter is the application of a preference measurement technique for complex products as well as the identification and prioritisation of what potential buyers of prefabricated homes really focus on when configuring a house.

5.1. Introduction

Lessons learnt from other sectors (e.g. automotive, clothing) show how important it is to know the client's exact preferences in order to deliver new product variety at a price that is acceptable to house buyers (Hofman et al., 2006 and Stäblein et al., 2011). There is therefore a need to find out how potential customers assign priorities to the different elements in a house that can be customised. If house building companies knew customers' preferences in advance, they could increase variety where it is really necessary and offer standardised solutions where individualisation is not needed, taking advantage of economies of scale.

This chapter identifies buyer preferences in prefabricated house building projects through the application of a modified Analytical Hierarchy Process approach, using a paired comparison-based preference measurement (PCPM). This method considers changing attribute positions in a survey, which compels respondents to continuously reconsider the importance of a feature. A preference measurement method is thus applied in order to prioritise and identify what buyers of prefabricated homes really focus on when configuring a house. This is important as only knowledge of the preferences will enable practitioners to be effective in customisation efforts and also in ensuring operational efficiency.

Determining the appropriate level of choice is difficult and insight into the nature of choice is sparse within the literature. Collecting and analysing empirical data in this area is also a complex undertaking, meaning the evidence base is thinner than would be expected.

5.2. Overview of modus operandi

On the basis of the case study, a view of the house as a system of components and sub-components has been developed. Furthermore, the locations of multiple CODP for the components and sub-components have been identified.

The online customer preference measurement survey used a modified AHP approach which structured around the product architecture matrix. This preference measurement task applied a pairwise comparison questionnaire based survey to define the level of choice expected by customers for the components. There are a number of techniques that have been used to measure customer preferences, for example: Quality Functional Deployment, Analytic Hierarchy Process and Conjoint Analysis. A comparison of these techniques is shown in the Method chapter.

The Paired Comparison-based Preference Measurement (PCPM) was identified as being most suitable for this research. This is because the PCPM has a proven track record of application in complex product environments. The PCPM approach offers a number of advantages which are also highlighted in the Method chapter. The determination for

using PCPM in this study was further strengthened by the availability of appropriate software which facilitated the set-up of the online questionnaire and the data analysis as well.

Data was then collected using an 'ad hoc' survey which is defined as a one-off survey which is specific in its subject matter (Saunders et al., 2003). Furthermore, it was decided to conduct the survey online (i. e. in the web) as this involves low costs and enabled the collection of a lot of data within a short period of time.

5.3. Findings

In the following the findings of the preference measurement are presented. In general in social sciences, a 95% level of confidence is considered to be an arbitrarily acceptable standard (Silver, 1997). The sample size calculation has been completed using both a 95% and a 99% level of confidence in order to show the impact a change of the level of confidence has on the sample size. The variables included in the calculation are as follows:

- e: error margin (the larger the error margin, the less confidence one can have that the results of the survey are representative for the whole population)
- p: estimated sample proportion
- Z: level of confidence
- n: sample size

As mentioned above, a 95% level of confidence is assumed and an acceptable error margin of plus or minus 4.00% and a sample proportion of 0.4, then
 $p = 0.4, Z = 1.96, e = 0.04$

$$n = \frac{(1.96)^2(0.4)(1-0.4)}{(0.04)^2} = 576.24 \quad \dots(5.1)$$

Sample Size Table			
Error margin "e"	Estimated "p"	Sample Size	
		95% Confidence	99% Confidence
4.00%	40.00%	576	998

Sensitivity - Alternative allowable error values			
Error margin "e"	Estimated "p"	Sample Size	
		95% Confidence	99% Confidence
2.00%	40.00%	2305	3994
2.50%	40.00%	1475	2556
3.00%	40.00%	1024	1775
3.50%	40.00%	753	1304
4.00%	40.00%	576	998
4.50%	40.00%	455	789
5.00%	40.00%	369	639
5.50%	40.00%	305	528
6.00%	40.00%	256	444
6.50%	40.00%	218	378
7.00%	40.00%	188	326
7.50%	40.00%	164	284
8.00%	40.00%	144	250
8.50%	40.00%	128	221
9.00%	40.00%	114	197
9.50%	40.00%	102	177
10.00%	40.00%	92	160
10.50%	40.00%	84	145
11.00%	40.00%	76	132
11.50%	40.00%	70	121
12.00%	40.00%	64	111

Table 5.1: Calculation of sample size (source: adapted from Silver, 1997)

Hence, a sample size of 576 respondents is required for an error margin of plus or minus 4% at a 95% level of confidence. The sample size that was achieved with the snowball sampling method was 87 respondents. Table 5.1 shows the full sample size table considering different error margins. It can be seen that the error margin increases to 10.50% with the sample size that has been achieved. This means that for the results presented in this thesis an error margin of 10.50% is applicable.

Table 5.2 shows the responses to the online survey over time. Following the piloting the link was sent out to the sample of available email addresses for the first time on 28th July 2012. Responses then arrived rapidly within the first two days to reach approximately 38%. Over 70% of the responses arrived within a week after the link was sent out. After

four weeks a reminder was sent out in order to maximise the response rate but this did not have a huge effect as can be seen in table 5.2. The questionnaire was then deactivated at end of September 2012.

Date	20.06.2012	11.07.2012	13.07.2012	29.07.2012	30.07.2012	31.07.2012	01.08.2012	02.08.2012	03.08.2012	04.08.2012	05.08.2012	06.08.2012	07.08.2012	08.08.2012	09.08.2012	10.08.2012	11.08.2012	12.08.2012	11.09.2012	12.09.2012	17.09.2012	19.09.2012	Sum
Number of respondents	1	2	1	14	19	7	11	4	5	3	4	1	2	2	1	2	3	1	1	1	1	1	87

Table 5.2: Response rate over time (source: author)

Sample constitution

A sample that is used for marketing research should always represent the target group. Otherwise the results cannot be used for company purposes. According to Jobber (2004), the target market is a group of individuals that are separated by distinguishable and noticeable aspects such as for example: geographic, demographic, psychographic and behavioural segmentation. Hence, before a cost intensive survey is conducted the marketing department needs to be consulted and a sample needs to be constituted on the basis of the company specific target market profile.

In the following, we present the structure of the sample first. When suitable, each presentation of a finding is followed by a statistical analysis determining the arithmetic mean, the variance, and the standard deviation of the collected data. As most of the data is grouped in class intervals the appropriate formulae for grouped data are applied.

First, the arithmetic mean is calculated. In the formula, x refers to the midpoint of the class intervals and f is the class frequency:

$$\text{Arithmetic mean: } \bar{x} = \frac{\sum fx}{\sum f} \quad \dots(5.2)$$

Secondly, the variance of a set of values is determined as follows:

$$\text{Variance: } \sigma^2 = \frac{\sum fx^2}{\sum f-1} - \bar{x} \quad \dots(5.3)$$

Finally, the standard deviation for a set of grouped data is determined by:

$$\text{Standard deviation: } s = \sqrt{\sigma^2} \quad \dots(5.4)$$

Note that for all of the above, formulae $\sum f = n$ is used. Moreover, for the variance and standard deviation calculation it must be considered that this survey is not concerned with the whole population but rather with a sample of it. Therefore, according to Bessel's correction, the n value needs to be replaced by $n - 1$ (Puhani, 2001).

As mentioned before, this online survey was conducted in Germany and, hence, was limited to participants living in Germany. By capturing the IP-address of the participants as well as asking them to enter a German post code it was ensured that the online survey was not completed by people from outside Germany. In order to present the origin of the sample in a way that enables a quick understanding of where most participants come from, the post code data was transferred in an Excel spreadsheet. A list of all German post codes with the appropriate longitudes and latitudes was retrieved from the internet. A simple macro plug-in that was found on the internet was then used to position the above location data on a map of Germany. A grey star with a '1' represents one participant. The size of the star grows with the number of participants from one and the same location. Figure 5.1 thus provides a compact overview of the sample's origin.



Figure 5.1: Sample location (source: author)

As can be seen, most of the participants stem from the western part of Germany. The main reason for this is that the majority of the available email addresses were from people based in west Germany. It is assumed that although the link to the questionnaire has been forwarded frequently by the participants, it was still only forwarded to people living in the area. Therefore, it needs to be stated that the sample can have a regional bias and this needs to be considered when conducting a preference measurement.

Furthermore, it is possible to conduct a preference measurement for a particular regional market. The case company's management, for example, stated that typical regional markets are cities like Munich, Hamburg, Stuttgart and Berlin. Hence it certainly further increases the accuracy of the preference measurement if preference measurements are conducted within these regional markets.

With regard to a demographic profile of the sample, it can be deduced that the majority of the participants were between 31 and 60 years old as given in Figure 5.2.

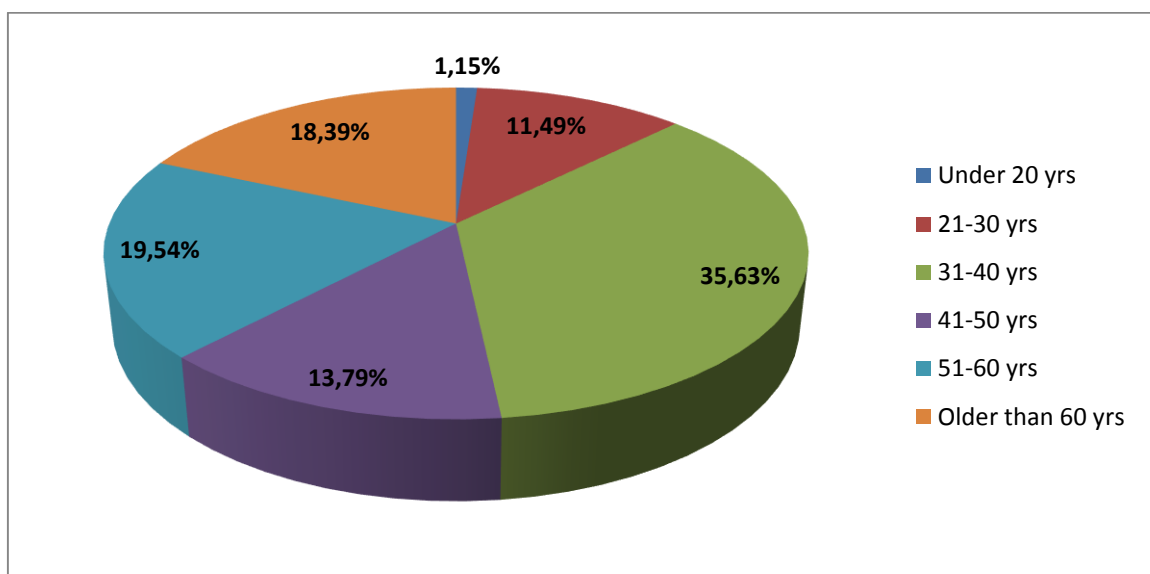


Figure 5.2: Demographics of sample (source: author)

Mid interval value (x)	Frequency (f)	fx	x ²	fx ²
15	1	15	225.00	225.00
25	10	250	625.00	6250.00
35	31	1085	1225.00	37975.00
45	12	540	2025.00	24300.00
55	17	935	3025.00	51425.00
65	16	1040	4225.00	67600.00
Sum	87	3865		187775.00

Mean **44.425**
Variance **163.659**
s (stand dev) **12.793**

Table 5.3: Statistical analysis of demographics

Table 5.3 gives the statistical analysis of the demographics. The centre of the distribution, the mean, is 44.43 years. The variance of the demographics in this study is high at 163.66. This means that the data points are not close to the mean and very spread out from each other as well. The dispersion from the mean is given by the standard deviation of the sample, s . For the demographics of this study, s is 12.79. It can thus be concluded that the distribution of the demographic data set is spread out over a large range of values. This is a logical consequence of the sample being randomly selected rather than aimed at one particular demographic group.

As the distribution of the data is not symmetrical and bell-shaped, s can be further interpreted by considering the simple rule or Chebyshev's theorem (Silver, 1997). This states that for any set of numbers, approximately 90% of their values will lie between plus or minus 3 standard deviations of the mean of the values. Thus it can be determined that 90% of the data's values lie between:

	$\bar{x} \pm 3s$	contains approximately 90% of all observations
∴	44.43 ± 38.37	contains approximately 90% of all observations
∴	6.06 to 82.80	contains approximately 90% of all observations

68% of the respondents indicated that they are male while 32% of the respondents were female. As mentioned before, the snowball sampling method was applied in order to increase the number of responses. Hence, the questionnaire was not intentionally targeted at male respondents. Nevertheless, the majority of questionnaires were completed by male respondents.

The gender overview has been extended by an overview of the age profile of the male and female respondents. As can be seen, over 50% of the participants are older than 41 years. (see Figure 5.3). During a piloting of the questionnaire, the Head of Technics of the BDF states that, according to the association's recent surveys of their member companies, the most frequent customer is between 40 and 70 years old. Likewise, discussions with the case company managers determined that their customer base consists mainly of those over 50 years old, and these are usually couples. According to

the managing director of the business, this is mainly due to the availability of funds. Over 50s usually have a strong financial background and, even if the funds are not readily available, obtaining a mortgage should not pose a problem. Hence from a demographic perspective the results of the survey stem from the industry's population profile.

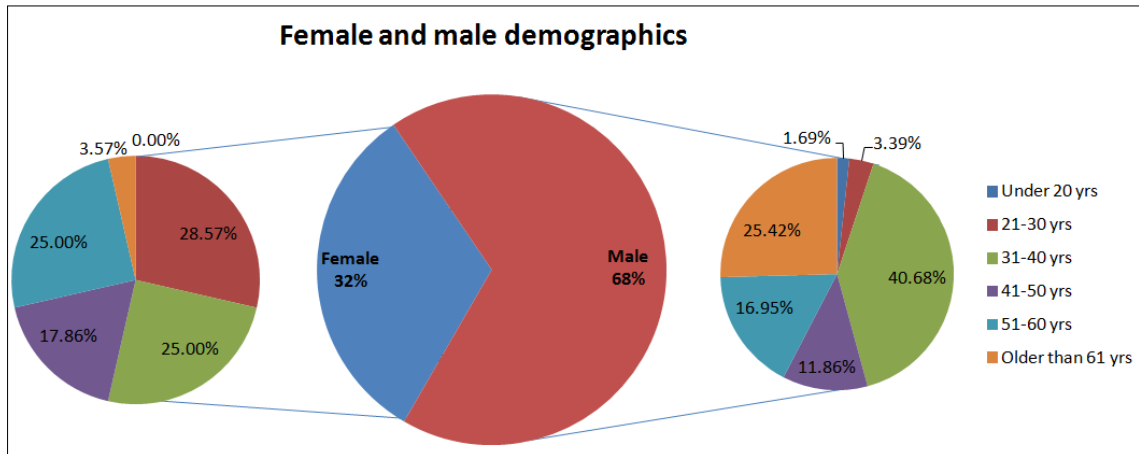


Figure 5.3: Overview of demographics for gender groups of respondents (source: author)

A further question asked the respondents how many people live in the household on a permanent basis. Figure 5.4 shows that 82 respondents (or 94.25%) live in a household with more than two people. Asking for the size of the household can indicate to the company whether the respondents are a part of the target group or not. As mentioned above, the managing director of the case company stated that the typical buyers are normally a couple. Hence in further company specific analysis, the survey results given by the single households could be removed in order to avoid results that are not representative of the company's target market.

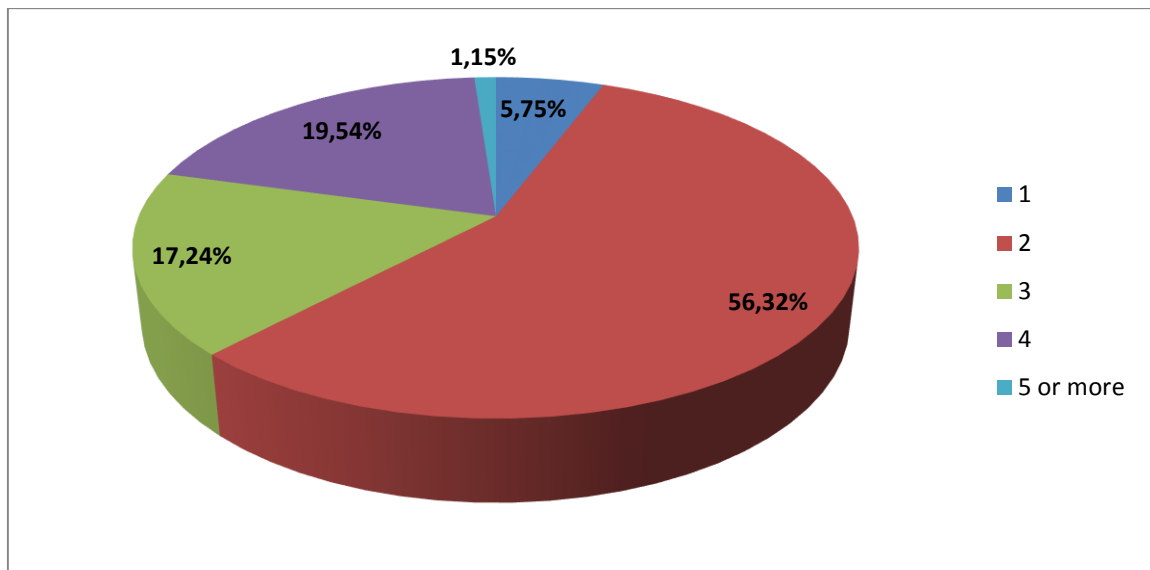


Figure 5.4: Size of household (source: author)

x	Frequency (f)	fx	x ²	fx ²
1	5	5	1.00	5.00
2	49	98	4.00	196.00
3	15	45	9.00	135.00
4	17	68	16.00	272.00
5	1	5	25.00	25.00
Sum	87	221		633.00

Mean **2.540**
Variance **0.757**
s (stand dev) **0.870**

Table 5.4: Statistical analysis of size of household

Table 5.4 gives the statistical analysis of the size of households. The centre of the distribution is 2.54. The variance of the size of the households in this study is low at 0.76. This means that the data points are close to the mean and not too spread out from each other. The dispersion from the mean, is 0.87. It can thus be concluded that the distribution of the data set is not spread out over a large range of values. It could be interesting to see whether there is any correlation between the demographics and the size of the households. This can only be assumed for now as nearly 38% of the

respondents were over 50 years and usually over 50s live in a small household. Children, if there are any, have already moved out of the house.

As the distribution of the data is bell-shaped, s can be further interpreted by considering the empirical rule. This states the following:

- $\bar{x} \pm s$ contains approximately 68% of all observations
- $\bar{x} \pm 2s$ contains approximately 95% of all observations
- $\bar{x} \pm 3s$ contains approximately all observations

Thus it can be determined that 95% of the data's values lie between:

- $\bar{x} \pm 2s$ contains approximately 95% of all observations
- $\therefore 2.54 \pm 1.74$ contains approximately 95% of all observations
- $\therefore 0.80 \text{ to } 4.28$ contains approximately 95% of all observations

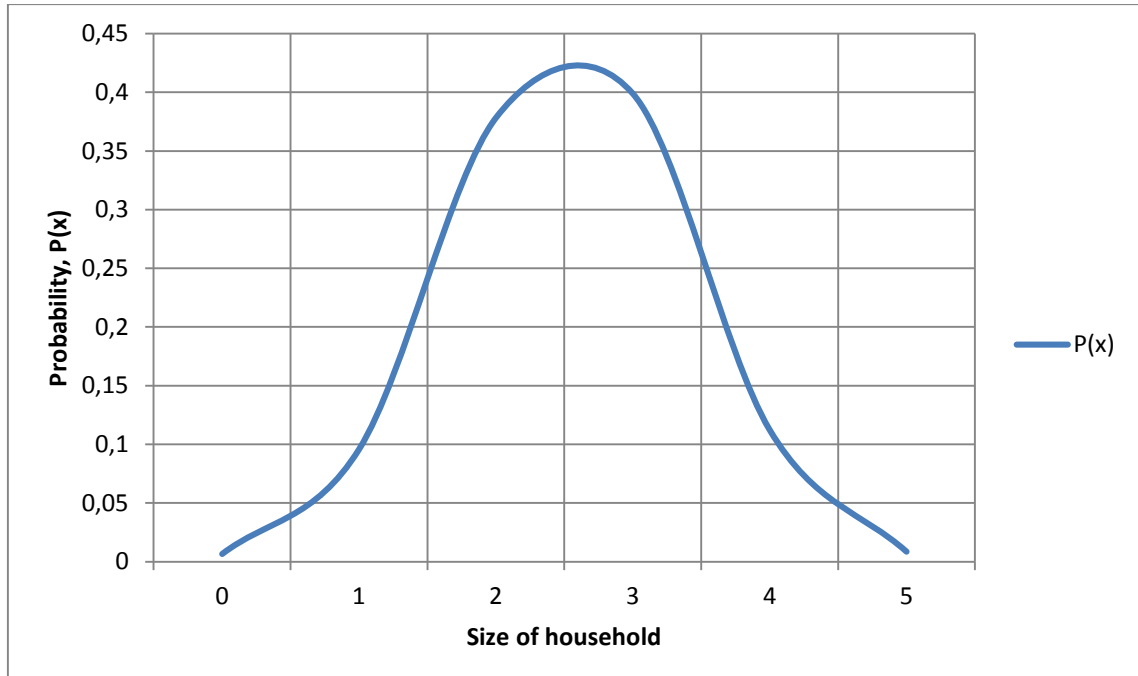


Figure 5.5: Probability distribution: size of household (source: author)

In Figure 5.5, the probability distribution for the size of households is shown. As can be seen, the distribution is normal and bell-shaped. The probability of a zero, and five

person household is very low. In contrast, the probability of a two or three person household is very high. Values of x for >6 are not given since the associated probabilities are very small.

A further so-called socioeconomic aspect for market segmentation is the income so this question was also posed to participants. Respondents could indicate to which annual income group they belong. It was clarified in the question that the total income should be indicated. This means that if more than one person lives in a household, the accumulated income is to be considered as this is the basis for any financing scheme when planning to build a house.

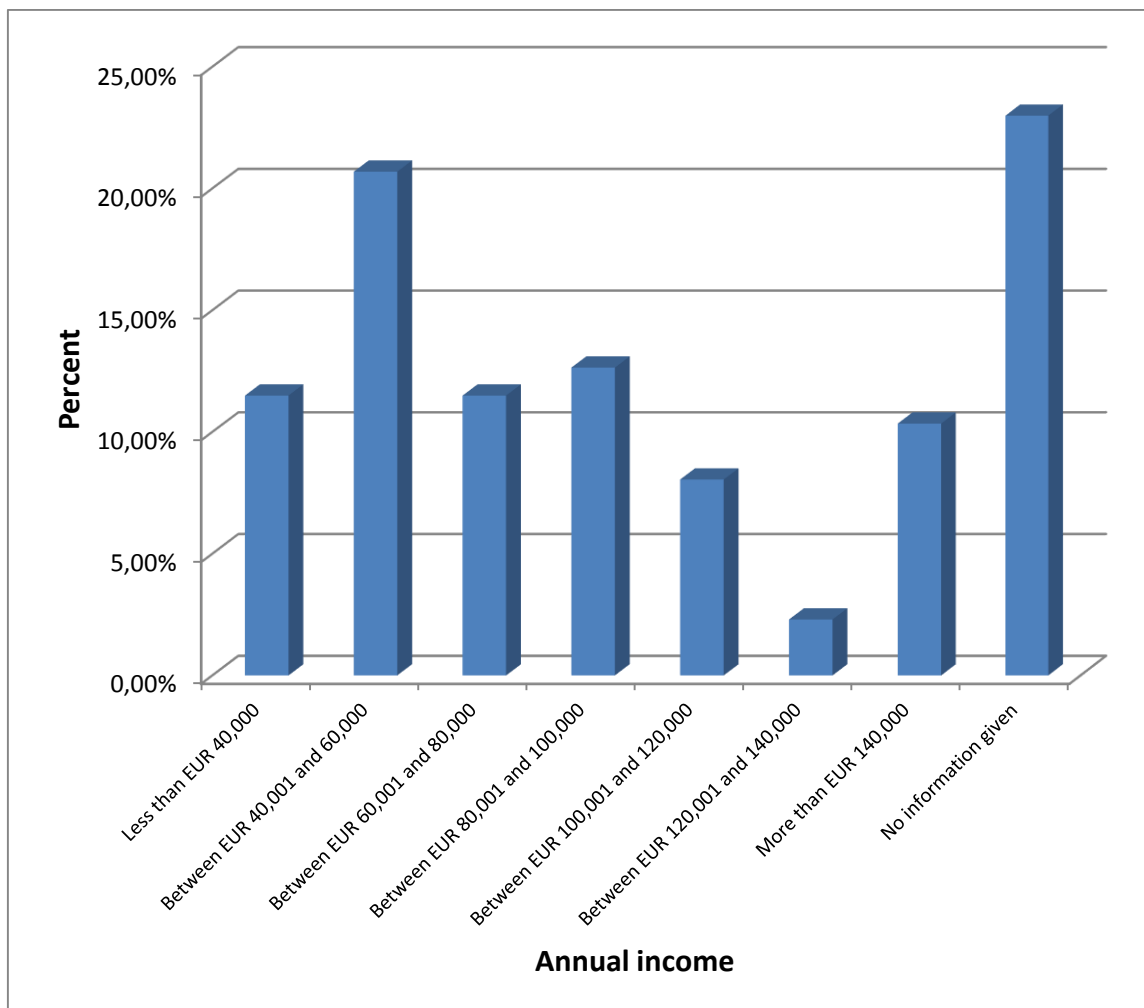


Figure 5.6: Annual income of household (source: author)

Whilst doing the IDA it became apparent that this is a sensitive question and most of the respondents indicated that they did not want to give information with regard to their

income. However, 67 respondents responded to the question and almost 21% indicated that they have an annual income of €40,001 – €60,000 (see Figure 5.6).

