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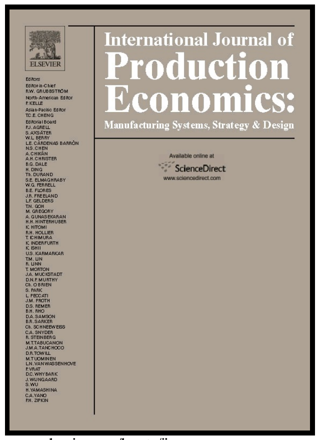

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Product, process and customer preference alignment in prefabricated house building

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Abstract

Much of the extant literature exploits the customer order decoupling point (CODP) from an aggregate product level. We develop a systematic approach to determine the alignment of CODP configurations at product, category and component levels, with customer preferences in terms of their customisation requirements. We adopt a participatory research method incorporating focus groups and interviews with personnel from a German case study company that builds prefabricated houses. From this we determine the product architecture. We also undertake a customer preference survey utilising a questionnaire that is based on a paired comparison technique. The survey informs customer preferences for choice for various elements of the architecture. We find that while at the product level the company produces a house that as a whole offers a high degree of customisation, at a category or components levels there are various offerings from pure standardisation to pure customisation. Furthermore, there is not always alignment between what customers want and what is actually being offered by the customer. So the company has options in terms of reconfiguring its operations, design new products/categories/components and/or seeking new marketplace opportunities. While the research has developed a technique that determines the extent to which