Table 5.5 below gives the statistical analysis of the income. The centre of the distribution, i. e. the mean, is 78,656.72. The variance of the size of the households in this study is very high (i. e. 1,398,461,891.64). This means that the data points are not close to the mean and are very spread out from each other. The dispersion from the mean is shown by the standard deviation of the sample, s . For the annual income s is 37,396.01. It can therefore be concluded that the distribution of the annual income data set is spread out over a large range of values. This is a logical consequence as the sample was randomly selected with all income groups being represented. It will be interesting to see whether there is any correlation between the demographics and the income.

As the distribution of the data is bell-shaped, s can be further interpreted by considering the empirical rule. This states the following:

$\bar{x} \pm s$	contains approximately 68% of all observations
$\bar{x} \pm 2s$	contains approximately 95% of all observations
$\bar{x} \pm 3s$	contains approximately all observations

Thus it can be determined that 95% of the data's values lie between:

	$\bar{x} \pm 2s$	contains approximately 95% of all observations
∴	78,656.72 ± 74,792.03	contains approximately 95% of all observations
∴	3,864.69 to 153,448.75	contains approximately 95% of all observations

Mid interval value (x)	Frequency (f)	fx	x ²	fx ²
30,000	10	300,000	900,000,000	9,000,000,000
50,000	18	900,000	2,500,000,000	45,000,000,000
70,000	10	700,000	4,900,000,000	49,000,000,000
90,000	11	990,000	8,100,000,000	89,100,000,000
110,000	7	770,000	12,100,000,000	84,700,000,000
130,000	2	260,000	16,900,000,000	33,800,000,000
150,000	9	1,350,000	22,500,000,000	202,500,000,000
Sum	67	5,270,000		513,100,000,000

Mean **78,656.716**
1,398,461,891.64
Variance **4**
s (stand dev) **37,396.014**

Table 5.5: Statistical analysis of income

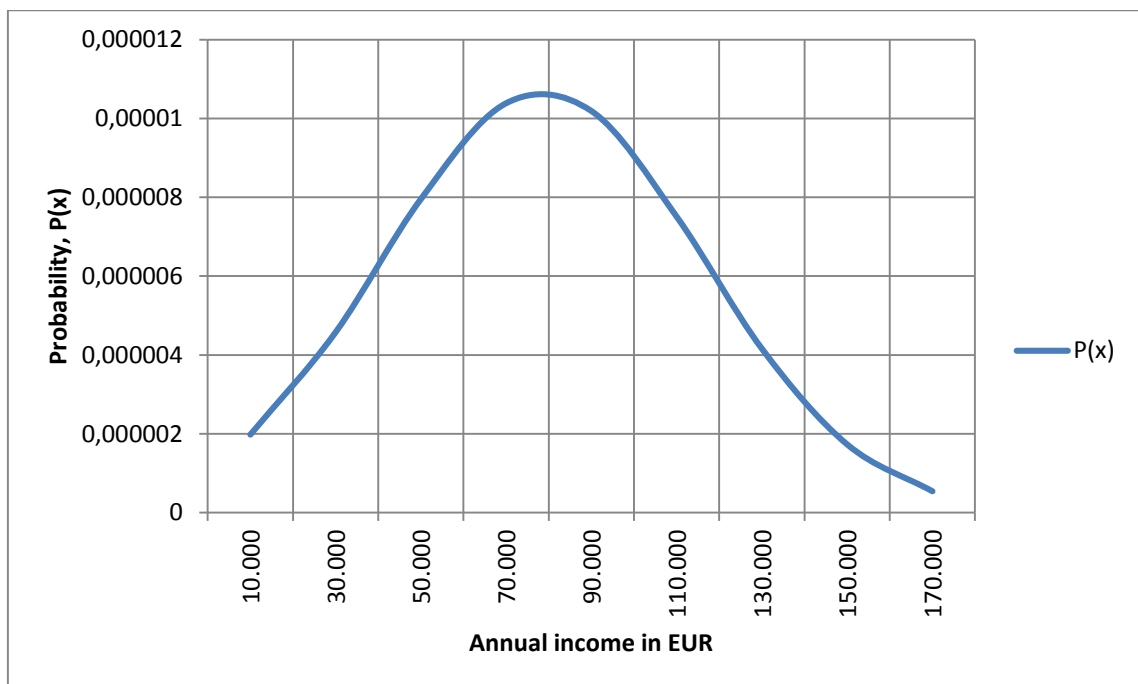


Figure 5.7: Probability distribution of annual income (source: author)

Figure 5.7 shows that the probability distribution of the annual income is slightly skewed towards the left hand side. Hence, there is a rather high probability of an annual income of €80,000. Annual incomes between €10,000 and €30,000 and between €130,000 and €170,000 show a very low probability.

Data correlations

As mentioned before, it is possible that there is an association between certain variables such as the demographics and size of a household or the demographics and level of income. In order to test the variables for a correlation, one needs to apply a method that can measure the degree of association between two nominal variables. Furthermore, it needs to be considered that the number of possible values for the two variables is unequal thus yielding a different number of rows and columns in a data matrix. Hence, the chi-squared combined with Cramer's V was identified as being suitable for this particular situation (Silver, 1997). The chi-squared is a test of independence that assesses whether paired observations on two variables, expressed in a so-called contingency table (see Table 5.6) are independent of each other. Furthermore, the chi-squared value is then needed to calculate Cramer's V. The chi-squared calculation is given by:

$$\chi^2 = \sum(O_i - E_i)^2 / E_i \quad \dots(5.5)$$

Cramer's V has a maximum value of 1 and a minimum of zero. A zero denotes full independence. The advantage of Cramer's V compared with the contingency coefficient is that it has a maximum value that does not depend on the dimensions of the contingency table (Puhani, 2001). Cramer's V is thus given by:

$$\text{Cramer's V} = \sqrt{\frac{\chi^2}{n(m-1)}} \quad \dots(5.6)$$

where n is the number of observations and m is the minimum number of rows (r) or columns (c).

Degree of association between age and size of household

Hence for the determination of the degree of association between the demographics and the size of household the calculation is as follows:

$$\chi^2 = 41.06$$

This value as such can only tell that the variables included in the correlation testing are not independent because if they were, the value for χ^2 would be zero. Hence, there are now two further issues of concern. Firstly, it needs to be determined whether the indication of dependency is due to sampling errors and secondly, the strength of association is still unknown.

In order to be able to find a critical value for χ^2 by referring to the statistical tables of the chi-squared distribution (see Appendix 4), one must follow the following process (Silver, 1997):

Step 1:

The degree of freedom (df) for the problem needs to be determined:

$$df = (r - 1) (c - 1) \quad \dots(5.7)$$

where r is the number of rows in the contingency table and c is the number of columns. For this example the $df = (87 - 1) (2 - 1) = 86$

Step 2

The significance level, which is the probability of rejecting independence when the variables are independent, is taken to be 0.05 which equals a 5% level. According to Silver (1997), it is usual in the social sciences to establish a 5% level.

Step 3

The critical value of χ^2 is determined from the statistical tables of chi-squared distributions (see Appendix 4) at the intersection of the appropriate degrees of freedom (= 86) and significance level (= 0.05). As the value for a df of 86 is not given in the table, the difference of a df of 80 and a df of 90 was divided by 10 and multiplied by 6. This resulted in a value of 6.76 which was added to the df of 80 (101.879). The df of 86 was thus determined to be 108.639

Step 4

When comparing the calculated value (= 41.06) with the critical value from the statistical table, it is found that the critical value exceeds the calculated value considerably. This means that the hypothesis of independence at the 5% level can be rejected. The demographics of the sample are not independent of the size of the household at a 5% level.

Step 5

The above testing does not reveal any information about the relationship of the data sets. Hence, as previously mentioned in order to determine the strength of any association, the Cramer's V is applied:

$$\text{Cramer's V} = \sqrt{\frac{41.06}{87(2-1)}} = 0.7 \quad \dots(5.8)$$

It can thus be concluded that the departure from the independence of the values is fairly large. There is therefore a relatively strong association between the demographics and the size of household.

Respondents	Age (years)			Number in Household			Sum
	O (age)	E	Chi Square	O (household)	E	Chi Square	
1	3	4.26	0.37	4	2.74	0.58	7
2	4	4.87	0.15	4	3.13	0.24	8
3	6	4.87	0.26	2	3.13	0.41	8
4	4	4.87	0.15	4	3.13	0.24	8
5	3	4.26	0.37	4	2.74	0.58	7
6	3	3.04	0.00	2	1.96	0.00	5
7	2	2.43	0.08	2	1.57	0.12	4
8	5	4.87	0.00	3	3.13	0.01	8
9	5	4.26	0.13	2	2.74	0.20	7
10	2	2.43	0.08	2	1.57	0.12	4
11	3	3.04	0.00	2	1.96	0.00	5
12	3	3.04	0.00	2	1.96	0.00	5
13	3	4.26	0.37	4	2.74	0.58	7
14	3	4.26	0.37	4	2.74	0.58	7
15	6	4.87	0.26	2	3.13	0.41	8
16	6	4.87	0.26	2	3.13	0.41	8

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Respondents	Age (years)			Number in Household			Sum
	O (age)	E	Chi Square	O (household)	E	Chi Square	
17	3	4.26	0.37	4	2.74	0.58	7
18	6	4.87	0.26	2	3.13	0.41	8
19	3	3.04	0.00	2	1.96	0.00	5
20	5	4.26	0.13	2	2.74	0.20	7
21	5	4.26	0.13	2	2.74	0.20	7
22	4	3.04	0.30	1	1.96	0.47	5
23	3	4.26	0.37	4	2.74	0.58	7
24	4	3.65	0.03	2	2.35	0.05	6
25	5	4.26	0.13	2	2.74	0.20	7
26	3	3.65	0.12	3	2.35	0.18	6
27	6	4.87	0.26	2	3.13	0.41	8
28	5	3.65	0.50	1	2.35	0.78	6
29	2	2.43	0.08	2	1.57	0.12	4
30	2	2.43	0.08	2	1.57	0.12	4
31	3	3.04	0.00	2	1.96	0.00	5
32	2	2.43	0.08	2	1.57	0.12	4
33	3	3.65	0.12	3	2.35	0.18	6
34	6	4.87	0.26	2	3.13	0.41	8
35	6	4.87	0.26	2	3.13	0.41	8
36	3	4.26	0.37	4	2.74	0.58	7
37	3	4.26	0.37	4	2.74	0.58	7
38	5	4.26	0.13	2	2.74	0.20	7
39	5	4.26	0.13	2	2.74	0.20	7
40	4	3.65	0.03	2	2.35	0.05	6
41	6	4.87	0.26	2	3.13	0.41	8
42	3	3.65	0.12	3	2.35	0.18	6
43	3	3.04	0.00	2	1.96	0.00	5
44	1	3.65	1.92	5	2.35	2.98	6
45	4	4.87	0.15	4	3.13	0.24	8
46	4	4.26	0.02	3	2.74	0.02	7
47	2	3.04	0.36	3	1.96	0.55	5
48	6	4.87	0.26	2	3.13	0.41	8
49	4	3.65	0.03	2	2.35	0.05	6
50	6	4.87	0.26	2	3.13	0.41	8
51	5	4.26	0.13	2	2.74	0.20	7
52	6	5.47	0.05	3	3.53	0.08	9
53	5	4.26	0.13	2	2.74	0.20	7
54	2	2.43	0.08	2	1.57	0.12	4
55	5	4.26	0.13	2	2.74	0.20	7
56	2	2.43	0.08	2	1.57	0.12	4
57	6	5.47	0.05	3	3.53	0.08	9

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Respondents	Age (years)			Number in Household			Sum
	O (age)	E	Chi Square	O (household)	E	Chi Square	
58	3	4.26	0.37	4	2.74	0.58	7
59	3	3.04	0.00	2	1.96	0.00	5
60	3	2.43	0.13	1	1.57	0.21	4
61	4	4.87	0.15	4	3.13	0.24	8
62	3	3.04	0.00	2	1.96	0.00	5
63	6	4.87	0.26	2	3.13	0.41	8
64	3	3.65	0.12	3	2.35	0.18	6
65	2	1.82	0.02	1	1.18	0.03	3
66	5	4.26	0.13	2	2.74	0.20	7
67	4	4.26	0.02	3	2.74	0.02	7
68	5	4.26	0.13	2	2.74	0.20	7
69	4	4.26	0.02	3	2.74	0.02	7
70	3	3.04	0.00	2	1.96	0.00	5
71	3	3.65	0.12	3	2.35	0.18	6
72	5	4.26	0.13	2	2.74	0.20	7
73	3	3.04	0.00	2	1.96	0.00	5
74	3	3.65	0.12	3	2.35	0.18	6
75	6	4.87	0.26	2	3.13	0.41	8
76	6	4.87	0.26	2	3.13	0.41	8
77	6	4.87	0.26	2	3.13	0.41	8
78	3	2.43	0.13	1	1.57	0.21	4
79	5	4.26	0.13	2	2.74	0.20	7
80	4	4.87	0.15	4	3.13	0.24	8
81	3	4.26	0.37	4	2.74	0.58	7
82	5	4.26	0.13	2	2.74	0.20	7
83	5	4.87	0.00	3	3.13	0.01	8
84	2	3.65	0.75	4	2.35	1.16	6
85	3	3.65	0.12	3	2.35	0.18	6
86	3	3.04	0.00	2	1.96	0.00	5
87	3	4.26	0.37	4	2.74	0.58	7
Sum	343	343.00	16.09	221	221.00	24.97	564

O = observed values

E = expected values

Table 5.6: Contingency table for determination of chi-squared (χ^2) (source: author)

Degree of association between demographics and level of income

In the following, the calculation for the degree of association between demographics and level of income is presented in a shortened form as all the necessary explanations with regard to the modus operandi have been given above.

Step 1:

The degree of freedom (df) for the problem needs to be determined:

$$df = (r - 1) (c - 1) \quad \dots(5.9)$$

where r is the number of rows in the contingency table and c is the number of columns.

Thus for this example the $df = (87 - 1) (2 - 1) = 86$

Step 2

The significance level which is the probability of rejecting independence (when the variables are independent) is taken to be 0.05 which equals a 5% level. According to Silver (1997), it is usual in the social sciences to establish a 5% level.

Step 3

The critical value of χ^2 is determined from the statistical tables of chi-squared distributions at the intersection of the appropriate degrees of freedom (= 86) and significance level (= 0.05). As the value for a df of 86 is not given in the table, the difference of a df of 80 and a df of 90 was divided by 10 and multiplied by 6. This resulted in a value of 6.76 which was added to the df of 80 (101.879). The df of 86 was thus determined to be 108.639

Step 4

When comparing the calculated value ($\chi^2 = \sum(O_i - E_i)^2 / E_i = 78.03$) with the critical value from the statistical table, it is found that the critical value exceeds the calculated value considerably. This means that the hypothesis of independence at the 5% level can be rejected. The demographics of the sample are not independent of the level of income at a 5% level.

Step 5

The above testing does not reveal any information about the relationship of the data sets. Hence, as mentioned before, in order to determine the strength of any association, the Cramer's V is applied:

$$\text{Cramer's } V = \sqrt{\frac{78.03}{87(2-1)}} = 0.9 \quad \dots(5.10)$$

It can therefore be concluded that the departure from the independence of the values is fairly large. Considering that the Cramer's V has a maximum value of 1, there is a very strong association between the demographics and the level of income.

Market specific data analysis

Statistical analysis was not completed for the findings of the following questions as they are not relevant for the objective of this study. Nevertheless the findings are presented here as, although they are not relevant, they do reveal some interesting aspects.

Since this study was conducted in the prefabricated house building sector, it was decided that respondents would be asked the following question:

What advantages do you think a prefabricated house has? Why would you prefer a prefabricated house?

Figure 5.8 gives the results which appear to be highly interesting and relevant to prefabricated house building companies. As can be seen, prefabricated houses seem to be associated with time compressed building processes and a complete solution package. In a brochure of The Association of German Prefabricated Building Manufacturers (BDF), it is exactly these two advantages are presented as major advantages of a prefabricated house. An extract from one of its brochures reads: "One-Stop Shopping. Before building works starts, the manufacturer will help you find a suitable site, handle planning permission, talk to insurance companies, and even help you with a home loan."

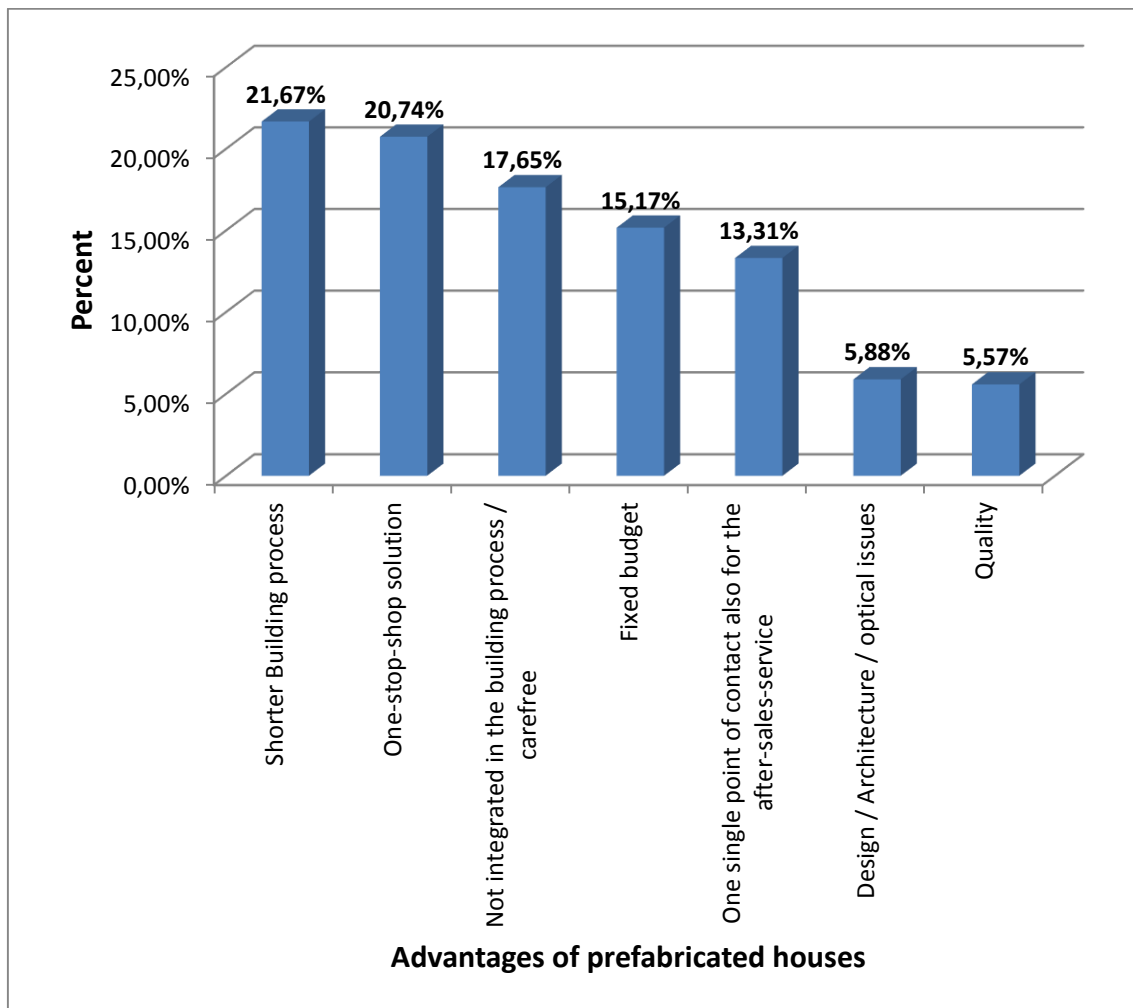


Figure 5.8: Advantages of prefabricated houses (source: author)

In regard to time-compressed building processes, the brochure says: “Time is money. Assembling a modern house shell takes 48 hours at the most, including closing the roof. This reduces costs for interim financing and saves you rent during the building period.” (BDF, 2007, p. 3 and 8). Because these two aspects are considered to be advantages by the survey respondents, the marketing messages of the BDF and the manufacturers seem to have reached their potential customers.

Quality seems to be an issue in the prefabricated house building sector. Certainly, further marketing campaigns are necessary in order to decrease the level of expectation (i.e. that it is low quality) that potential customers have.

The questionnaire also asked people to indicate what would be an acceptable price for a prefabricated house. Obviously, this is a difficult question as there is a whole variety

of different manufacturers and building designs. Nevertheless this question is worthwhile and it is certainly an important pricing indicator for the players in this sector. Hence, these two questions appeared in the questionnaire:

Question 1: If you think about the pricing of a prefabricated house – which price level would be too high so that you would not be willing to build a house? Please give an amount in EUR:

Question 2: Which price level would be too low so that you would actually question quality and security? Please give an amount in EUR:

Figure 5.9 shows the results of the above questions. As one can see a price level of €0 – €200,000 seems to be too low for a prefabricated house. Furthermore, a price level of over €300,000 is too high for the majority of the respondents. Interestingly, according to verbal information from the Head of Technics of the BDF, many manufacturers sell their houses for prices in exactly this price range.

As can be seen in Figure 5.9, a low percentage of respondents (i. e. 4.60% or 4 people) indicated that €950,000 – €1,000,000 was too expensive for a prefabricated house. Looking at the income data of these respondents, it became apparent that their annual income level is above national average, which is €34,071 according to the German Federal Pension Fund (Deutsche Rentenversicherung, 2014). One indicated that the annual income is over €140,000 and the second stated that the annual income is between €100,001 and €120,000. A third respondent indicated that he was not prepared to reveal this information. Therefore, there seems to be an association between the price that a respondent finds acceptable and the income of that person.

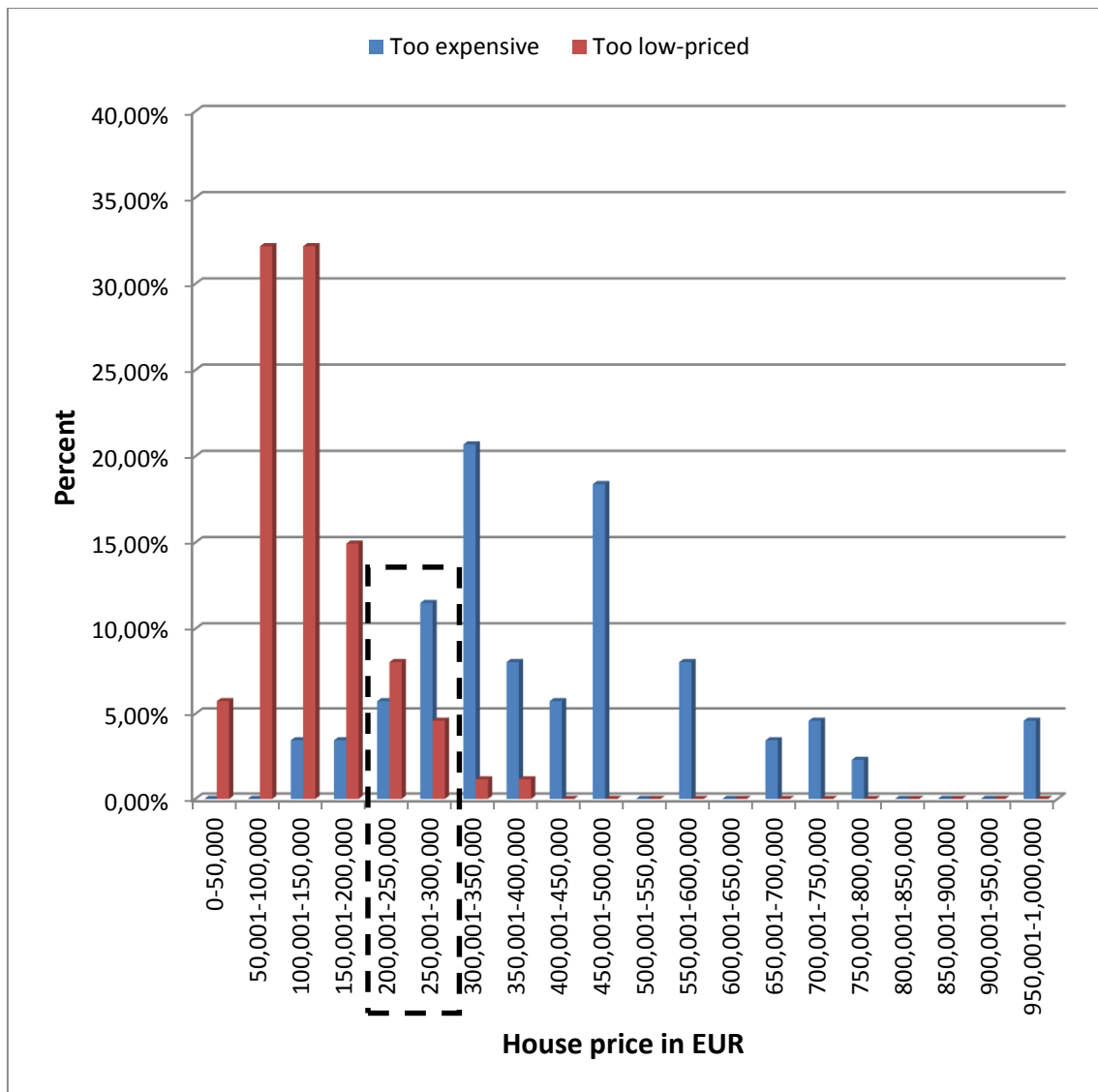


Figure 5.9: Acceptable price level of prefabricated house (source: author)

Following the analysis of the above findings, one conclusion with regard to these pricing questions is that it is certainly better to give the respondent an impression of the product. Otherwise, the product variety within the prefabricated house building sector makes it impossible to receive relevant pricing information. Hence, looking back, the quality of this particular information could have been increased considerably by showing the respondent photos of houses and then asking for a pricing on this basis.

In this example, the results of the variance and the standard deviation calculation show that there is no clear trend with regard to the price level of a prefabricated house. However, as mentioned above the price level between €200,001 and €300,000 seems to be the bandwidth between a price that is too high and one that is too low. However,

quite clearly the above can only be described as a cautious interpretation, and further research with the above mentioned changes to the question is necessary to make the appropriate results more reliable.

In the following, further questions from the questionnaire and the appropriate results are shown:

How often have you previously built a house?

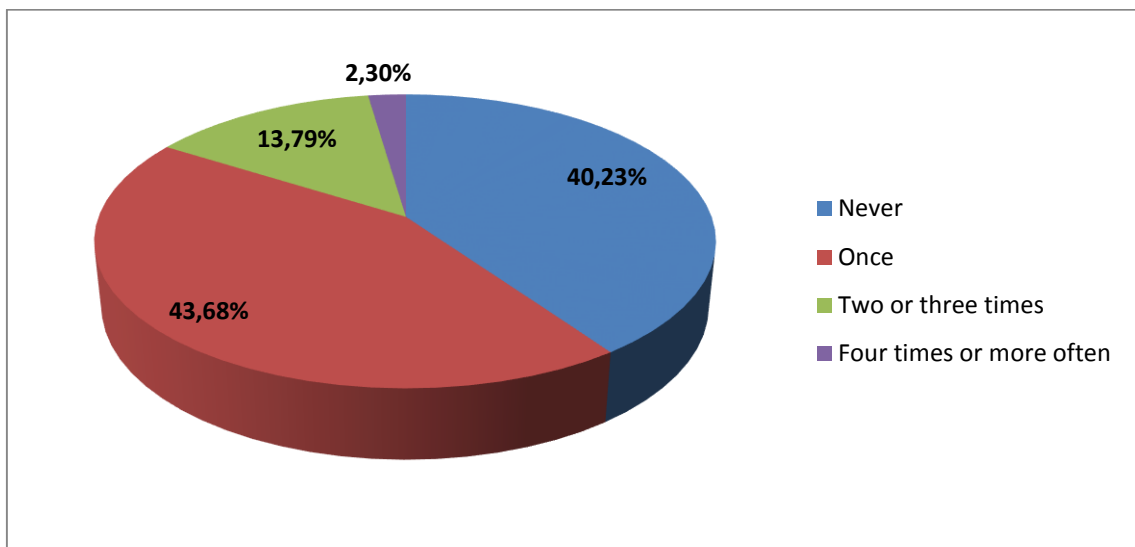


Figure 5.10: House building experience (source: author)

The majority of the respondents indicated that they have some building experience – nearly 60% have built a house before (see Figure 5.10). Therefore, some knowledge about the house building process in general can be assumed for this 60%.

How interested are you in general, from ‘not interested at all’ to ‘very interested’, to build a prefabricated house in the near future?

Here, the respondents were asked to rate their interest in building a house in the near future on a 9-point scale from ‘not interested at all’ to ‘very interested’. The result shows that almost 50% stated that they were not interested in building a prefabricated house in the near future. Only approximately 30% stated that they were interested in building a prefabricated house (see Figure 5.11). This information could be important data for the BDF to see how many potential customers visit the show house centre. If such a data

reveals that the majority of the visitors over a certain time span are people who have a house already and only want some inspiration for its interior design, the reasonability of such show house centres for the member companies of the BDF needs to be scrutinised.

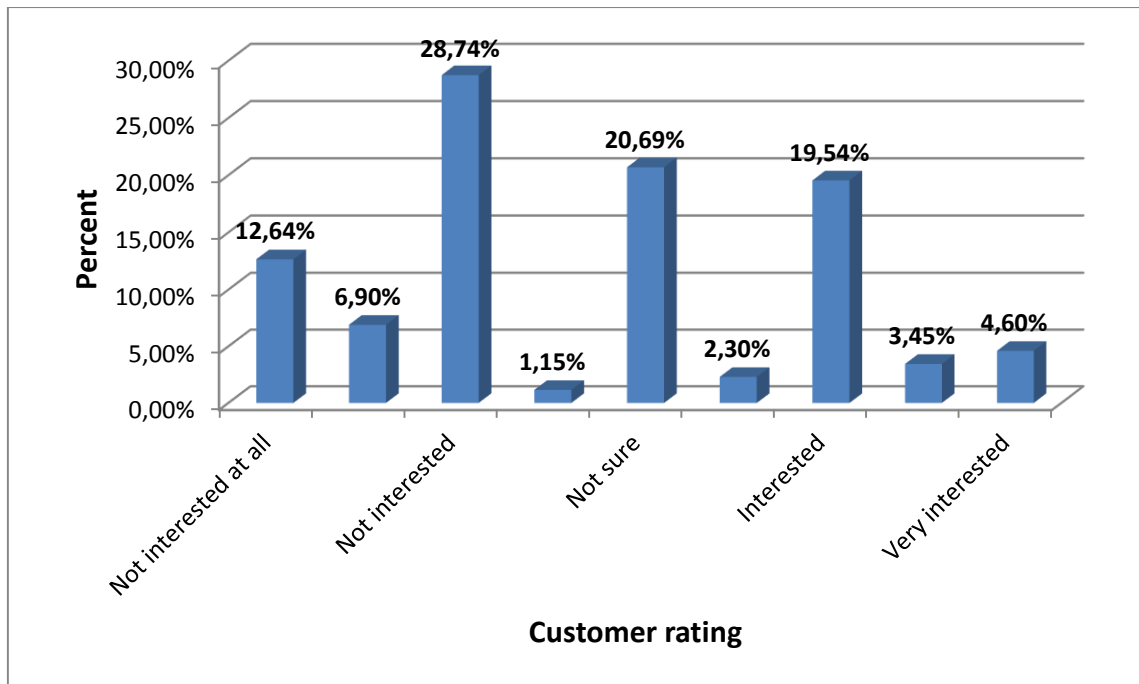


Figure 5.11: Interest in building a prefabricated house (source: author)

How good is your knowledge of prefabricated houses?

The aim of this question was to test whether there could be any biased responses due to an exceptional knowledge of prefabricated houses. However, as can be seen in Figure 5.12, nearly 50% of the respondents stated that their knowledge of prefabricated houses ranged from ‘not good but not bad either’ (not included) to ‘not good at all’. Nearly 20% indicated that their knowledge of prefabricated houses was ‘not good but not bad either’ and the rest stated that their knowledge ranged from ‘good’ to ‘very good’. Only 2.3% (two respondents) said that their knowledge of prefabricated houses was ‘very good’. Interestingly, one of these respondents also indicated that he was very keen to build a prefabricated house. Therefore, it can be assumed that this is a person who is in the process of collecting information about prefabricated houses in order to select the manufacturer that fulfils his requirements the most. The other respondent has no building experience and is not interested in building in the very near future. Hence, it

can be assumed that this person gained their knowledge another way, for example, via their job.

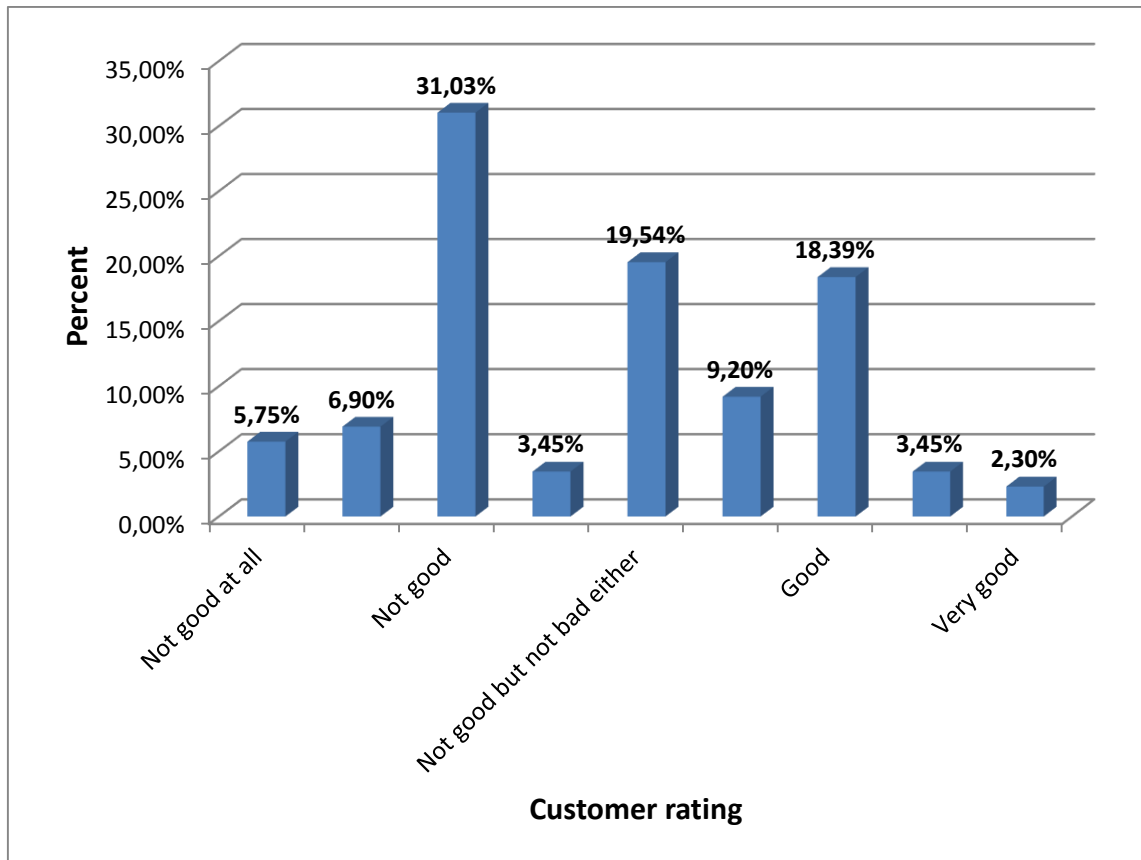


Figure 5.12: Knowledge about prefabricated houses (source: author)

Preference measurement

Before the preference measurement started with paired comparisons, general questions with regard to choice and the degree of choice in certain areas were asked. One of the first questions was therefore whether respondents think that it is important to have a certain degree of choice when configuring a house. Nearly 90% of the respondents thought that it is rather important or very important to have a certain degree of choice (see Figure 5.13).

However, this can only indicate that house buyers actually appreciate choice. But it is much more relevant for companies offering prefabricated houses to know exactly where choice is required and where options can be reduced.

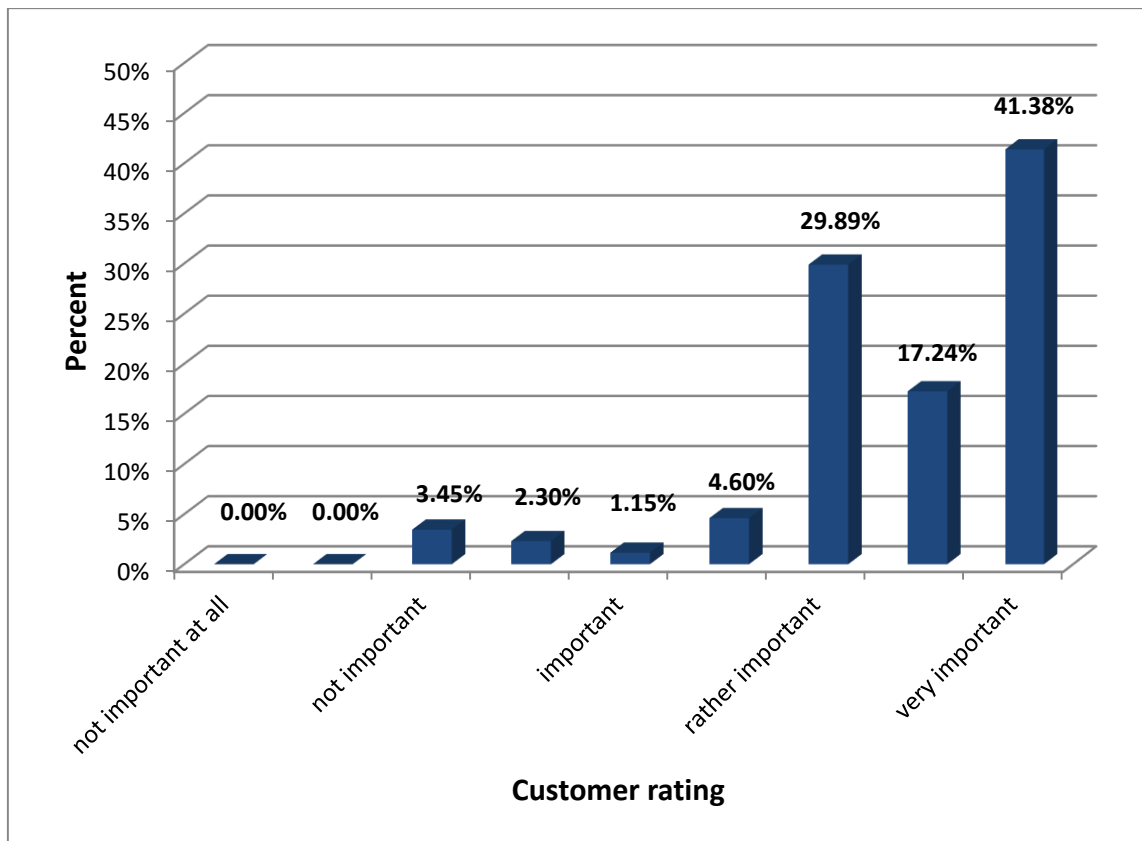


Figure 5.13: Importance of component choice when configuring a prefabricated house (source: author)

Classification value (x)	Frequency (f)	fx	x ²	fx ²
1	0	0	1.00	0.00
2	0	0	4.00	0.00
3	3	9	9.00	27.00
4	2	8	16.00	32.00
5	1	5	25.00	25.00
6	4	24	36.00	144.00
7	26	182	49.00	1274.00
8	15	120	64.00	960.00
9	36	324	81.00	2916.00
Sum	87	672	285.00	5378.00

Mean **7.724**
Variance **1.477**
s (stand dev) **1.215**

Table 5.7: Statistical analysis of importance of choice

As can be seen in Table 5.7, the mean of this data is set at 7.72 and the variance and the standard deviation is low meaning that the results are not dispersed but rather very close to the mean. Furthermore, the probability distribution of the result as depicted in Figure 5.14 reflects this finding graphically as it is strongly skewed towards the ‘very important’ category (i. e. classification 9).

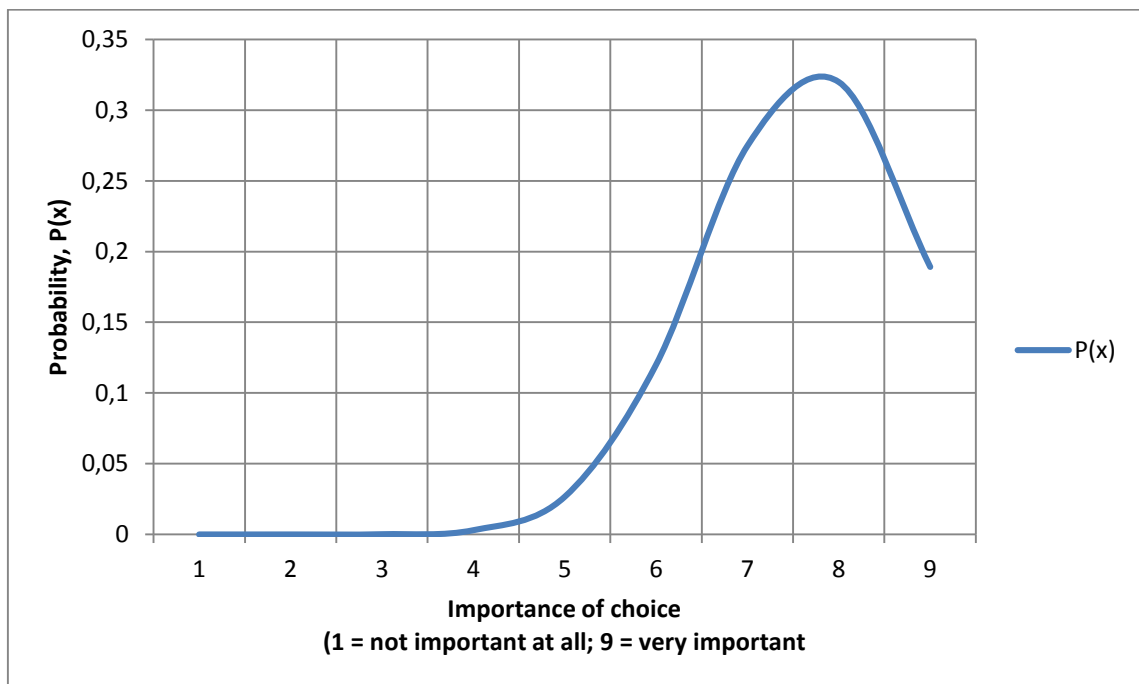


Figure 5.14: Probability distribution of importance of choice (source: author)

In the following it is investigated whether there is a level of association between the annual income and the importance of choice. From a logical point of view it can be assumed that the more people earn the higher their motivation is to customise. This is mainly because the funds are available to pay for a customised product. Therefore, as shown before, Cramer’s V is applied to show the strength of the association:

$$\text{Cramer's } V = \sqrt{\frac{101.87}{87(2-1)}} = 1 \quad \dots(5.11)$$

Here it is also necessary to compare the calculated chi-squared value (i. e. 101.87) with the critical value from the statistical table (i. e. 113.15). The critical value exceeds the calculated value which is why the hypothesis of independence at the 5% level can be rejected. Furthermore, by looking at Cramer’s V it can be concluded that there is the

strongest possible degree of association between the annual income and the importance of choice.

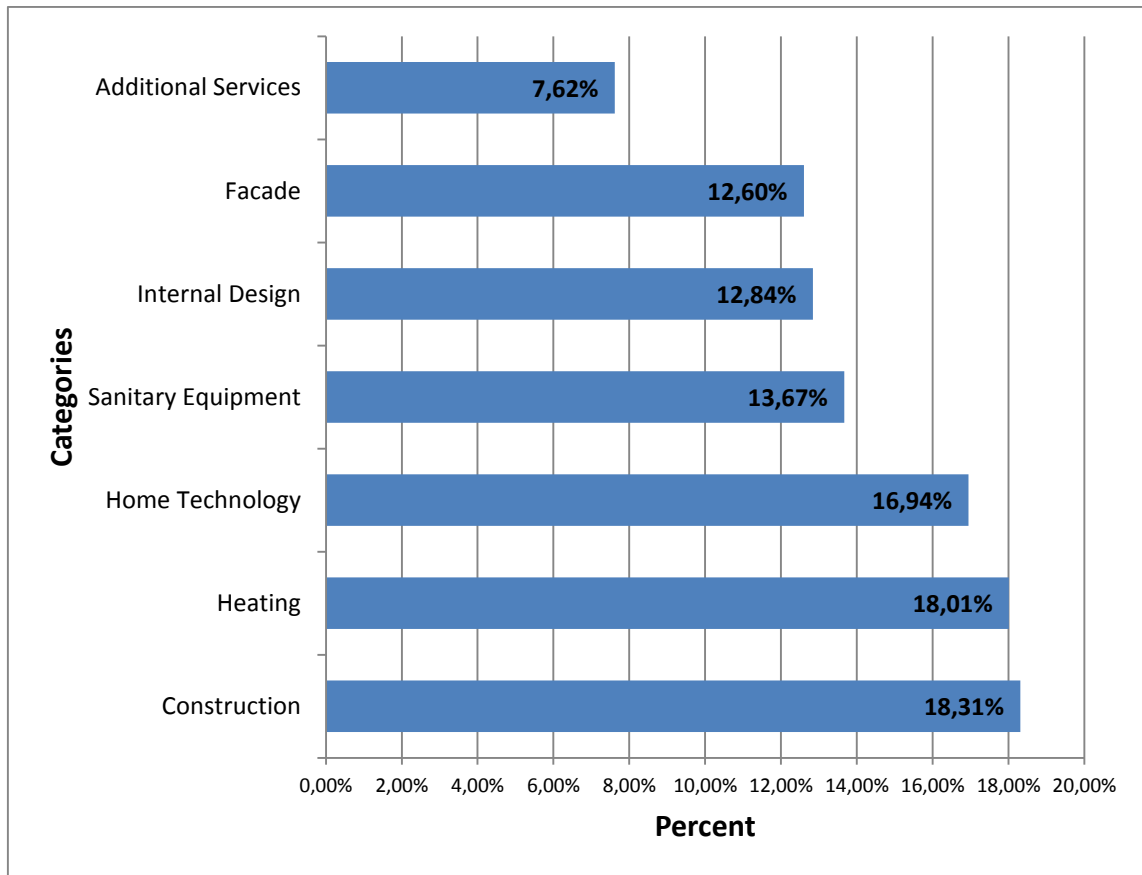


Figure 5.15: Importance of categories (source: author)

Respondents were then asked to rate the importance of the categories of a prefabricated house as identified in the case study. This is the first real pointer with regard to customer preferences in the prefabricated house building industry. As can be seen in Figure 5.15 the respondents indicated particular interest in the customisation of the following categories: construction (18.31%), heating (18.01%) and home technology (16.94%). In categories like internal design (12.84%) or facades (12.60%), the need to customise is rather low. Choice for additional services does not need to be offered by the market. Often, prefabricated houses have specific design traits that are common to all, and many of the components for this are within these categories. However, this does not mean that within these categories customers do not wish to have a high degree of choice for certain components. Hence it is important to consider all layers of the product

architecture in the preference measurement exercise. Only then can the option list be set up according to customer preferences and needs.

Category	Weighting	Component	Weighting
Facade	12.60%	Locks with normal or higher security	33.94%
		Design of main door	20.27%
		Manual or automatic window or door opener	18.58%
		Material of window and door handles	17.15%
		Material of main door handle	10.06%
Construction Design	18.31%	Change of footprint	49.28%
		Jamb wall	21.51%
		Design of roof	15.74%
		Balcony	13.47%
Internal Design	12.85%	Opening in ceiling	52.53%
		Design of ceiling	47.47%
Home Technology	16.94%	Electrical fit-out	25.08%
		Smoke detector	21.14%
		Photovoltaic	19.26%
		Alarm system	16.70%
		Home automation	12.02%
		Vacuum cleaner system	5.80%
Sanitary	13.67%	Shower	23.71%
		Bath tub	19.55%
		Washing stand	19.20%
		Taps and fittings	17.01%
		Toilet	14.95%
		Urinal	5.58%
Heating	18.01%	Heat distribution system	25.87%
		Hot water generator	22.79%
		Heat generator	19.82%
		Solar thermal	17.20%
		Ventilation system	14.32%
Additional Services	7.62%	Basement	31.83%
		Garage	20.27%
		Financing service	20.21%
		Carport	11.75%
		Landscaping services	9.61%
		Furniture	6.33%

Table 5.8: PCPM results on category and component level (source: author)

At the core of the preference measurement survey, however, were the paired comparison-based questions on a component level. The justification for choosing the PCPM method in this survey is given in the method chapter of this thesis. Thus, in the PCPM section of the questionnaire, the respondent indicated a preference of one element over another element. The two paired comparisons are shown on a 9-point bipolar equidistant rating scale. Depending on the number of components within one category, multiple paired comparisons were on one page.

Table 5.8 provides a summary of the PCPM scores. In the third column, the categories have been decomposed into components and the fourth column shows the appropriate results of the preference measurement.

Focussing on the construction design category, it can be seen that customers prefer flexibility in the design of the footprint of the house over the other attributes. It needs to be adaptable to the appropriate family situation and/or life style of the house buyer. Related to this is the design and construction of the ceiling. An opening in the ceiling, for example, influences the overall footprint of the building and this seems to be highly relevant for respondents.

In general, concentrating on the category level alone does not give sufficient information about customer preferences. It is important to consider all layers of the product architecture in the preference measurement exercise. Only then can the option list be set up according to customer preferences and needs.

Case company specific data analysis

This section provides an analysis of the customer preference measurement findings specific to the target group of the case company. As mentioned earlier, discussions with the case company managers determined that their market segmentation analyses identifies mostly of people over 50 years old, and couples as target group. It has to be mentioned, though, that there does not exist a written profile of the target group. Demographics and size of household have been sampled from the respondents. Hence it is possible to extract the data sets which are most relevant to the case company.

However, due to the size of the sample, data reliability and the potential to generalise on the basis of the appropriate results is even further sacrificed. Here, the importance of a target market oriented sample constitution needs to be highlighted once again. The statistical analysis of the complete data set has been given above where suitable. Therefore, in the following the analysis is limited to the presentation of the findings.

No	ID	Age	Size of household
1	18	older than 61	2
2	32	51-60	3
3	33	51-60	2
4	44	older than 61	2
5	45	older than 61	2
6	48	older than 61	2
7	51	51-60	2
8	52	51-60	2
9	59	51-60	2
10	62	older than 61	2
11	64	51-60	1
12	71	older than 61	2
13	73	older than 61	2
14	78	51-60	2
15	79	51-60	2
16	81	older than 61	2
17	90	older than 61	2
18	93	older than 61	2
19	95	51-60	2
20	96	older than 61	3
21	98	51-60	2
22	100	51-60	2
23	103	older than 61	3
24	110	older than 61	2
25	115	51-60	2
26	117	51-60	2
27	122	51-60	2
28	127	older than 61	2
29	129	older than 61	2
30	130	older than 61	2
31	134	51-60	2
32	137	51-60	2
33	138	51-60	3

Table 5.9: Target group specific data analysis (source: author)

Table 5.9 shows the relevant data sets. The first column is a consecutive number that shows that 33 data sets fulfilled the demographic criterion given by the case company's management. An individual identification number (ID) was assigned to each respondent once the online questionnaire was completed. This ID is shown in the second column and facilitates the analysis of the appropriate data sets. The third column gives the demographics and the third column shows the second main characteristic of the case company's target group, which is the size of the household. As one can see there is only one data set that does not conform to the target group profile. This is highlighted in yellow. This data set must be removed before further analysis can be conducted.

Therefore, 32 data sets are included in the analysis of the customisation preferences for the case company's specific target group. The majority (i. e. approximately 78%) of the 32 respondents are male.

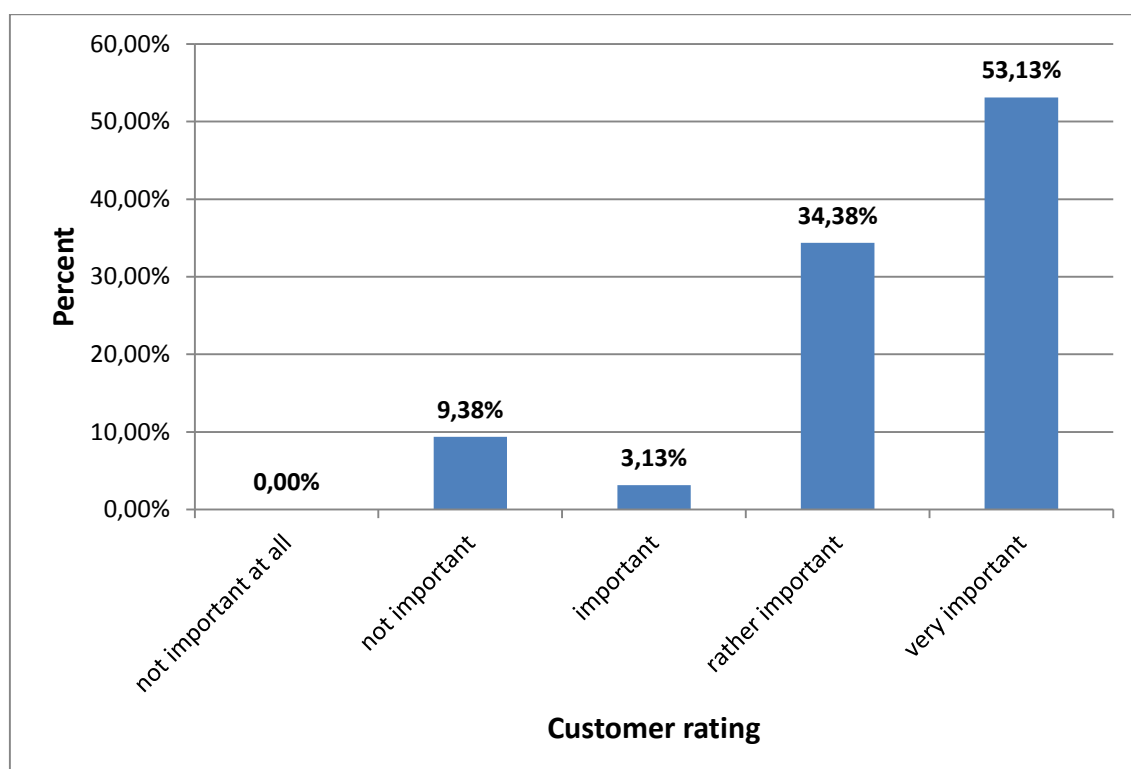


Figure 5.16: Importance of choice in general for case company target group (source: author)

Furthermore, over 50% of the 32 respondents identified above stated that when configuring a prefabricated house, choice in general was very important (see Figure 5.16). Only approximately 10% indicated that choice was not important. This is a clear indicator for the company that choice in general is appreciated by customers. However, as discussed above, this general statement does not help the company much. What is required is a detailed overview of where exactly choice is required. If this is not known and the business decides to offer a high degree of choice in all categories and for all components and sub-components, it can result in information overload for the customers and they will consequently be dissatisfied.

An analysis of the original data set and the target group specific data set revealed that there are no big differences between the results of the total sample and those of the target group sample. Figure 5.17 presents the comparison of the total sample and the target group sample findings. As mentioned before, the possibility to change the footprint is an option where choice is much appreciated by both samples. However, choice for the material of balcony, ventilation system, home automation and vacuum cleaner are not very high in demand. Hence, one conclusion that comes out of this comparison is that the company's target group confirms the findings of the total sample and that the aforementioned options need to be revised so that unnecessary customisation effort can be avoided. In doing this, the company not only improves the processes but it also reduces the variety offered to customers, thus increasing customer satisfaction.

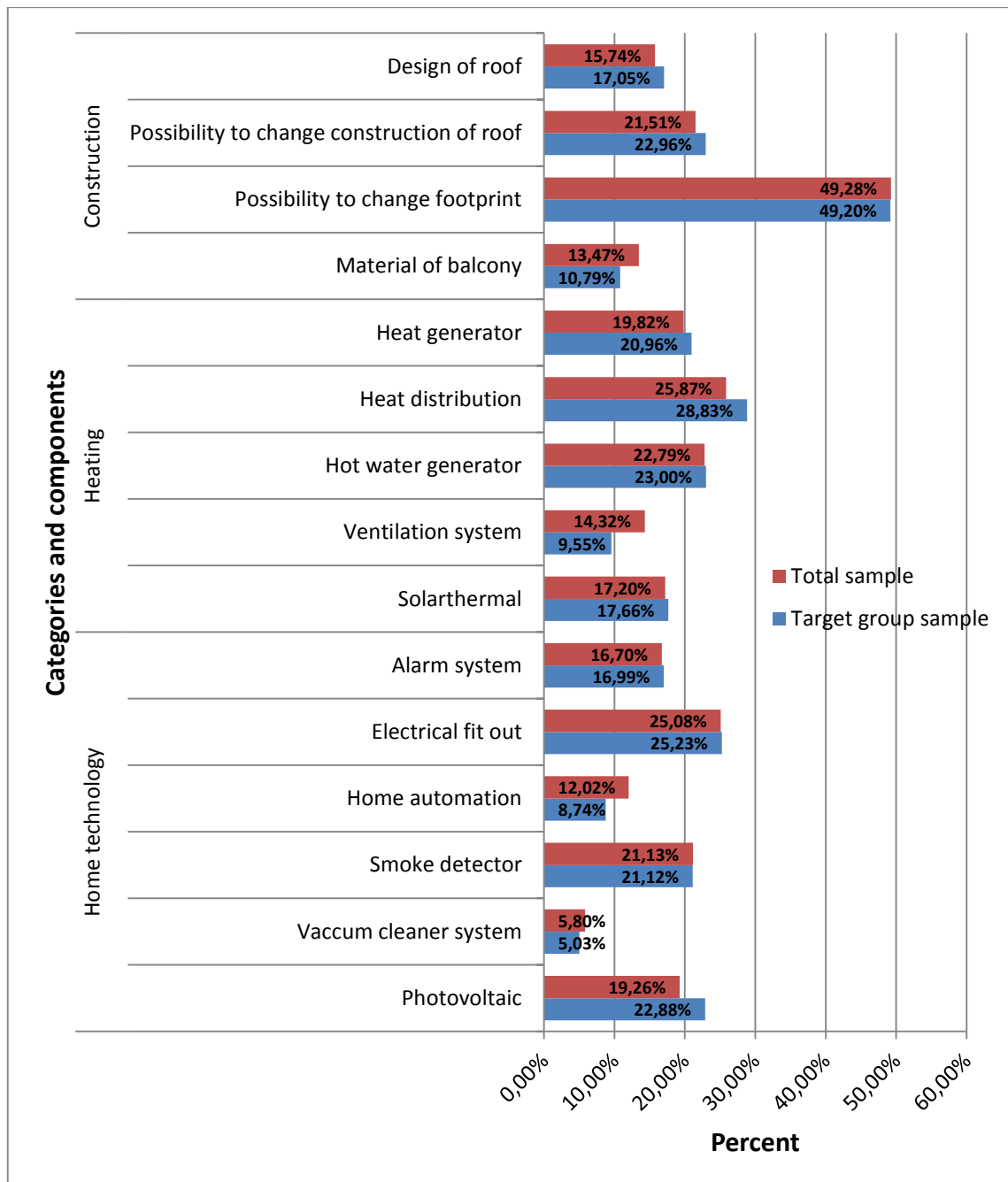


Figure 5.17: PCPM scores on component level – total and target group sample compared (source: author)

5.4. Discussion of findings and statement of contribution

The findings of the survey are multifaceted and extensive information about the structure of the sample is given. This is important, as companies wishing to follow the process outlined above need to constitute a sample that conforms to the target market profile. Usually this is determined by the marketing department which is why the latter needs to be consulted before a survey is conducted.

Although the survey focuses on a preference measurement in the prefabricated house building sector, additional data was captured that enables a more detailed analysis of the data set. Hence, where suitable, statistical analysis of the findings is given and correlations are tested. In this regard, it was found that there is a strong level of association between the demographics of the survey data and the size of the household. Furthermore, a strong correlation could also be found between the demographics and the level of income and finally the strongest degree of association was found between the annual income and the importance of choice. The latter seems to be highly interesting and offers the opportunity to transfer this finding from the survey to a theory that was proposed over 70 years ago by psychologist Abraham Maslow. The theory is called the Maslow's hierarchy of needs and is often presented as a pyramid. Essentially, it places the most fundamental levels of human needs at the bottom and the need for self-actualisation at the top (Jobber, 2004). Maslow suggested that the most basic needs must be fulfilled before a person will strongly desire the next higher level need. Figure 5.18 below shows the results from these needs in relation with the desire to customise products or in this particular case, a house. It is assumed that with an increasing level of income a person will reach a higher level of need. The results show that there is a level of association between income and the desire to customise. Hence, the hierarchy has been combined with the house building specific customisation categorisation model presented by Barlow et al. in 2003. It is therefore suggested that whilst climbing up the hierarchy of needs, enabled by a rising level of income, there will also be an increased desire to customise.

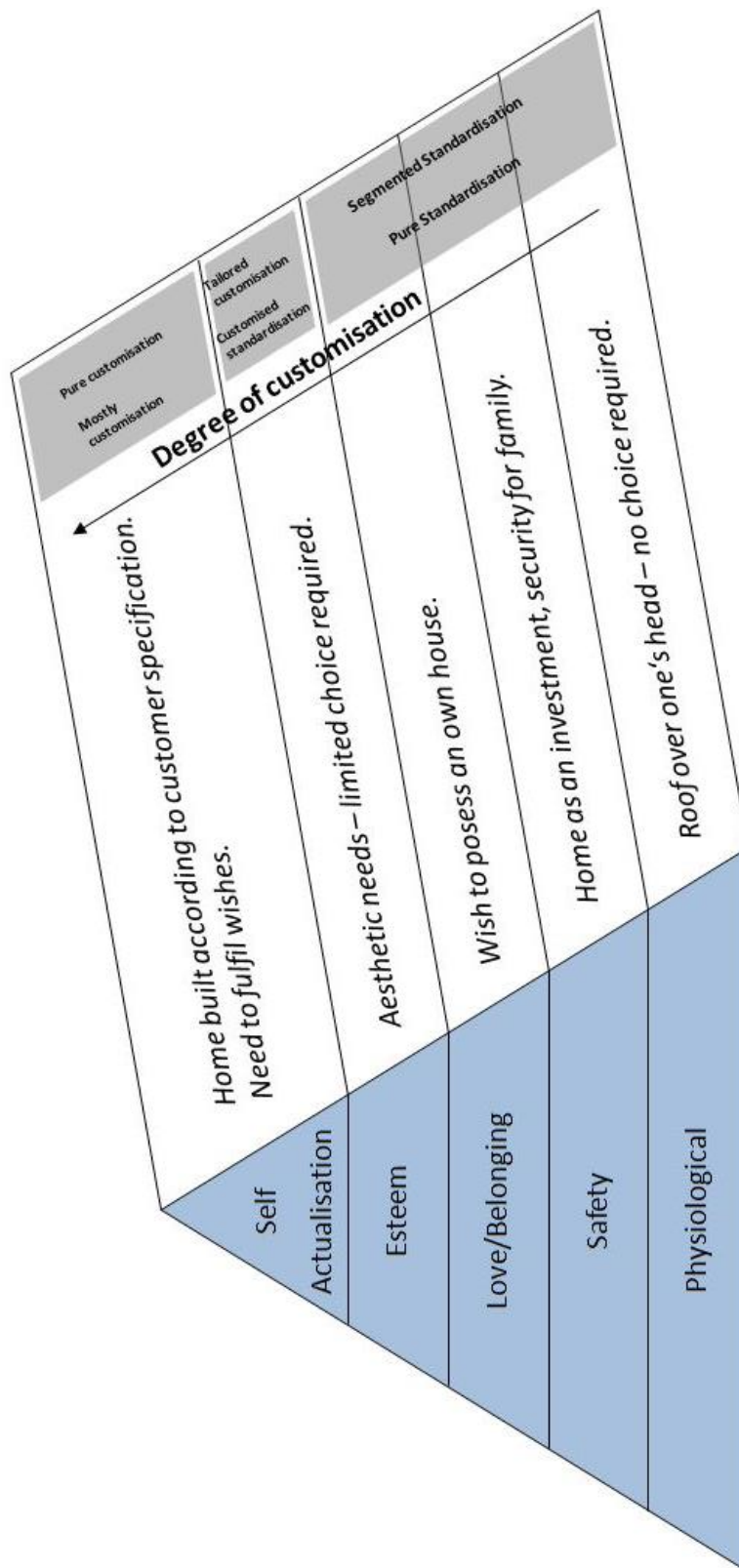


Figure 5.18: Maslow's hierarchy of needs combined with house building specific degree of customisation (source: author)

It is also noticeable that the majority of the respondents came from Western Germany thus introducing a potential regional bias into the sample. This is one of the disadvantages of a snowball-sampling method: there is no control over the selection process of the sample.

Furthermore, it is apparent that the majority of the sample is male. It can be hypothesised that although the questionnaire was forwarded to a random sample of available email-addresses, the topic as such is rather a male topic. Thus the questionnaire, although it was also sent to a female, could have been forwarded by that female to a male (i. e. husband, partner or friend). Again, it is a disadvantage of an online survey in general that one cannot be certain by whom the questionnaire is completed.

This study confirms that retrieving personal financial information is highly sensitive. More than 20% of the respondents refused to give any information. Furthermore one cannot be certain whether the other respondents actually made accurate indications with regard to the annual income. Hence, one needs to be careful with any analysis that relies on personal financial information.

The market specific data analysis generated interesting aspects with regard to the impression the prefabricated house building industry gives to the participants of this study. The most prominent advantages of building a prefabricated house are:

- Shorter building process,
- one-stop-shop-solution, and
- the customer is not integrated in the building process.

The fixed budget aspect of a prefabricated house also seems to be an important advantage. It is noticeable from the results that the quality aspect does not seem to be associated with a prefabricated house. On the contrary, only 5.57% of the respondents stated that quality is an advantage of the prefabricated house. In fact, however, with regard to quality, prefabricated houses are better than houses that are built with brick and mortar. The BDF applies strict quality monitoring to all member companies which

results in the houses delivering exceptionally good insulation values. This is mainly due to the good air tightness (Owen, 2007).

The results of the questionnaire also gave some information about acceptable price levels for prefabricated houses. However, it has previously been discussed that the information retrieved is too vague. Similar studies need to specify what is meant by a prefabricated house as the variety, also with regard to pricing, is just too high.

The PCPM results presented in Table 5.7 already gives some guidance for prefabricated house builders on where to focus customisation efforts at a component level. However, not all prefabricated house builders offer a one-stop-shop-solution to their customers. This means that not all the categories highlighted as being important to potential house buyers are relevant. However, even if the components and subcomponents contained in an important category are not offered to customers, it may be a sensible decision to at least offer support and consultation in these areas.

It is important to point out though that the results not only show where choice needs to be offered but that they also show which attributes and categories can be neglected. This is probably more important than knowing what needs to be offered as every option that needs to be offered reduces variety and complexity. Features like a central vacuum cleaner, photovoltaic system or furniture can be identified as not being high in demand.

The survey presented above contributes by applying a preference measurement method for multi-attribute products (i. e. PCPM) in order to prioritise and identify what buyers of prefabricated homes really focus on when configuring a house. This is important as only knowledge of the preferences will enable practitioners to be effective in customisation efforts and ensuring operational efficiency accordingly.

5.5. Conclusion

There are two main outcomes of the preference measurement. First of all, a procedure has been developed that prioritises categories and components in a prefabricated house design. This procedure can be adopted by building companies that would like to offer

customised houses. Second of all, the results of an online survey have been presented which can help prefabricated house building companies to make the right decisions about the level of variety they offer. Furthermore, the importance of market segmentation before conducting a preference measurement has been highlighted and it has also been mentioned that a survey in general offers a unique opportunity to gather additional data from the target group. However, one needs to be careful with this additional data gathering as too many questions will overburden the respondent.

The results of the online survey clearly show that attributes associated with flexibility and security have a significantly higher impact on the overall product preference compared to others. However, one has to be careful with the interpretation of the results as these can be biased by current trends influencing respondents. Furthermore, due to the multi-layer product architecture and the many different alternatives, the possible preference orders can be very long and therefore respondents have to make a lot of difficult decisions.

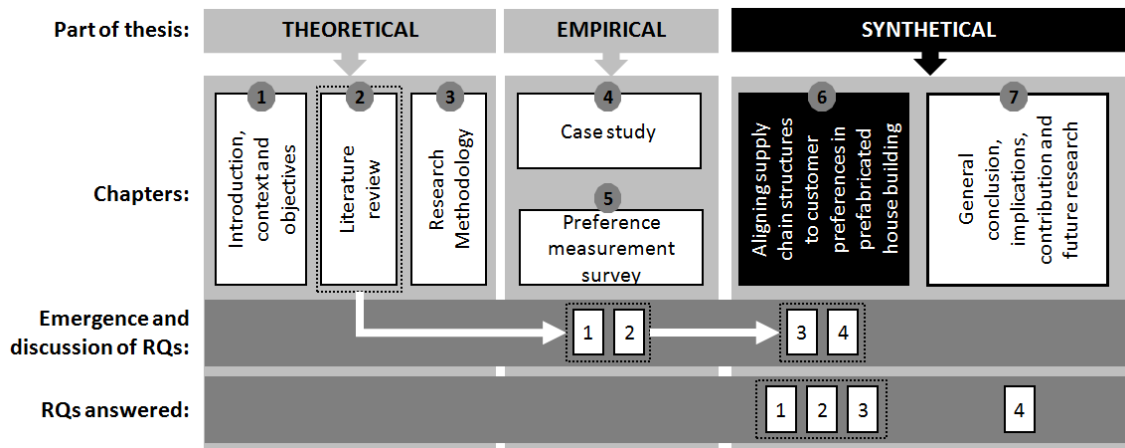
Differences between the results of the case study and the survey indicate that although customers have other interests and preferences, customisation in certain areas is considerable when customers configure their house. A reason for this could be that they only take up options because these are made available. If this can be confirmed, there would be considerable potential for house builders to reduce variety and hence costs in order to align options offered with potential buyers' preferences.

There are some limitations to this research. Firstly, the survey was conducted in Germany, thus there may be cultural differences influencing preferences and requirements when building a house. Secondly, an online survey excludes all nonusers of the internet. The latter could have different preferences when it comes to technological issues. Hence, any conclusions drawn from the above mentioned results cannot rely exclusively on the internet sample. Thirdly, house building companies need to decide who their target customer is and any sample needs to be constituted on this basis, rather than the random sample used above.

The following chapter is concerned with merging the above findings. Furthermore the findings are linked to the existing literature so as to highlight why the above analysis is important after all.

Chapter 6

“Houses, I have come to believe, like love, like nature herself, should not reassure, should not attempt to soothe, or give comfort, but should, rather, excite.” (Patrick McGrath)



6. Aligning product and processes with customer preferences in prefabricated house building

In chapters 4 and 5, the findings of the case study and the survey have been presented. This chapter is concerned with merging these findings which enables the analysis of mismatches between choices offered and customer requirements as identified by the preference measurement. The key contribution of this chapter is the presentation of a framework that is transferable to general application in the area of mass customisation.

6.1. Introduction

Kincane (2007) states that a successful application of a mass customisation strategy requires cross-functional integration and concurrency of product development, production and distribution activities. As mass customised products are driven by customer preferences, an ignorance of these requirements at the lowest level of a product’s architecture will have a negative influence on the company’s performance. In contrast, fully aligning product, process and supply chain will result in a competitive advantage or at least better operational performance (Fisher, 1997; Pero et al., 2010). Hence, it is important to do this as only then can the business strategy be

operationalised and supported effectively. However, few studies have measured and analysed customer preferences in the house building industry in order to create a basis for the industry's customisation efforts.

Having contextualised the research in the general body of knowledge, in particular identifying the research gaps resulting in the research questions as stated before, chapter 4 enabled the development of a house as a system of components. A detailed analysis of house building projects determined the customisability of each item. Chapter 5 presented the findings of an online preference measurement, using a modified AHP approach, structured around the product architecture that was determined in the case study.

The primary research objective of this thesis is to develop a framework for aligning a house building company's product architecture with what customers really want in terms of choice. Hence, by connecting the case study results with the results of the preference measurement it can be determined whether the company's offering is in alignment with the requirements of the customers. This also addresses the gaps in the literature as identified in chapter 2.8.

6.2. Dynamic product architecture and customer needs alignment model

The matrix shown in Figure 6.1 has been adapted from Barlow et al. (2003) and shows two dimensions. The y-axis differentiates between pure standardisation, segmented standardisation, customised standardisation, tailored customisation and pure customisation with the positioning of the categories derived from the case study. The x-axis categorises the survey results as high, medium and low choice. The thresholds have been identified using the class interval calculation which is suitable for grouping data into categories (Silver, 1997). The first step when calculating the class interval is to determine how many categories are needed, in this case three. Equation 1 is applied to the data set, which in this case, consists of the results of the preference measurement on a component level:

$$\text{Class Interval} = \frac{\text{Highest Value} - \text{Lowest Value}}{\text{Number of Categories Required}} \quad \dots(6.1)$$

which yields

$$\text{Class Interval} = \frac{90.00 - 0.80\%}{3} = 29.73\% \quad \dots(6.2)$$

As class intervals should always be integers, the value is rounded to the nearest whole number which in this case is 30%. Hence the interval between the categories of high, medium and low is 30%.

As an example, and in order to keep the diagram as clear as possible, only the category with the highest level of customisation interest has been decomposed, namely 'construction design' consisting of 'change of footprint', 'jamb wall', 'design of roof' and 'balcony' (see Figure 6.1). The percentage figures are the scores determined by the PCPM. All other categories and components are shown in Appendix 5. The appropriate percentage reflecting the particular customisation interest of respondents can be seen above the category and components. The components mapped are also for the 'construction design' category. This shows very clearly that although the category was assigned to 'tailored customisation', the components need to be allocated differently. The theoretical reasoning for this has been provided in chapter 2.5.4. where the importance of the recognition of multiple CODPs is highlighted.

As can be seen, the category, and three components (i. e. change of footprints, jamb wall and balcony) are outside the unshaded area which signifies an 'area of best fit'. This means that for this example the choice required by potential buyers is not in alignment with the offering. In general, it can be stated that if buyers require a high degree of customisation then this may be offered by a 'pure customisation' approach, while those that are happy to have low customisation may be satisfied from a 'pure standardisation' approach. Categories/components that are positioned in the darker shaded area are of concern for the house builder; customers only require low choice according to the

preference measurement but nevertheless, the company makes a relatively high degree of customisation effort indicating time, effort, resources and, therefore, costs. Typically costs in customisation systems occur both in sales and customer interaction as well as in manufacturing (Piller et al., 2004). In the latter case costs increase because of an increased complexity in production planning and control as well as an over-capacity of inventory of components (Zipkin, 2001). Hence, in order to counter-balance these costs it is important that the interaction with the customer is increased in order to identify the customer' preferences bring these in alignment with the company's offerings.

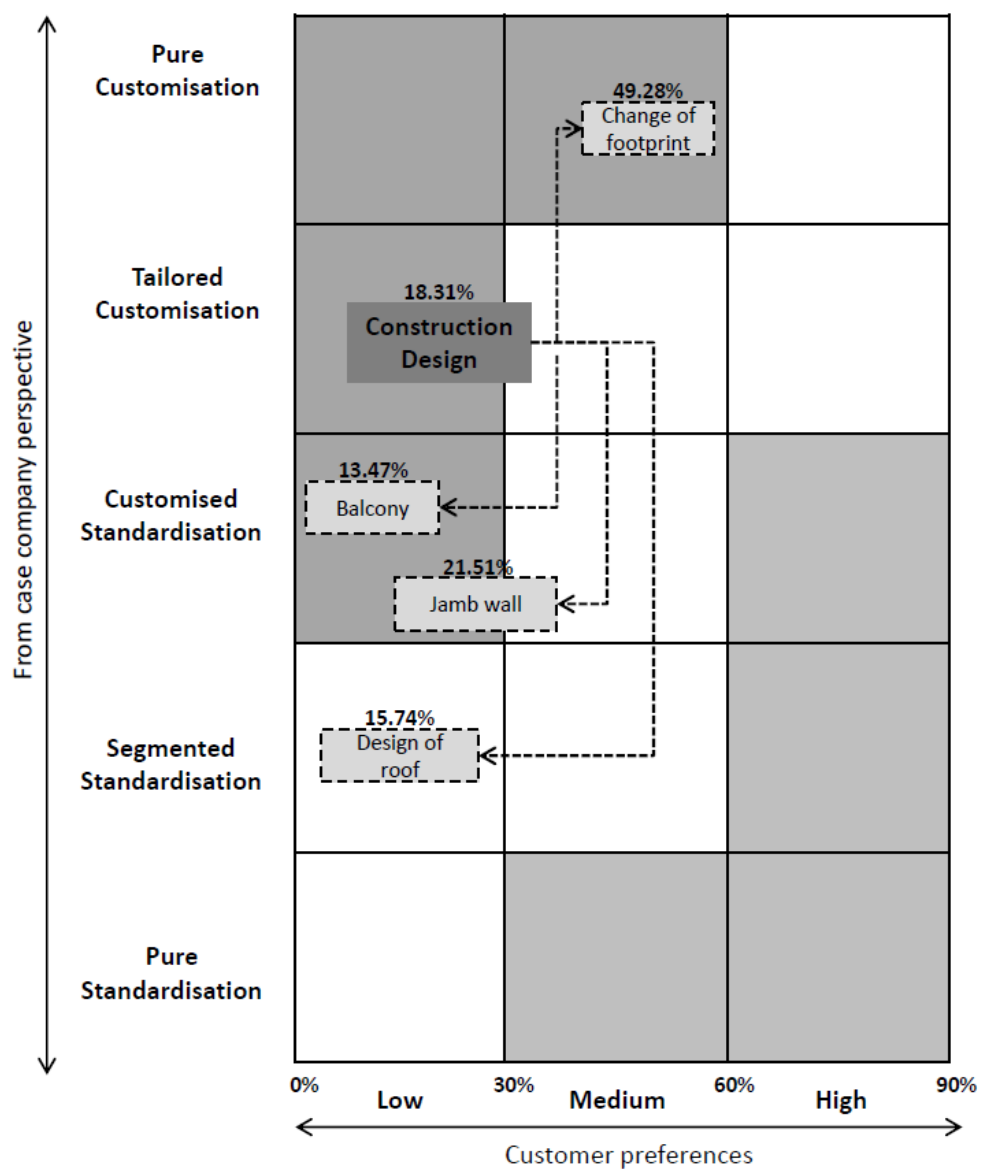


Figure 6.1: As-is-model (source: author)

The categories/components in the lighter shaded area require some investigation by the house builder. If customers require customisation, the company may be able to offer choice through a range of standardised offerings, that is, providing a range of components from which customers may make choices. While in a high volume production environment this often means short lead-times and off-the-shelf service provision, as the categories/components in this case are part of a more complex and longer lead-time product, namely the house, these may not be critical considerations for the house builder. Nevertheless, the house builder should make a strategic decision about which elements need to be bespoke and which can be part of a range of standardised options. More recently we have seen that the production of bespoke components or sub-assemblies has been supported by the use of modelling tools which facilitates the fabrication through computer controlled machinery (Bechthold 2013). Moreover, it could be worthwhile to sub-contract the production of highly customised components or sub-assemblies to suppliers which enables the company to concentrate on the production of the more standardised parts thus increasing the exploitation of the economies of scale effect.

The procedure, as described above, shows whether the options offered match the needs of the targeted market segment. It is thus an analysis of the situation as it currently is. A mismatch indicates that change in the product or process development is required with a potential impact on the process design.

Area of alignment

As mentioned above, companies must aim for alignment of the choice required by potential buyers and the offerings. In Figure 6.1, a model shows the degree of alignment for the customer preference measurement score of one particular component. Furthermore, the customisation strategy used by the company for the production of this component is shown. A range (i. e. white squares in Figure 6.1) is proposed for the customisation strategies so as to offer some flexibility with regard to the positioning. Mapping products or components in this model enables the company to determine for which component there is a need of adapting the customisation strategy. However, depending on the product complexity and the number of components that are mapped

in the model, it can be difficult to see where there is immediate need for action. Hence, there is a need to be able to prioritise the need for action. Therefore, mapping components in a matrix as shown in Figure 6.2 helps in making these decisions and thus gives guidance on how the situation should be. As pointed out above, the dark shaded area gives more reason for concern and, hence, the customisation strategy for components that end up in this area needs to be examined as soon as possible. Furthermore, a repositioning and adaptation of the customisation strategy is suggested so that alignment is achieved.

Figure 6.2 shows that if customers indicate a medium degree of preference then there are three customisation strategies that can be adopted by the company: tailored customisation, customised standardisation and segmented standardisation. If the preference measurement score is low there are two customisation strategies that can be adopted: segmented standardisation and pure standardisation. When the preference measurement yields a high score then the customisation strategy needs to be either tailored customisation or pure customisation. According to the appropriate properties of the aforementioned strategies the company then must decide where the particular component will be positioned in the future. The customisation strategies considered in Figures 6.1 and 6.2 have previously been applied to the prefabricated house building sector (e.g. Barlow et al. 2003). Hence, this classification can act as a guidance for any alignment effort and companies need to locate the appropriate strategy depending on the following factors (Barlow et al., 2003):

- product demand
- product cost
- product complexity

It is important to realise that the functional nature of many companies on an operational level often acts as a barrier to aligning the products and processes effectively with the markets they serve (Godsell, 2006). Therefore, an appropriate strategy needs to be adopted that meets the needs of the market segment which the company identified to be suitable.

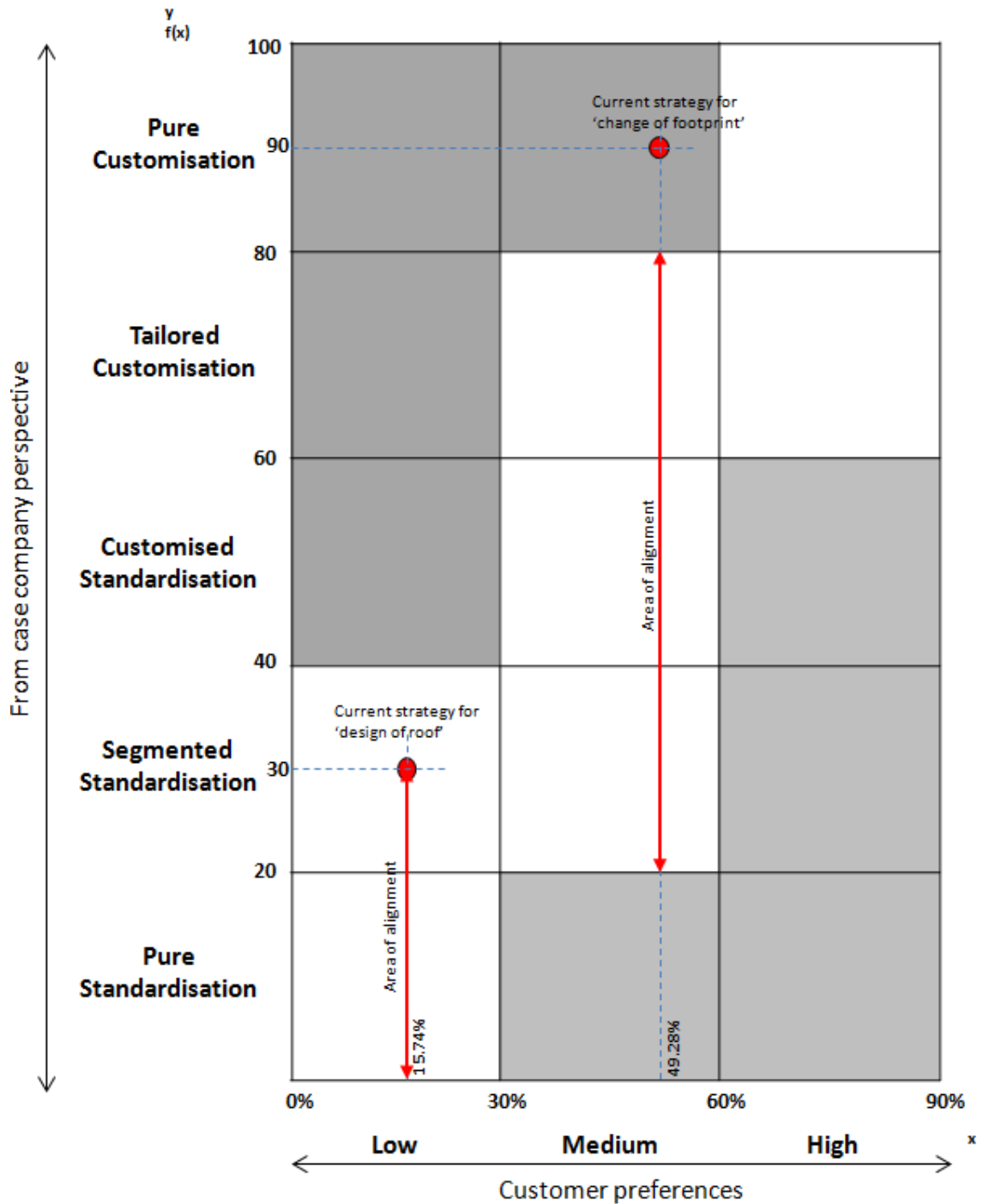


Figure 6.2: As-should-be-model (source: author)

It needs to be pointed out that in this example there is only one customer preference measurement result as only one preference measurement has been conducted. However, as mentioned earlier customer needs and market trends will change over time. Therefore, the positioning of the components based on a customer preference measurement should be a continuous task that ideally should be completed by a team

consisting of researchers and company representatives from the marketing and operations management department.

6.3. Presentation of product, processes and customer preferences alignment framework

This empirical work provides a framework that can be adopted by other practitioners who manufacture multi-attribute products and want to pursue a mass customisation strategy. In the first stage of the research, substantive product architecture was established. This formed the basis for the preference measurement task which was conducted using an 'ad hoc' online survey. An important outcome of the survey was to identify how customers actually prioritise categories and components in a prefabricated housing design. Combining the results of these two exercises helps in making the correct decisions about the level of choice to offer, whether via variety or customisation.

This framework is potentially transferable to general application in operations management. Using the five generic customisation strategies developed by Lampel and Mintzberg (1996), this research suggests an approach that enables an allocation of categories, components or sub-components into these strategies thus giving recommendations on the degree of alignment with customer requirements. Figure 6.3 is a visualisation of a managerial framework that reviews the gap between customer preferences and the degree of choice offered. Note that there can be three results of the gap analysis. Firstly, if the product does not conform to the customer requirements then the product needs to be redesigned. It is well established in the literature that customer expectations and demands can be regarded as the driver to effectively select and form the functional requirements for product redesign (Shieh et al., 2008). This means that a product's redesign is a direct response to customer needs. In this regard, it is important that the customer preference measurement is conducted in the appropriate target market. However, there is also a second level that drives product redesign: introduction of new technologies, new processes and a fundamental change in the product architecture (Otto and Wood, 1998). With regard to the case company a specific example for this is the optimisation of the building shell. This was necessary due to new regulations that required a better U-Value (measure of heat loss). This

improvement had a direct effect on the product architecture as new materials were introduced. Secondly, if the gap analysis results in a misfit between the customisation strategy applied and the requirements as determined in the preference measurement, processes need to be reconfigured. As highlighted in chapter 2.5 of this thesis companies can react to this by adapting for example their manufacturing processes so that these can respond quickly to differing customer needs (Towill, 2001). A good example for this is given in Barlow et al. (2003) where one particular Japanese house builder is presented. They follow a 'customised standardisation' approach to prefabricated house building which means that standardised components and subassemblies are used to configure the house on-site according to customer requirements. This reconfiguration of the processes was conducted to meet customer requirements more efficiently. According to the 3-DCE concept as proposed by Fine (2000), this shuffles the set-up of all capabilities and, hence, there is a need to concurrently redesign product, manufacturing process and supply chain. Thirdly, there is also the possibility of market repositioning if the product as such cannot be changed but does not fit to customer requirements. A new preference measurement needs to be conducted in a different market segment in order to find out whether there is sales potential elsewhere. Again the literature recognises this as a valid method if the target group does not appreciate the product (Jobber, 2004). However, this result is the most critical one as it can involve far-reaching organisational change and, thus, has a direct influence on the business strategy (Kotler and Kotler, 2000). With regard to the case company a good example for market repositioning is the launch of a new house type in 2012. This house type offers a more modular approach to the design of the layout and it also involves a less complex architecture which is why it can be offered at a lower price. According to the management one aim of launching this new house type was to increase the target market.

Due to many external factors, influences and constraints on both the product architecture as well as customer preferences, the process in this framework needs to be repeated on a regular basis. In particular customer preferences can change and with this customisation requirements can be different as well. Furthermore, considering a complex product such as a prefabricated house, there are also regulations that will have

an influence on the overall product architecture. Obviously it is necessary to monitor these changes and assess the influence on the operations and option list. Only this ensures that there is constant alignment between the customisation strategy and the customisation requirements. As a consequence, according to Piller (2013) combining product, process and customer preferences in a meaningful and integrated way will result in competitive advantage.

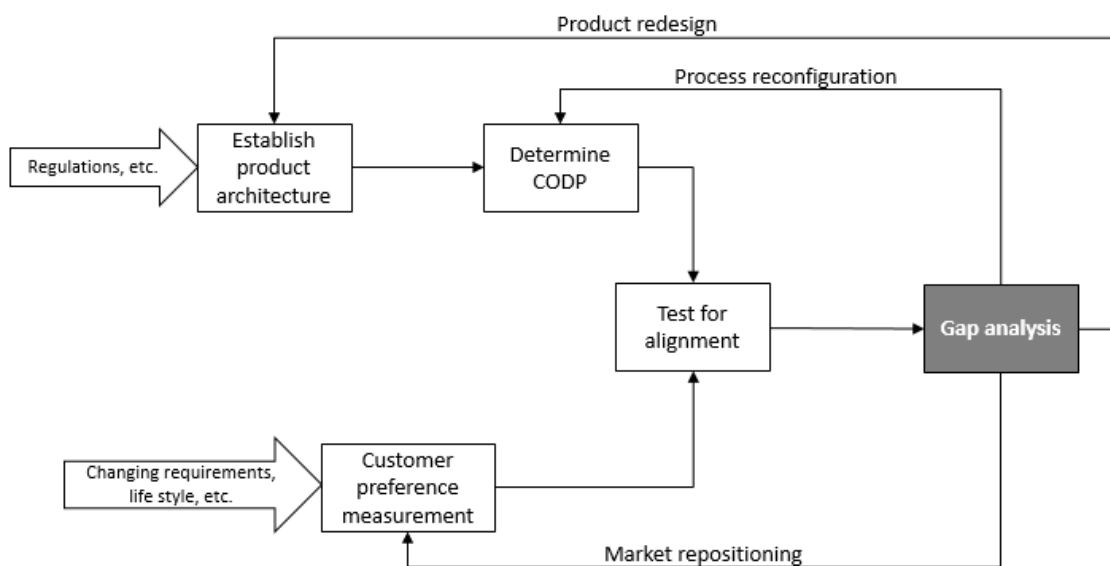


Figure 6.3: Product, processes and customer preferences alignment framework (source: author)

The framework as depicted in Figure 6.3 can also be linked to the value process by Payne and Holt (2001) as presented in chapter 2.7. The value process is a more general concept aimed to deliver products to the customer that are actually valued by the latter. Figure 6.4 shows an adaptation of the value process. Each of the four value activities can be connected to activities in the product, process and customer preferences alignment framework as shown in Figure 6.3. In the latter the value determination is achieved by completing the customer preference measurement. As pointed out by Payne and Holt (2001) this activity needs to be completed in order to identify what is driving customers when “trading off the benefits and sacrifices, both when they are purchasing and when they are using or consuming products” (p. 174).

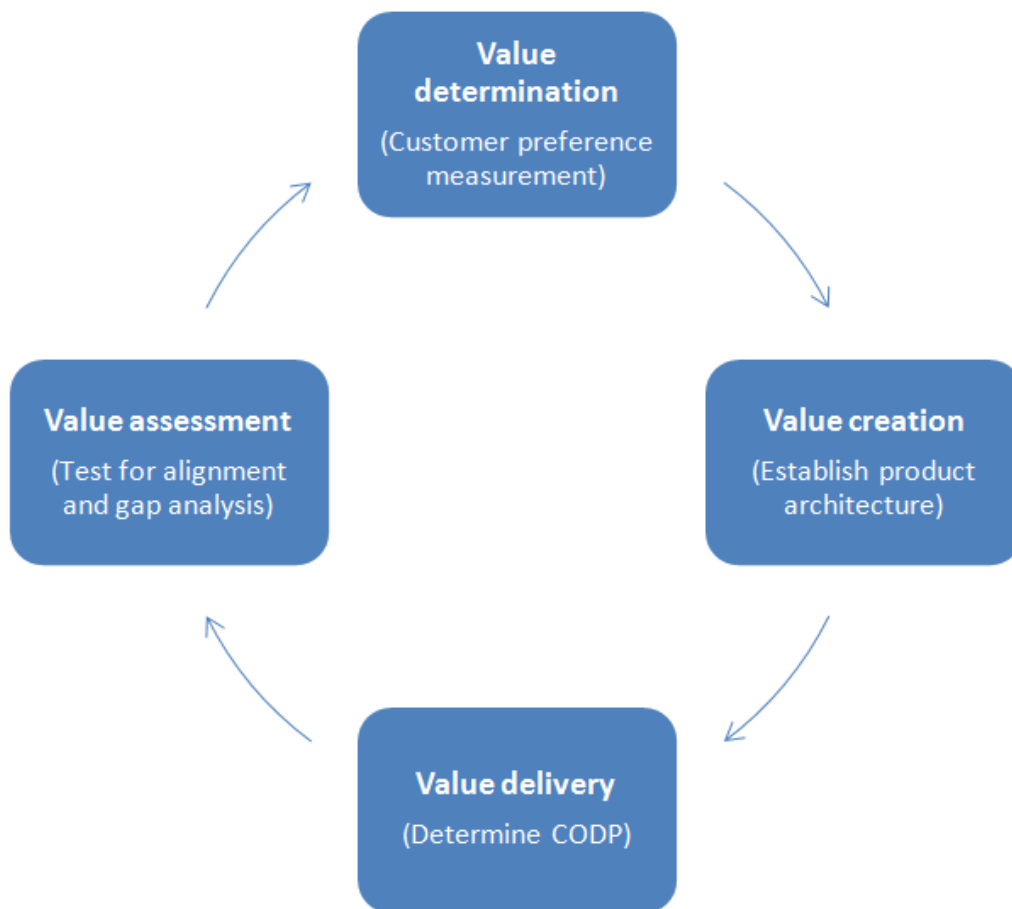


Figure 6.4: The value process (source: adapted from Payne and Holt, 2001)

In the second activity value is created. This involves an alignment of the products or services on offer with the requirements identified during the value determination activity. With regard to Figure 6.3 this means that the product's architecture is set up according to customer requirements. Following value creation decisions need to be made with regard to how the value is delivered. Hence, the CODP is positioned so that the operations can be aligned accordingly. In the final activity it is assessed whether value has been delivered to the customer. With reference to the framework presented in Figure 6.3 this means that a test for alignment needs to be conducted and depending on the appropriate result a gap analysis determines whether there is a mismatch and, hence, a need for the following: product redesign, supply chain reconfiguration or market repositioning. One method for value assessment has been suggested in this

chapter. Payne and Holt (2001) also suggest customer satisfaction surveys or service quality measures as alternatives.

In essence the framework suggested in Figure 6.3 provides a dynamic approach to bring value to customers at a profit. It is important to realise that value is subject to external influences. Hence, the alignment task needs to be completed in order to ensure that the company will achieve customer satisfaction.

As pointed out in Section 2.8 creating value for customers is important for the company in gaining competitive advantage. However, it is important to identify what exactly constitutes customer value and what other resources and skills enable the company to gain a competitive advantage. As clarified by Hinterhuber (2013) there are a number of different dimensions that have an influence on a company's competitive status. Apart from the customer perspective, which includes the identification of customer needs, these are:

- Company perspective: value of resources for the company and the degree to which the company is able to exploit these resources.
- Competitive perspective: availability of resources to competitors and the cost of imitation/substitution.

The application of the VRIOLU framework as suggested by Hinterhuber (2013) provides an understanding of the most important unmet customer needs and the suitability of current resources and competencies to meet these needs. The framework as shown in Figure 6.3 can be described as a similar approach but with a focus on matching product architecture and customers unmet needs. Therefore, a combination of the VRIOLU framework with the operational capabilities and customer preferences alignment framework as presented in Figure 6.3 can potentially result in sustained superior performance. It would be highly interesting to test this proposition but this is outside the scope of this study.

6.4. Conclusion

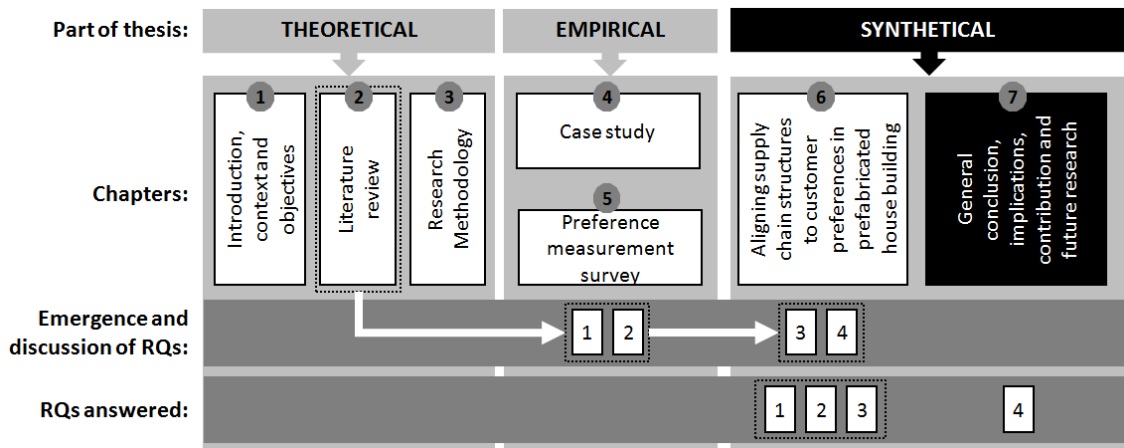
This chapter has produced an alignment model that can highlight mismatches between what is offered by the company and what is required in terms of choice by the customer. This enables the identification of so-called 'hot spots' that need further and more detailed examination. The question as to whether lessons in aligning the product and processes with customer requirements can be generalised to different industry sectors emerges as research question four from this chapter. The appropriate discussion will be found in the following chapter.

Furthermore, the process in this thesis is summarised and reflected in a framework that researchers as well as practitioners can apply in order to review the gap between customer preferences and the degree of choice offered. Depending on the outcome of the test for alignment using the alignment model as shown in Figure 6.1, the framework gives recommendations on what to do. Furthermore, it has been pointed out that according to the competitive advantage literature a combination with the VRIOLU model could potentially result in sustained superior performance.

Chapter 7

“I think and think for months and years. Ninety-nine times, the conclusion is false. The hundredth time I am right.”

(Albert Einstein)



7. General conclusions and implications

This final chapter gives a summary of the research findings. Furthermore, the main findings are discussed and each of the research questions is addressed concisely. A statement with regard to the generalisability of this study’s findings is made followed by a discussion of the limitations. The academic contributions and implications for the house building industry are stated before recommendations for future research are made.

7.1. Introduction

As it is the primary research objective of this thesis, a framework for aligning a house building company’s operational capabilities with what customers really want in terms of choice has been developed. This framework enables a study of the influence of customer preferences on the operations of a house building company. Looking at the summary of the research objectives as stated in the introduction of this thesis, it can be said that each of the objectives has been achieved.

Firstly, the findings of the case study as presented in chapter four enabled the author to:

- prove that choice in the house building industry is appreciated by customers and can be an order-winning criteria, thus achieving customer satisfaction (Hill, 1985).
- decompose the product architecture of a house and position the CODP to find out which components/categories can actually be influenced by customers.

Secondly, the customer preference measurement resulted in:

- discovering on which components/categories customers focus on when configuring/building a house.

Both research streams combined resulted in the:

- determination of whether the offer of choice corresponds to what customers actually wish to influence.

Thus, this thesis offers an empirical investigation into customer choice requirements and suggests a framework that helps to bring customer preferences and operational capabilities in alignment. In doing so, an approach is developed that helps to identify the architecture of a product. This was necessary so that the impact of choice could be traced into the lower levels of the product architecture.

7.2. Research questions answered

The research questions as given in the introduction chapter are a result of the identification of literature review gaps in the body of knowledge as presented in chapter 2.8. Following the two-stream empirical research approach, the first three research questions could be answered. For the third and fourth research question, these findings combined with a comparison of the general body of knowledge, lead to findings with which research question four could be answered. In the following, each of the four research questions will be answered concisely:

Research question 1:

What relevance does product architecture have for the provision of a customised product?

The decomposition of a prefabricated house into categories, components and sub-components combined with a determination of the customisability gives an indication regarding the customisation strategy applied. In particular, Figures 4.8 and 4.9 determined by the case study show that more than one order fulfilment strategy can be applied to supply a product or product category. This is important as it shows that it is an oversimplification to conclude that within product categories customers do not wish to have a high degree of choice for certain components or sub-components. Hence it is important to consider the complete product architecture in the preference measurement exercise. Only then can the future list of options be set up according to customer preferences and needs, thus achieving customer satisfaction.

Furthermore, this research suggests that different CODP can exist concurrently within the product architecture of one ETO product. It can be deduced that the position and number of CODP changes depending on the perspective of the supply chain member. This also happens with each project, component, sub-component and attribute level. Moreover there are CODPs on many interfaces which can be of customer-to-business or business-to-business nature. This fact is often neglected by researchers when positioning the CODP. However, there are dependencies between the different components and sub-components which is why the knowledge of each CODP in the supply network is vital in order to better control and organise company activities such as engineering, purchasing, inventory control and production.

Research question 2:

How do customers prioritise their preferences with regard to the configuration of a prefabricated house?

The role of customer preference measurement for complex, multi-attribute products has been clarified. A preference measurement method for multi-attribute products (PCPM) has been applied in order to prioritise and identify what potential buyers of prefabricated homes really focus on when configuring a house. This is important as only

knowledge of the preferences will enable practitioners to be effective in customisation efforts, thus ensuring operational efficiency accordingly.

The results of the online preference measurement have been presented and the results can help prefabricated house building companies to make the right decisions about the level of variety to offer. Furthermore, the importance of market segmentation before conducting a preference measurement has been highlighted and it has also been mentioned that a survey in general offers a unique opportunity to gather additional data from the target group. However, one needs to be careful with this additional data gathering as too many questions will overburden the respondent.

The results of the online survey clearly show that attributes associated with flexibility and security have a significantly higher impact on the overall product preference compared to others. However, one has to be careful with the interpretation of the results as these can be biased by current trends influencing respondents. Furthermore, due to the multi-layer product architecture and the many different alternatives, the possible preference orders can be very long and so respondents have to make a lot of difficult decisions when completing the PCPM questionnaire.

Research question 3:

How can customer preferences be aligned to what is offered in terms of customisation?

In chapter six a method has been developed that helps to prioritise a company's option list by coupling marketing and operations. Furthermore, based on existing literature, a matrix has been suggested on which the PCPM results can be mapped in a way that shows the alignment between the customisation strategy currently applied by the company and the customer's preferences. Combining the positioning of the CODP within the identified product architecture and the results of the AHP-based survey resulted in an identification of opportunities to improve strategic alignment between the operational capabilities and customer requirements. Furthermore, the results enabled recommendations on how and where to remove options without diluting customer value.

An area of 'best fit' has been developed that indicates the degree of alignment between the customisation strategy and customer preferences. If product categories or components are outside this area, the company needs to review the options offered. This enables practitioners to spot problem areas instantly and helps to concentrate improvement efforts.

An optimisation method has been proposed which helps to prioritise the need for action. This enables the company to determine for which component there is a need of adapting the customisation strategy and prioritises the problem areas so that the most considerable misfits can be tackled first.

However, it needs to be highlighted that customer requirements can change over time. Hence, there is a need for the alignment to be dynamic. Essentially this means that a revision of the alignments should be conducted on a regular basis. Possible benefits of applying the framework presented in Figure 6.3 may include the identification of additional operational capabilities and a reduction of the time to introduce new products. Furthermore, the ability to be flexible in adjusting the operational capabilities can save costs for obsolete inventory and shorten delivery times.

In particular the framework presented in Figure 6.3 echoes the work of Fine (2000), Lambert and Cooper (2000) and Pine (2013) who all claim that sustained competitive advantage can only be achieved if process, product and supply chain development are done concurrently and in an integrated way.

Research question 4:

Can lessons in aligning the product and processes with customer preferences be generalised to different industry sectors?

The framework shown in chapter 6 presents a process that is potentially transferable to general application in operations management. Using the five generic customisation strategies developed by Lampel and Mintzberg (1996), this research suggests an approach that enables an allocation of categories, components or sub-components into these strategies thus giving recommendations on how to bring a product's architecture

its processes and customers' preferences in alignment. As pointed out in the literature review this involves a combination of production and process capabilities in an integrated way so that a value chain can be developed that meets customers needs. The managerial framework reviews the gap between customer preferences and the degree of choice offered.

It has been highlighted that the product architecture of a prefabricated house is not dissimilar to the product architecture of an automobile. Furthermore research conducted by Pil and Holweg (2004) shows that the automotive sector is also struggling with ever increasing numbers of variations. Hence, it can be assumed that there is therefore no reason why the approach that has been developed cannot be applied to other sectors and studies scrutinising the alignment of the operational capabilities with customer preferences.

7.3. Generalisability and limitations of findings

Although the basis of this research is the general mass customisation literature, the focus is on the prefabricated house building sector. Hence, the potential to generalise the findings presented in this research in particular with regard to the preference measurement survey as presented in chapter five is limited to the German self-build house building sector because the survey has been conducted in Germany. However, as mentioned above, the process of conducting the case study as well as the preference measurement is generalisable in research that concentrates on products with a complex product architecture. One example for such a sector is the automotive industry.

This study is designed to balance breadth and depth of knowledge. Figure 7.1 shows that the way this research is designed offers both depth and breadth or scope of understanding. The architecture of the company's product offerings are investigated in depth using qualitative research methods. The 16 projects of the case company provide increasing breadth with, however, less depth. The preference measurement survey provides the least depth but at the same time the most breadth is gained. By applying different levels of depth and breadth and different research methods the confidence in the level of generalisability of the results is increased (Towill et al., 2002). Furthermore,

the larger the sample size of each level is, the stronger the foundation of the theory becomes. Concerns relating to rigour, generalizability and validity issues of the case study in particular have been discussed in chapter 3.4.2 by applying the four tests for judging the quality of research designs, which are common to all social science methods: construct validity, internal validity, external validity and reliability (Yin, 2003). However, as pointed out by Lee and Baskerville (2003) a theory may never generalised to a setting where it has not yet been empirically tested and confirmed.

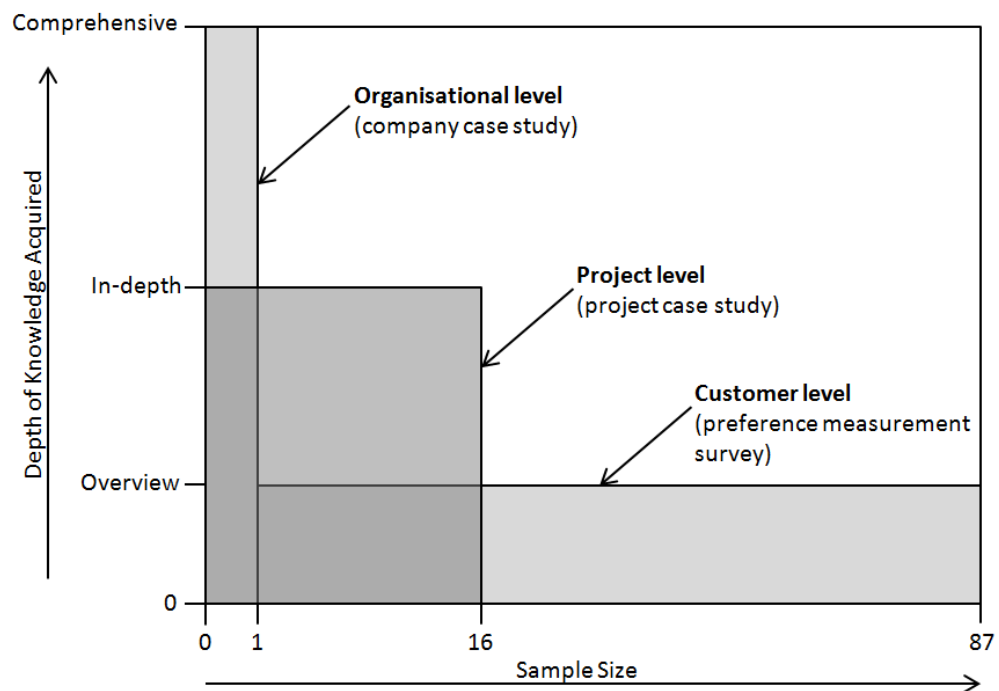


Figure 7.1: Scope and depth of understanding gained by the research (adapted from: Towill et al., 2002)

There is a further limitation to this research. The research method adopted a case study which was conducted with one prefabricated house manufacturer and is based on multiple projects over a long time-span. Furthermore, the survey results are based on a snow-ball sample and 87 responses. Even though an in-depth understanding of a single case study coupled with the survey responses can aid generalisation, further research, utilising additional cases and a wider survey are required to cover other populations and confirm the above findings.

7.4. Contributions of study

This research extends the existing body of knowledge through a number of novel contributions. A summary of these contributions is given in Table 7.1. For a better orientation, the chapter numbers are indicated and the final column states whether the contribution is to the academic sector or whether it is of interest for practitioners.

No	Chapter	Contribution	Academic (A) or Practical (P)
1	4	Development of a view of a prefabricated house as a system of components.	A + P A = researchers interested in product modularity and preassembly P = production department
2	4	Finding that clients, when given the potential to do so, are increasingly looking at customising their houses.	P P = marketing department,
3	4	Determination of degree of customisation on sub-component level.	P P = production and marketing department,
4	4	Positioning of CODP in product architecture and finding that multiple CODPs can exist. The position and the number of CODPs changes with the perspective and also with each project, component, sub-component and attribute level. Moreover there are CODP on many interfaces which can be of customer-to-business or business-to-business nature.	P P = production department, supply chain management
5	5	A procedure has been developed that prioritises categories and components in a prefabricated house design. This procedure can be adopted by building companies interested in offering customised houses.	P P = practitioners in the prefabricated house building industry
6	5	Online survey results can help prefabricated house building companies to make the right decisions about the level of variety to offer. Furthermore, the importance of market segmentation before conducting a preference measurement has been highlighted and it has also been mentioned that a survey in general offers a unique opportunity to gather additional data from the target group.	A + P A = marketing researchers, researchers interested in product modularity, preassembly and supply chain management P = marketing and production department
7	6	An alignment model has been developed that can highlight mismatches between what is supplied by the company and what is required in terms of choice by the customer.	A + P A = researchers in operations and supply chain management P = marketing and supply chain management
8	6	The process in this thesis is summarised and reflected in a framework that researchers as well as practitioners can apply in order to review the gap between customer preferences and the degree of choice offered.	A + P A = researchers interested in product modularity, preassembly, operations and supply chain management P = practitioners in the prefabricated house building industry

Table 7.1: Main contributions of research (source: author)

In general, past as well as current research on customisation in the construction industry is primarily concerned with an evaluation of strategic effects. To date, there is little scholarly work that explores the consequences of a customisation strategy on the operations of a company, particularly at the component level. It is this gap that this research is aimed to close.

7.5. Recommendations for future research

There is considerable scope for further research of this topic. One of the research opportunities could be to compare and contrast the findings with the same sector in other country markets, as well as for other types of house building. Furthermore, it has been shown that customer interaction is an important aspect when customising products. This is particularly relevant when the product is highly complex. Hence, if the understanding of the product and its customisation options are communicated properly the result will be an increase in customer satisfaction (Huffman and Kahn, 1998).

This also means that the presentation format of information to the potential customer is vital. Experience gained in other sectors has shown that there is considerable potential to optimise customer interaction by using product configurators (Huffman and Kahn, 1998). An alternative to that would be to follow the automotive industry and set up product packages (e. g. VW Premium Business package) where the company suggests a certain fit-out to customers, often combined with a financial benefit. Future research in this particular area should concentrate on the application of these methods. Piller (2013) promises that if companies provide “means of choice navigation to simplify the ways in which people explore their offerings” (p. 24) the reward will be customer satisfaction.

The methodological framework and alignment approach that have been developed and are presented in Figures 6.1, 6.2 and 6.3 can potentially be applied beyond the house building industry. It would be interesting to see further research being undertaken by other industries that produce customised products.

The third dimension of the 3-DCE concept as presented by Fine (2000), the supply chain design, should be in the focus of future research as this would complete the overall

research and provide the potential to fully align product design, process design and supply chain design. This can then help the case company competitively while minimising costs and increasing profitability. Furthermore, there is an opportunity to position the CODP on the basis of the P:D ratio. This enables the company to reengineer and improve production- or distribution-related activities.

And finally, if practitioners or researchers apply the framework suggested in this research it is vital that the importance of the sample accuracy is understood. The more accurate the sample the more accurate the results and the larger the sample the more confidence can one have in its informational value and validity. It is up to the person conducting the research to source the appropriate sample. With the ever increasing number of social media platforms there are a number of possibilities but the exact approach is dependent upon the type of product and its target market.

7.6. Recommendations for case company

A successful alignment of customer needs with the operational capabilities offers considerable benefits for the case company. If they follow the procedure outlined in this thesis, the case company will develop a basis for appropriate decisions.

Reflecting on the results generated by the case study and discussed above the following specific recommendations to the case company can be made:

- As mentioned by Piller (2013) a major success factor of a mass customiser and a source of competitive advantage is that the options on offer match the needs of the target market. A method has been presented in this thesis with which customer preferences can be measured and determined. This needs to be conducted by the company on a continuous basis.
- According to the alignment models as presented in Figure 6.1 and in Appendix 6, mismatches have been identified in the following product categories: Construction Design, Facade, Home Technology and Additional Services. The appropriate components need to be analysed in more depth and the analysis should be extended to the sub-component level. The latter, however, is also dependent on the results that are available from the customer preference

measurement. Hence, there is a need for the company to transfer the needs identified by the preference measurement into a products and processes that accommodate these needs. It is important to note that not all options must be offered. Only those that are consistent with the capabilities of the processes, the given product architecture and the degree of variety (Piller, 2013).

- Once a well-planned product architecture has been established, the company should think about introducing a product family approach as this can help to reduce complexity both for the company and for the customers.
- The need for action should be prioritised according to the optimisation model as presented in Figure 6.2.
- A joint meeting with marketing and operations management needs to be conducted so as to use the alignment framework as presented in Figure 6.3. This will result in the identification of the further *modus operandi* with regard to the overall product or different components of the product.
- In order to reduce complexity both for the operations of the case company and the choice the customer has to make, configurations can be set up as a result of the meeting with the operations and marketing management. Thereby the most popular choices are combined into configurations, which can be used as an effective marketing tool but also has an impact on operations as costs of obsolete inventory can be reduced and delivery times can be shortened.
- As indicated in chapter 6.3, a combination of the VRIOLU framework (Hinterhuber, 2013) with the operational capabilities and customer preferences alignment framework as presented in Figure 6.3 can potentially result in sustained superior performance. It would be highly interesting to test this proposition in collaboration with the case company in order to determine which criteria are relevant for securing sustained competitive advantage.

As mentioned before, markets are dynamic and customer requirements can change according to market trends. It is therefore important that the process described in this thesis is repeated on a regular basis. Only then can the positive impact of the alignment on the business be maximised.

In general, it is important for the company to understand that successful customisation requires a combination of process, product and supply chain development. Only if these capabilities are combined in a meaningful and integrated way will the result be a value chain that delivers value to the customer. Because the analysis of the company's supply chain is outside the scope of this research it is suggested that the findings of this study provide the basis for a supply chain analysis which ultimately enables the company to integrate all three dimensions.

7.7. Conclusion

This final chapter has provided a discussion of the primary objectives of this study. Furthermore, for each research question an answer has been articulated and discussed. This chapter has also presented the generalisability potential of the findings or of parts of the findings along with the limitations of this study. Finally, recommendations for future research have been made which will hopefully be picked up by fellow researchers.

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APPENDICES

Pull-out Appendix 1: Case study analysis matrix

Appendix 2: Translation of online questionnaire

Page 1

Befragung zu Fertighäusern Abschnitt 1 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)



Herzlich Willkommen zur Onlinebefragung zum Thema Fertighäuser und Individualisierung. Ziel dieser Befragung ist es, Ihre Vorlieben in Bezug auf Fertighäuser und Ihre Anforderungen an die Individualisierungsmöglichkeiten zu untersuchen.
Als kleines Dankeschön erhalten Sie am Ende der Befragung eine kurze Auswertung, welche Komponenten eines Fertighauses für Sie besonders wichtig sind!
Bitte nehmen Sie sich für das Ausfüllen des Fragebogens ca. 20 Minuten Zeit. Herzlichen Dank für Ihre Teilnahme und viel Freude beim Ausfüllen des Fragebogens!

[weiter](#)

Translation:

Welcome to the online survey on preferences and customization in the house building industry. The aim of this survey is to determine your preferences and choice requirements with regard to prefabricated houses.

On the final page of this survey we show you a brief summary of your data input which highlights the components which you defined to be important when configuring a prefabricated house.

The completion of this survey will take around 20 minutes. Many thanks for your support with this study.

Page 2

Befragung zu Fertighäusern Abschnitt 2 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

Datenschutzbestimmung

Die Teilnahme an dieser Studie ist ganz und gar freiwillig. Sie können jederzeit und ohne Angabe von Gründen die Befragung abbrechen. Hieraus entstehen Ihnen keinerlei Nachteile. Alle Informationen, die wir im Rahmen unserer Studie sammeln, werden absolut anonym erfasst und vertraulich behandelt.

Sie werden darauf hingewiesen, dass die bei den Untersuchungen mit Ihnen gewonnenen Daten mit Computern weiterverarbeitet und ausschließlich für wissenschaftliche Zwecke im Rahmen der laufenden Studie verwendet werden. Hiermit sind Sie einverstanden, wenn die Verarbeitung und Veröffentlichung in einer Form erfolgt, die eine Zuordnung zu Ihrer Person ausschließt. Die Speicherung und Auswertung dieser studienbezogenen Daten erfolgt nach den gesetzlichen Bestimmungen.

Bei Fragen und/oder Problemen können Sie den Studienleiter unter schoenwiztm1@cardiff.ac.uk erreichen.

Ich stimme zu.
 Ich stimme nicht zu.

[zurück](#) | [weiter](#)

Translation:

Data protection regulations

The participation in this study is entirely voluntary and you can withdraw from the study at any time without giving a reason.

The information provided by you will be processed and analysed using a special software. However, the data will be held confidentially, securely and will only be used for the purpose of this research.

You hereby confirm that you agree with the above if it is ensured that only the researcher himself can trace the information provided back to you individually. The

storage and analysis of this research related data is in accordance with the legal requirements.

If you have any queries, you can contact the responsible researcher under schoenwitzm1@cardiff.ac.uk.

- I agree.
- I disagree.

Page 3

Befragung zu Fertighäusern Abschnitt 4 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

4%

Unter einem Fertighaus soll hier ein Gebäude verstanden werden, das sich aus Standardkomponenten zusammen setzen lässt. Ein Fertighaus ist ein in Elementbauweise errichtetes Gebäude, welches einen hohen Vorfertigungsgrad hat und üblicherweise schlüsselfertig an den Bauherren übergeben wird. Normalerweise bieten Fertighaushersteller ihren Kunden unterschiedliche Möglichkeiten zur Produktspezifikation – einige bieten viel, andere wiederum eher wenig Auswahl.

Wie interessiert sind Sie generell daran, auf einer Skala von "sehr uninteressiert" bis "sehr interessiert", in den nächsten Jahren ein Fertighaus zu bauen? *

sehr uninteressiert	eher uninteressiert	teils teils	eher interessiert	sehr interessiert
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[zurück](#) [weiter](#)

Translation:

For this study a prefabricated house is defined as a product that consists of many different standard components. A prefabricated house is a building that is erected using modules which are usually manufactured off-site. The house building company usually offers a turnkey solution for the clients and different possibilities to specify the product (i. e. house) – some offer a high degree of choice, others a rather low degree.

How interested are you in general, from “not interested at all” to “very interested”, to build a prefabricated house in the near future?

Page 4

Befragung zu Fertighäusern Abschnitt 5 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

3%

Wie häufig haben Sie bereits gebaut? *

- keinmal
- einmal
- 2-3mal
- 4mal und häufiger

[zurück](#) [weiter](#)

Translation:

How often have you build a house before? Never, once, two or three times, four times and more

Page 5

Befragung zu Fertighäusern

Abschnitt 6 / 27

Kontakt Datenschutz Impressum

12 %

Was denken Sie: Wie gut kennen Sie sich insgesamt mit Fertighäusern aus? Ich kenne mich...

überhaupt nicht gut aus	eher weniger gut aus	weder gut noch schlecht aus	eher gut aus	sehr gut aus
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[zurück](#) [weiter](#)

Translation:

What do you think? How good is your knowledge about prefabricated houses? My knowledge is not good at all or very good.

Page 6

Befragung zu Fertighäusern

Abschnitt 7 / 27

Kontakt Datenschutz Impressum

15 %

Wie wichtig ist Ihnen eine Wahlmöglichkeit in Bezug auf die folgenden Komponenten eines Fertighauses?

	überhaupt nicht wichtig	eher weniger wichtig	wichtig	sehr wichtig	extrem wichtig
Verriegelung mit normaler oder erhöhter Sicherheit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Manuelle oder automatische Betätigung der Fenster und Türen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Material der Fenster- und Türgriffe (Edelstahl oder Kunststoff)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Griff der Haustür (Kinke oder Knopf)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Material des Balkons (Edelstahl oder Holz)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Möglichkeit zur konstruktiven Veränderung des Dachs (z.B. Dachgaube)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Optik der Deckenuntersicht (weiß gespachtelt oder Nut- und Federbretter)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Art der Wärmeverteilung (Fußbodenheizung oder Heizkörper)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[zurück](#) [weiter](#)

Translation:

How would you personally rate the importance of the degree of choice for the following components?

	not important at all	not important	important	Very important	Extremely important
Locks with normal or higher security					
Manual or automatic window or door opener					
Material of window and door handles (stainless steel or plastic)					
Material of main door handle (handle or knob)					
Material of balcony (stainless steel or timber)					
Possibility to change the construction of the roof (e. g. dormer)					
Design of ceiling (white or tongue and groove)					
Type of heat distribution (under floor heating or radiators)					



Wie wichtig ist Ihnen bei einem Fertighaus eine große Auswahl in Bezug auf folgende Komponenten?

	überhaupt nicht wichtig	eher weniger wichtig	wichtig	sehr wichtig	extrem wichtig
Große Auswahl an Designs der Haustür	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Grundrissgestaltung (Länge, Breite, Erker, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Designs des Dachs (z.B. Art der Dachziegel)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Photovoltaikanlagen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Elektroausstattungen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Urinalen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Toiletten	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Waschbecken	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Duschen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Armaturen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Badewannen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Solarthermieanlagen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Anlagen zur Warmwasserzeugung	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Große Auswahl an Wärmeerzeugern	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Translation:

How would you personally rate the importance of the degree of choice for the following components?

	not important at all	not important	important	Very important	Extremely important
Many options for design of main door					
High degree of choice with regard to footprint design					
Many options for design of roof tiles					
Many options for photovoltaic systems					
High degree of choice for the electrical installation					
High degree of choice for urinals					
High degree of choice for toilets					
High degree of choice for wash stands					
High degree of choice for showers					
High degree of choice for tabs					
High degree of choice for bath tubs					
High degree of choice for solar thermal systems					
High degree of choice for hot water generators					
High degree of choice for heat generators					

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Befragung zu Fertighäusern

Abschnitt 9 / 27

Kontakt Datenschutz Impressum

23 %

Wie wichtig ist es für Sie, dass ein Fertighausanbieter folgende Leistungen anbietet?

	überhaupt nicht wichtig	eher weniger wichtig	wichtig	sehr wichtig	extrem wichtig
Deckenöffnung (z. B. Galerie)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Staubsaugeranlage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rauchmelder	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gebäudeautomation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Alarmsystem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lüftungsanlage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gartengestaltungsservice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Finanzierungsservice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Carport	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Garage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Keller	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Auswahl an Möbeln	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

zurück weiter

Translation:

How important is it for you that the prefabricated house builder offers the following additional components.

	not important at all	not important	important	Very important	Extremely important
Opening in ceiling (gallery)					
Hoover system					
Smoke detector					
Home automation systems (e. g. KNX)					
Alarm systems					
Ventilation systems					
Landscaping services					
Financing service					
Carport					
Garage					
Basement					
Furniture					

Page 9 – page 17

Pairwise comparison of the components mentioned in the questions before. This means that the proband is asked what – in his/her opinion – is more important: component A or component B.

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Befragung zu Fertighäusern

Abschnitt 18 / 27

Kontakt Datenschutz Impressum

55 %

Wenn Sie an den Preis eines Fertighauses denken: Bei welchem Preis würden Sie das Fertighaus für so teuer halten, so dass Sie keines bauen würden? *

Bitte geben Sie den Betrag in € ein:

Bei welchem Preis würden Sie das Fertighaus für so günstig halten, dass Sie nicht bauen würden, da Sie Zweifel an der Sicherheit und Qualität hätten? *

Bitte geben Sie den Betrag in € ein:

Bei welchem Preis würden Sie das Fertighaus für relativ teuer halten, so dass ein Bauen für Sie erst nach reiflicher Überlegung in Frage käme? *

Bitte geben Sie den Betrag in € ein:

Bei welchem Preis würden Sie das Fertighaus für relativ günstig halten, so dass das Bauen für Sie ein tolles Angebot, ein regelrechtes Schnäppchen wäre? *

Bitte geben Sie den Betrag in € ein:

Translation:

Question 1: If you think about the pricing of a prefabricated house – which price level would be too high so that you would not be willing to build a house? Please give an amount in EUR:

Question 2: Which price level would be too low so that you would actually question quality and security? Please give an amount in EUR:

Question 3: Which price would be relatively high so that a realization of the project would only be relevant after careful consideration? Please give an amount in EUR:

Question 4: Which price would be so favourable so that it is a superb offer and a real bargain buy? Please give an amount in EUR:

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Befragung zu Fertighäusern

Abschnitt 19 / 27

Kontakt Datenschutz Impressum

75 %

Was denken Sie: Die Komponentenauswahl beim Bau eines Fertighauses ist... *

überhaupt
nicht wichtig

eher weniger
wichtig

weder
wichtig noch
unwichtig

eher wichtig

sehr wichtig

Translation:

What do you think: having a certain degree of component choice when configuring a prefabricated house is...

Not important at all, not important, important, rather important, very important

Page 20

Befragung zu Fertighäusern Abschnitt 20 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

77%

Welche Vorteile schreiben Sie dem Fertighausbau zu? Aus welchen Gründen würden Sie ein Fertighaus einem konventionell gebauten Haus vorziehen? *
(Mehrfachantworten möglich)

- Qualität
- Komplettleistung aus einer Hand / schlüsselfertig
- Design/Architektur/Optik
- Ich muss mich nicht um den Hausbau kümmern
- Kürzere Bauzeit
- Auch nach dem Hausbau habe ich einen Ansprechpartner für alles (Gewährleistung)
- Budgetsicherheit

[zurück](#) [weiter](#)

Translation:

What advantages do you think has a prefabricated house? Why would you prefer a prefabricated house?

- Quality
- One-stop-shop solution
- Design/architecture/optical reasons
- I will not be involved in the building process
- Shorter Building process
- Building a house with a prefabricated house builders also gives me one single point of contact for the after-sales-service
- Fixed budget

Page 21

Befragung zu Fertighäusern Abschnitt 21 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

81%

Nun ein paar abschließende Fragen zu Ihrer Person. Sie sind...? *

weiblich
 männlich

Wie alt sind Sie? *

Unter 20 Jahre
 21 bis 30 Jahre
 31 bis 40 Jahre
 41 bis 50 Jahre
 51 bis 60 Jahre
 über 61 Jahre

[zurück](#) [weiter](#)

Translation:

Now we have a number of questions with regard to yourself. You are...

- Female
- Male

How old are you?

- Under 20 yrs old
- 21 – 30 yrs
- 31 – 40 yrs

- 41 – 50 yrs
- 51 – 60 yrs
- Older than 60 yrs

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Befragung zu Fertighäusern Abschnitt 22 / 27 [Kontakt](#) [Datenschutz](#) [Impressum](#)

13 %

Wie viele Personen (einschließlich Ihnen) leben in Ihrem Haushalt? *

1 Person
 2 Personen
 3 Personen
 4 Personen
 5 Personen oder mehr

Wie hoch ist Ihr jährliches Bruttoeinkommen? *

weniger als 40.000,- €
 zwischen 40.001,- € und 60.000,- €
 zwischen 60.001,- € und 80.000,- €
 zwischen 80.001,- € und 100.000,- €
 zwischen 100.001,- € und 120.000,- €
 zwischen 120.001,- € und 140.000,- €
 mehr als 140.000,- €
 Keine Angabe

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Translation:

How many persons live in your household on a permanent basis?

- 1
- 2
- 3
- 4
- 5 or more

What is your annual salary?

- Less than €40,000
- Between €40,001 and 60,000
- Between €60,001 and 80,000
- Between €80,001 and 100,000
- Between €100,001 and 120,000
- Between €120,001 and 140,000
- More than €140,000
- No information

Page 23

Bitte geben Sie uns abschließend noch die Postleitzahl Ihres Wohnortes an: *

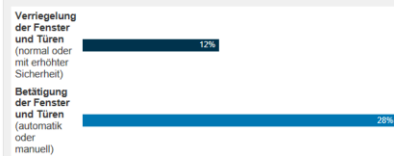
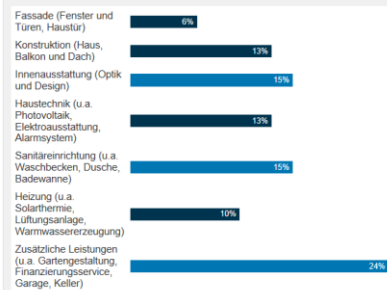
[zurück](#) [weiter](#)

Translation:

Finally please give your post code:

Page 24

Auf diesem Bildschirm sehen Sie die Wichtigkeit einzelner Leistungskomponenten eines Fertighauses, die wir aus Ihren Angaben berechnet haben.



Translation:

In the following please find a brief overview of the components you rated to be important when configuring a prefabricated house:

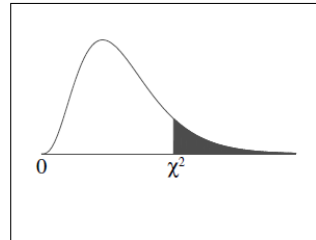
Appendix 3: Overview of the total uptake of each component as well as category

Category	Component	Total take up	Sum of choice	Sum total take up	in %
Facade	external wall	5	4	99	20.75%
	blinds	19	2		
	windows	24	5		
	doors	19	4		
	sliding doors	15	3		
	main door	17	3		
Construction design	house	13	2	69	14.47%
	roof	40	17		
	jamb wall	1	1		
	balcony	15	4		
Internal design	internal wall	25	4	94	19.71%
	additional cover boards	3	1		
	ceiling	7	5		
	doors	15	2		
	porch	7	1		
	stairs	11	6		
	open fireplace	5	3		
	flooring	21	3		
Home technology	alarm / security system	4	2	25	5.24%
	electric fit-out	20	4		
	hoover system	0	1		
	photovoltaic panels on roof	1	1		
Sanitary	bathtub	22	2	130	27.25%
	shower	21	2		
	washstand	23	2		
	toilet	22	2		
	urinal	9	1		
	connection for washing machine	14	1		
	external water tap	13	1		
	water softener	0	1		
	sink	6	1		
	Heating	heat generator	7		
heat distributor system		5	1		
hot water generator		1	1		
radiator (bathroom)		7	1		
ventilation system		1	1		
solar		1	1		
others		2	1		
Additional services	furniture	28	8	36	7.55%
	basement	0	2		
	garage	2	3		
	carport	3	3		
	financing service	2	1		
	landscape gardening	1	1		
Sum				477	100.00%

Table A3.1: Overview of total uptake of each component as well as category

Appendix 4: Chi-squared distribution table

Chi-Square Distribution Table



The shaded area is equal to α for $\chi^2 = \chi^2_{\alpha}$.

df	$\chi^2_{.995}$	$\chi^2_{.990}$	$\chi^2_{.975}$	$\chi^2_{.950}$	$\chi^2_{.900}$	$\chi^2_{.100}$	$\chi^2_{.050}$	$\chi^2_{.025}$	$\chi^2_{.010}$	$\chi^2_{.005}$
1	0.000	0.000	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766
50	27.991	29.707	32.357	34.764	37.689	63.167	67.505	71.420	76.154	79.490
60	35.534	37.485	40.482	43.188	46.459	74.397	79.082	83.298	88.379	91.952
70	43.275	45.442	48.758	51.739	55.329	85.527	90.531	95.023	100.425	104.215
80	51.172	53.540	57.153	60.391	64.278	96.578	101.879	106.629	112.329	116.321
90	59.196	61.754	65.647	69.126	73.291	107.565	113.145	118.136	124.116	128.299
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

Table A4.1: Chi-squared distribution table (source: <http://sites.stat.psu.edu/~mga/401/tables/Chi-square-table.pdf>)

Appendix 5: Customisation versus standardisation based on product architecture

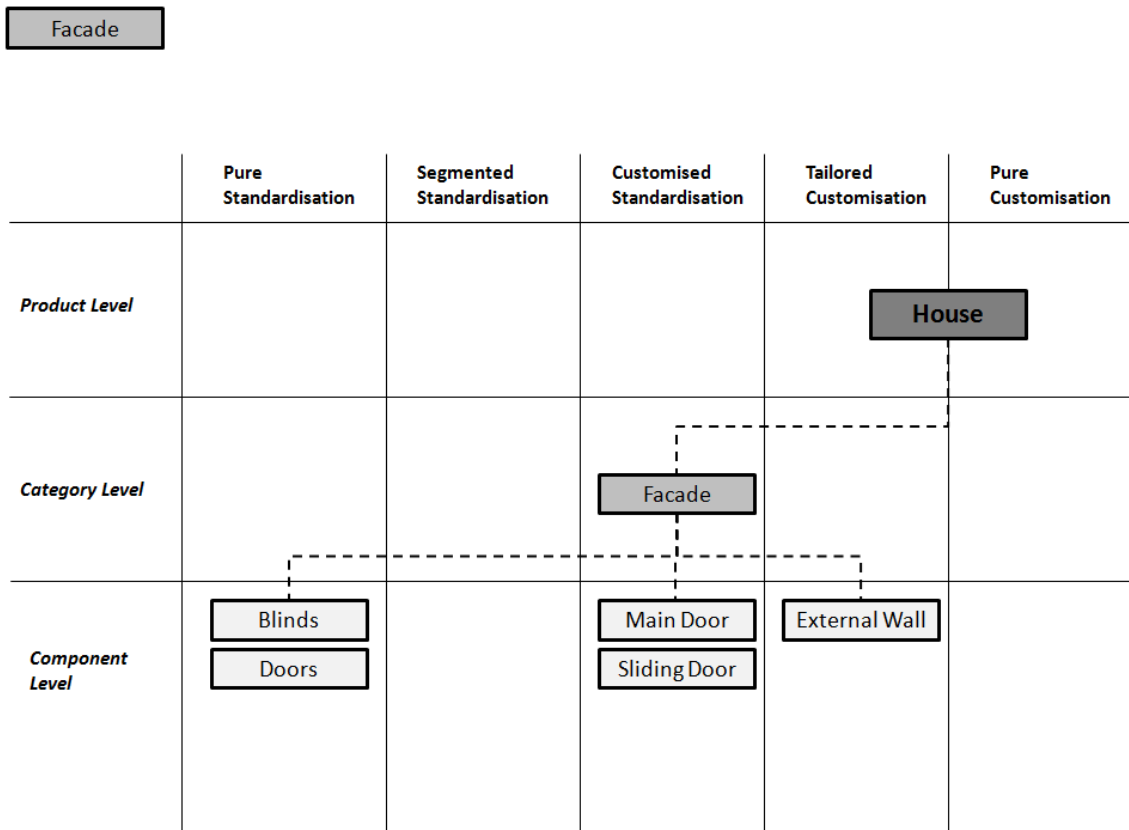


Figure A5.1: Product architecture for 'facade' in Barlow model (2003)

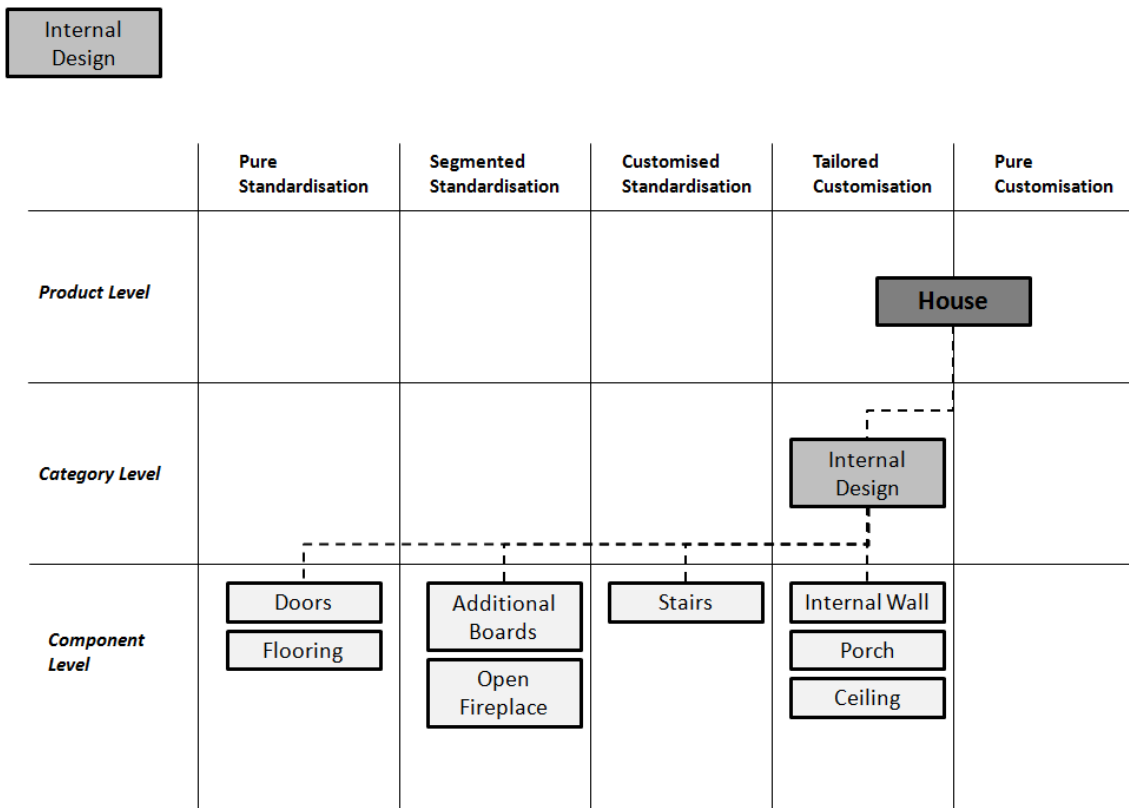


Figure A5.2: Product architecture for 'internal design' in Barlow model (2003)

Home Technology

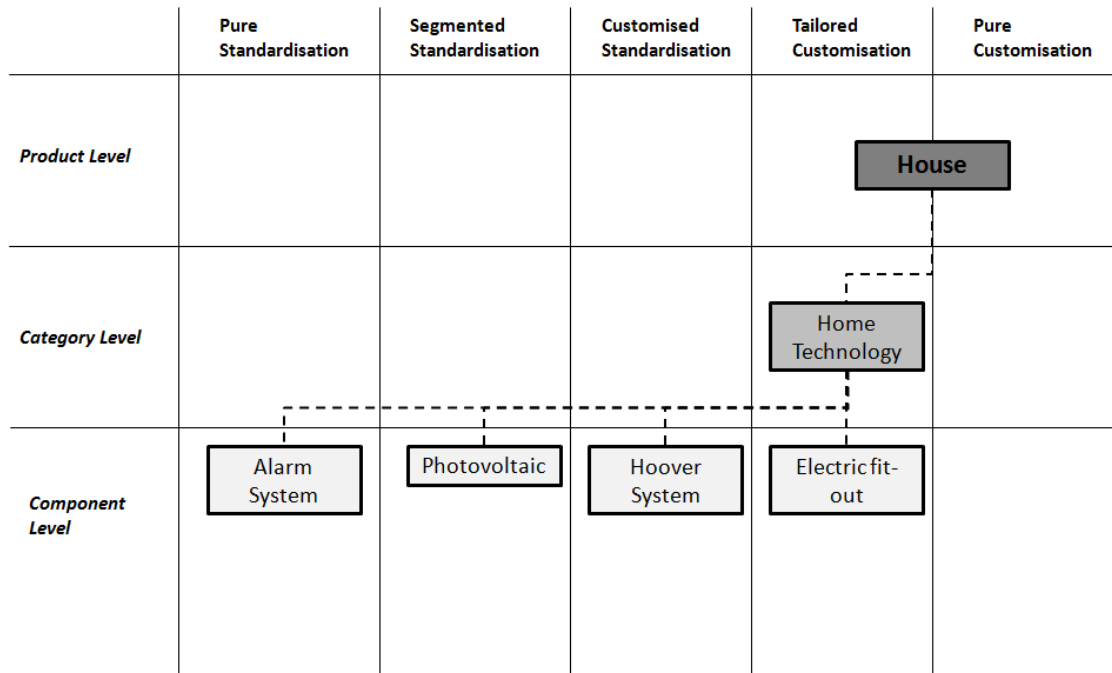


Figure A5.3: Product architecture for 'home technology' in Barlow model (2003)

Sanitary

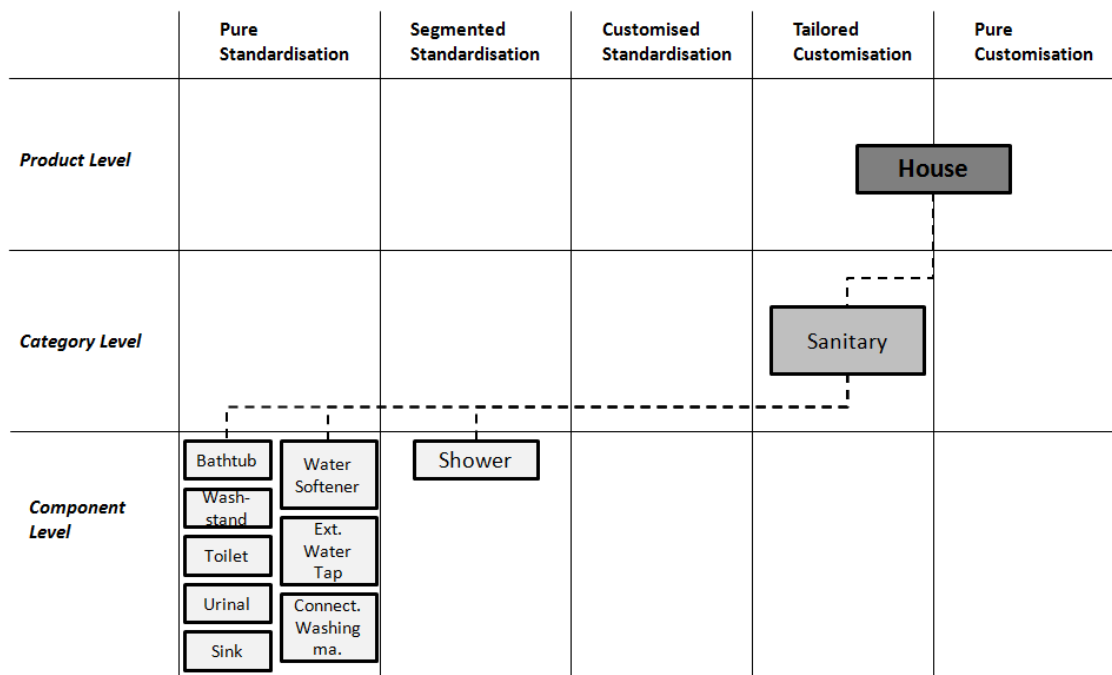


Figure A5.4: Product architecture for 'sanitary' in Barlow model (2003)

Heating

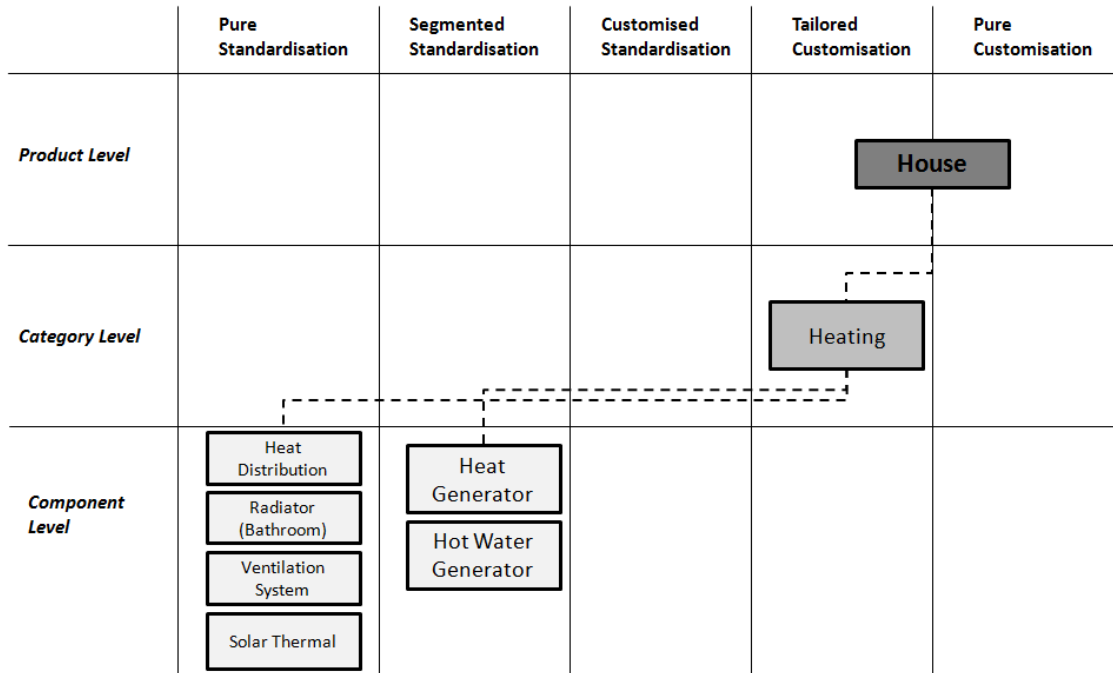


Figure A5.5: Product architecture for 'heating' in Barlow model (2003)

Additional Services

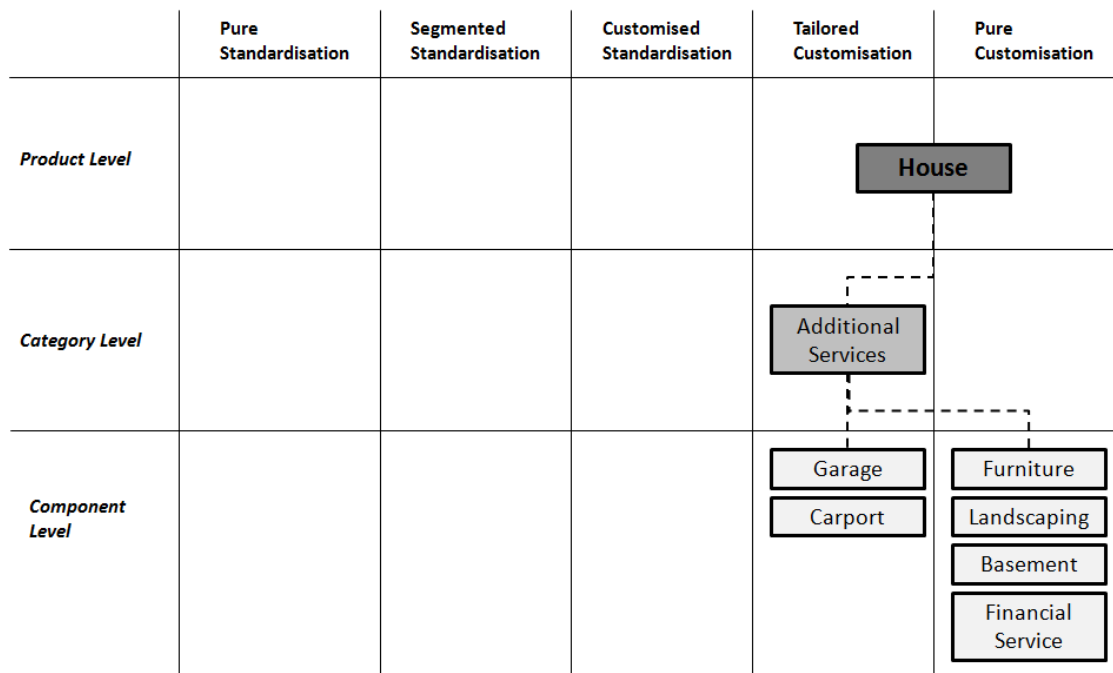


Figure A5.6: Product architecture for 'additional services' in Barlow model (2003)

Appendix 6: Alignment of product architecture and customer preferences for all categories

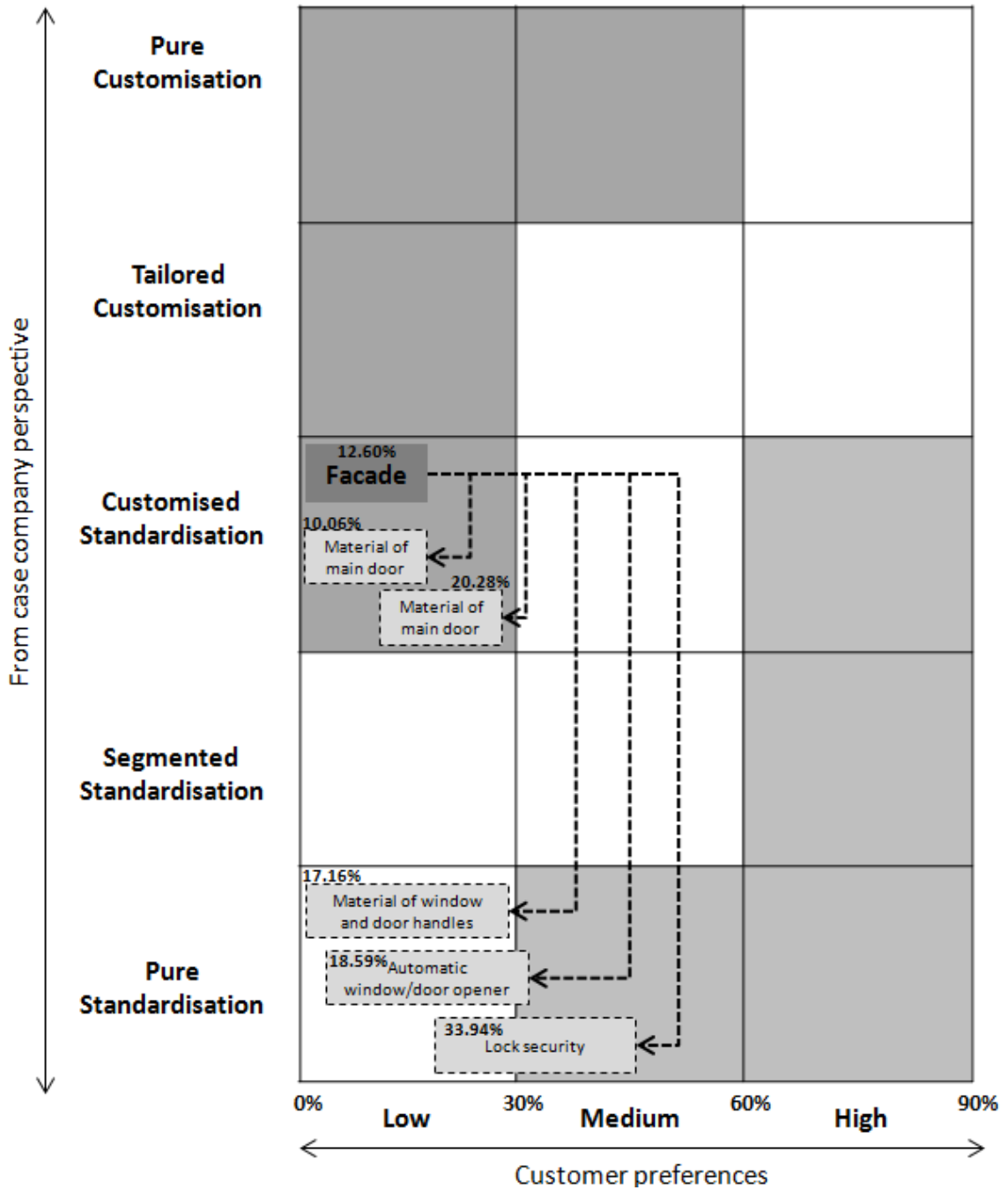


Figure A6.1: As-is-model for facade

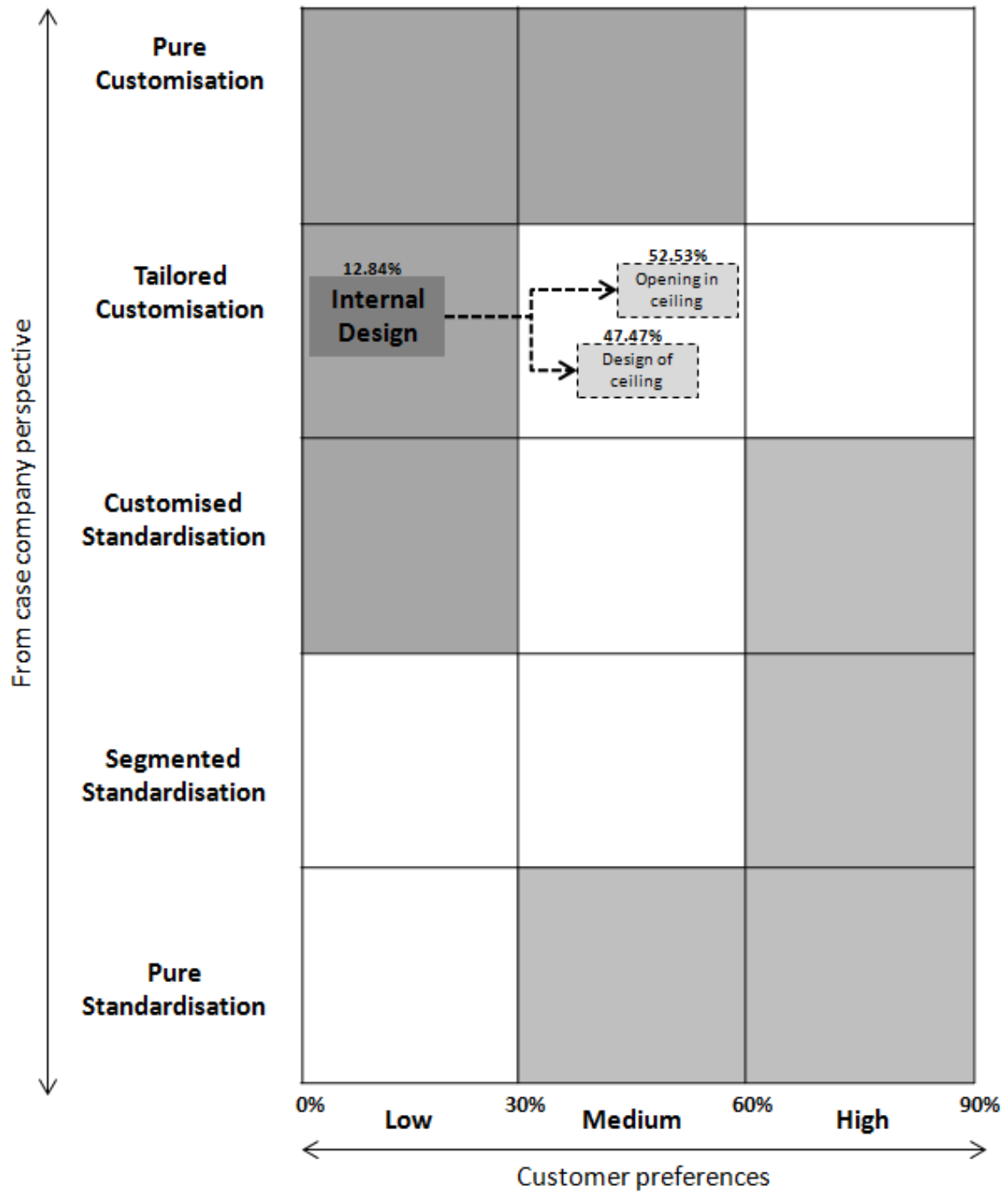


Figure A6.2: As-is-model model for internal design

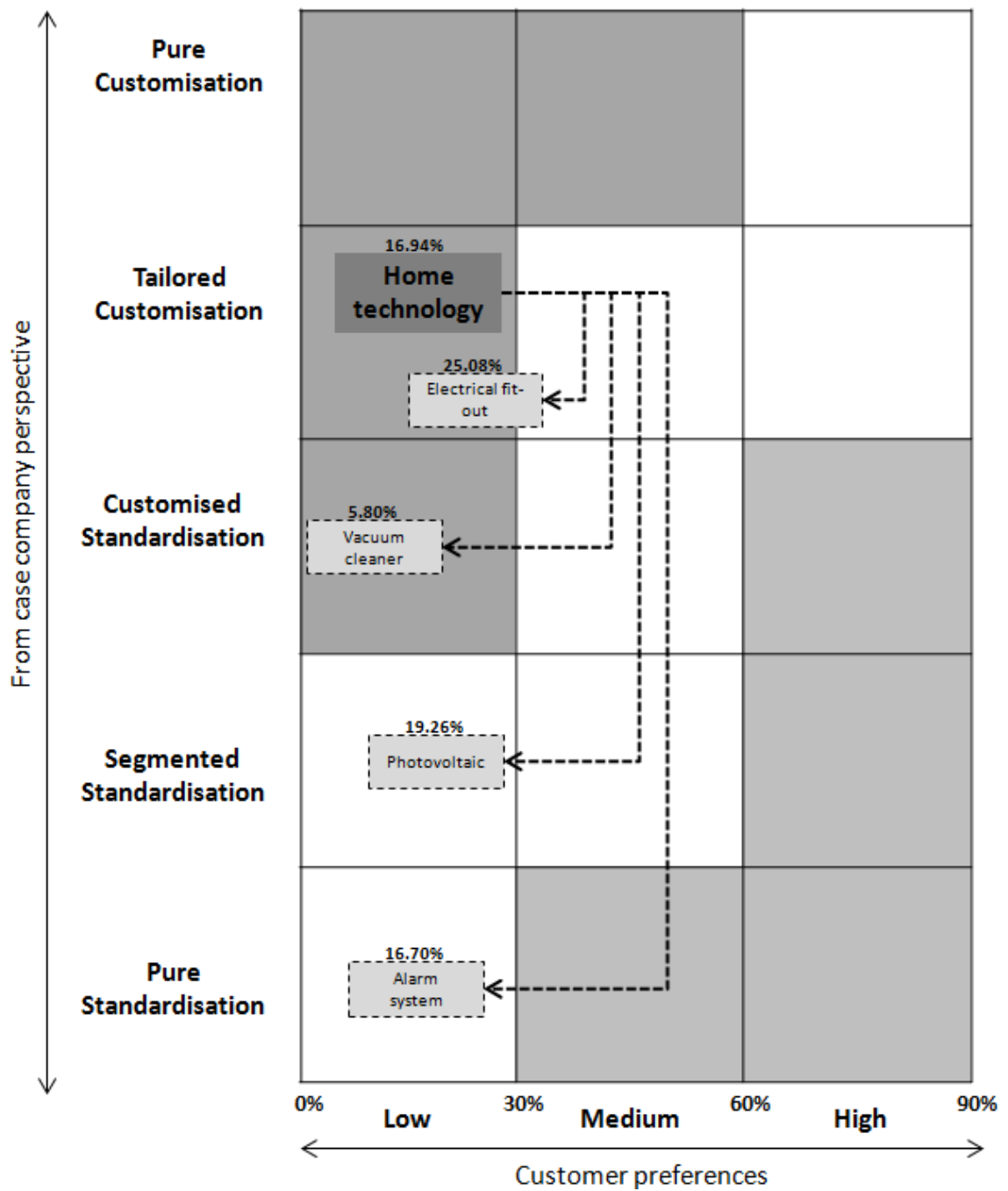


Figure A6.3: As-is-model model for home technology

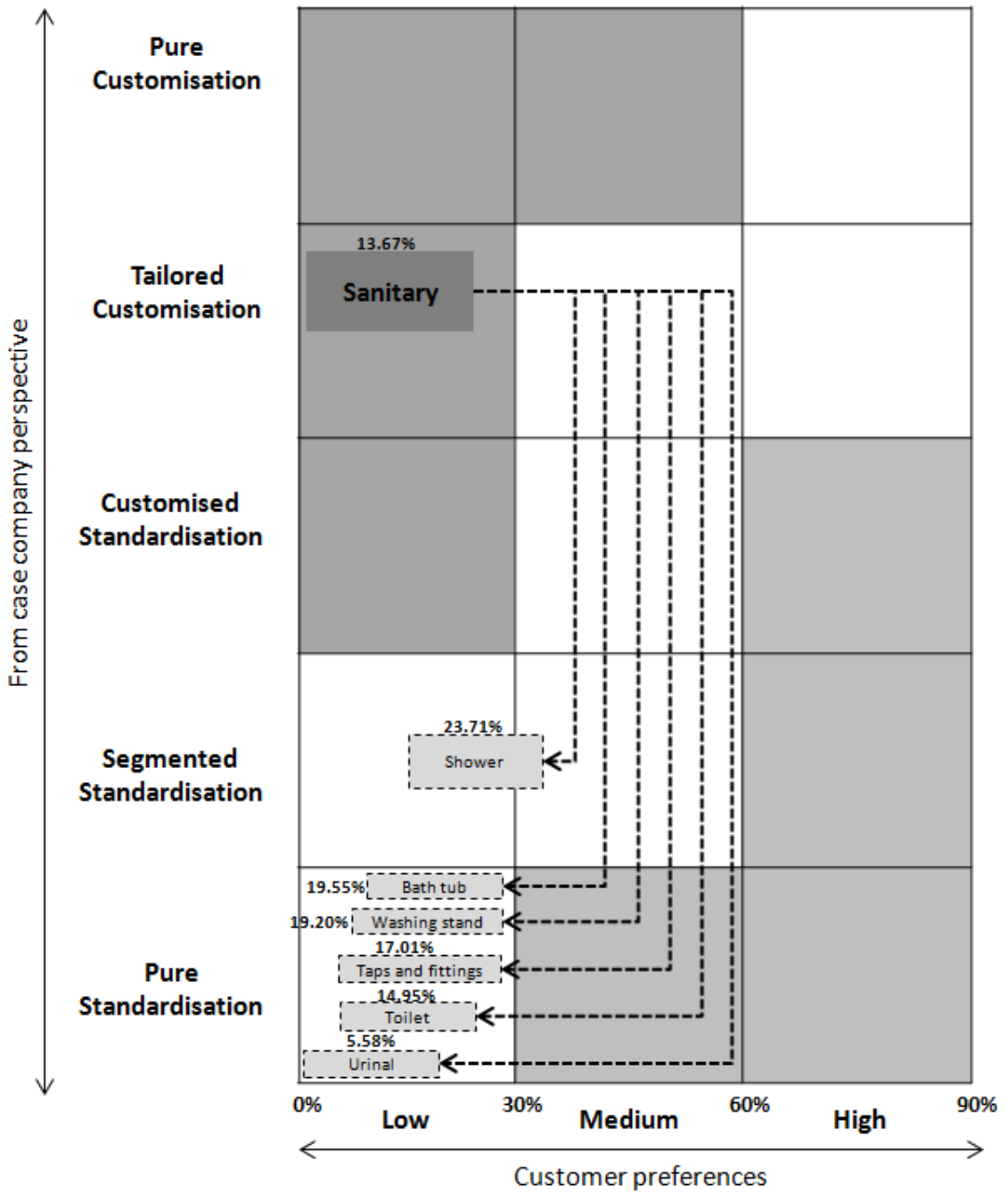


Figure A6.4: As-is-model model for sanitary

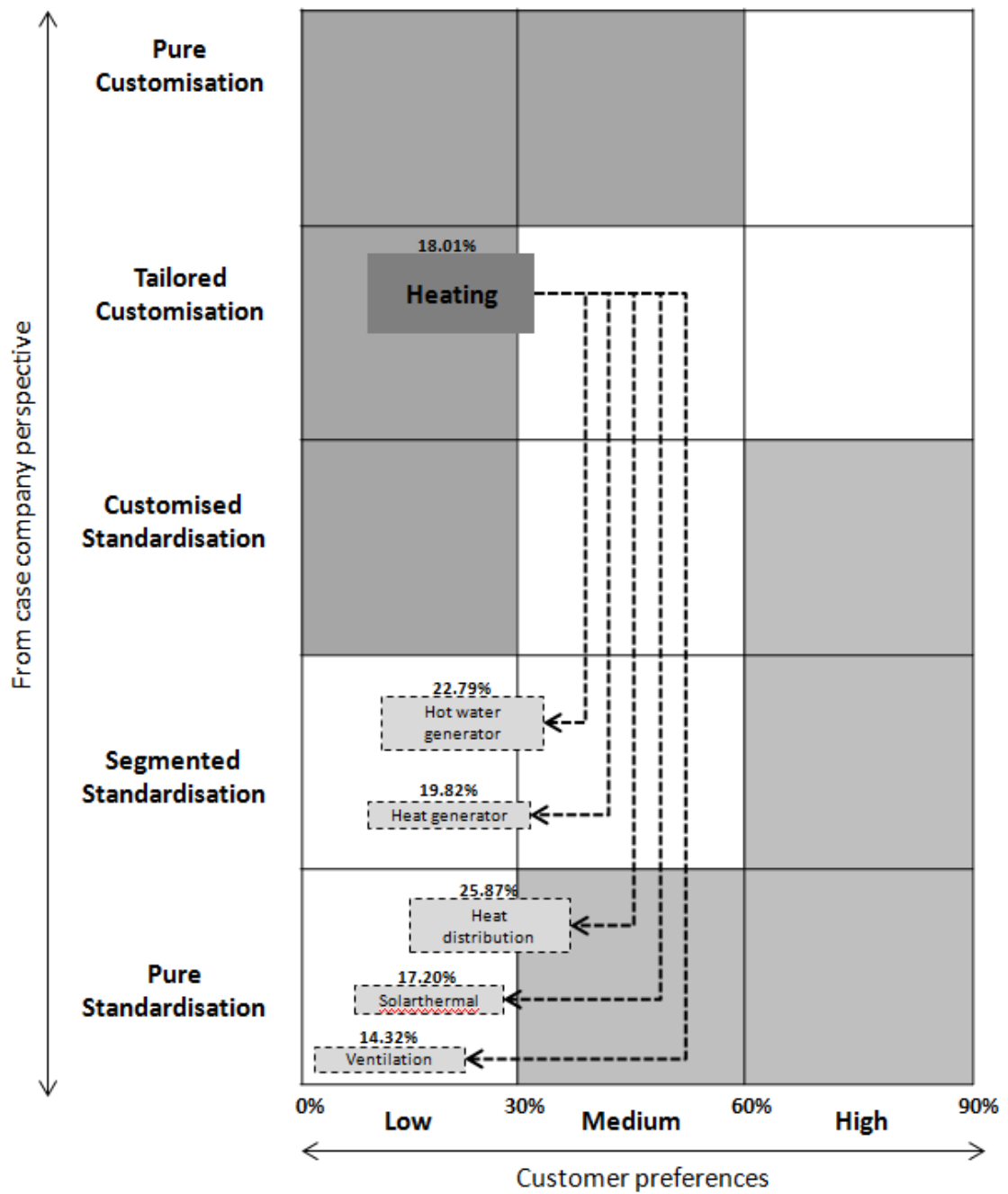


Figure A6.5: As-is-model model for heating

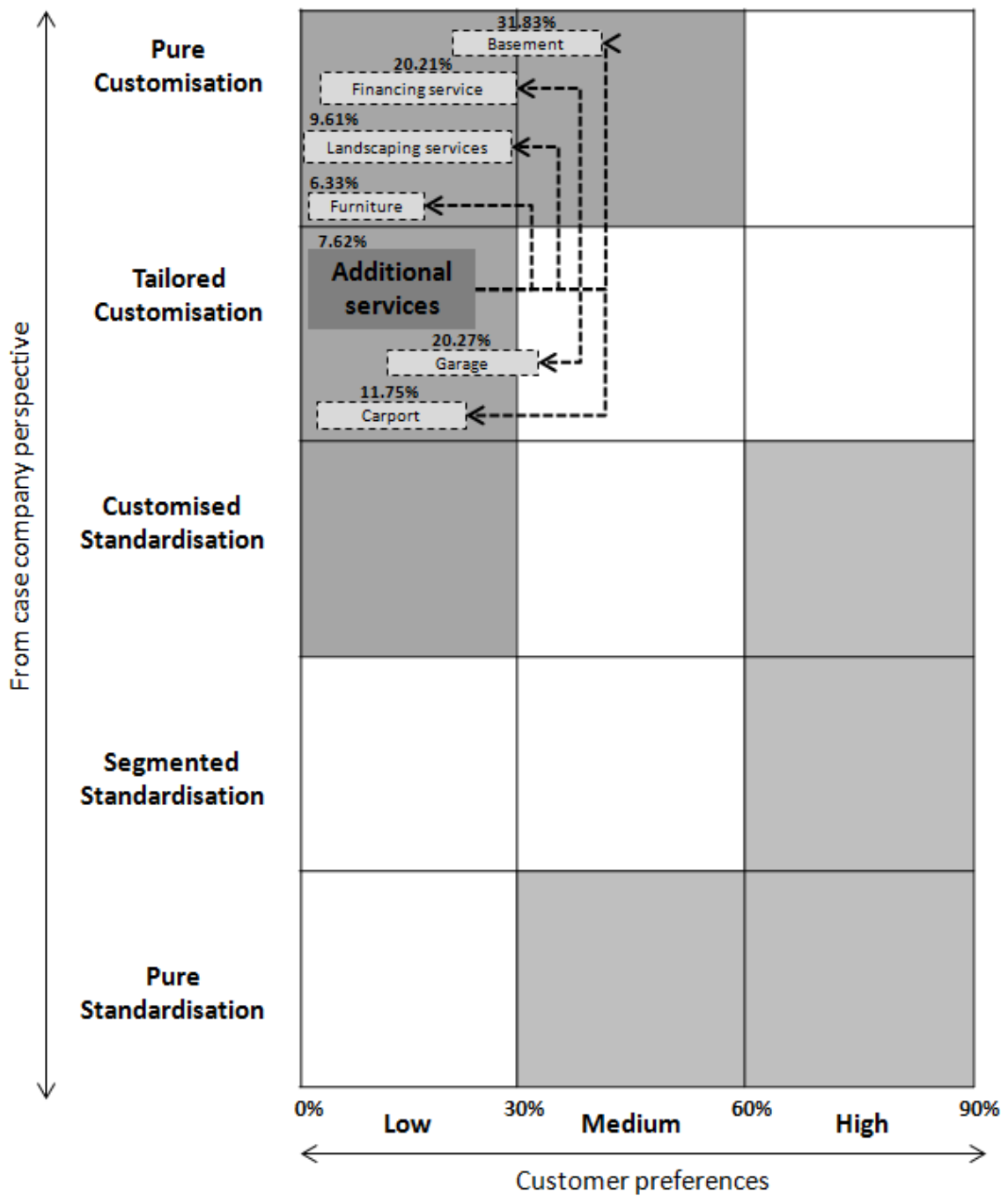


Figure A6.6: As-is-model model for additional services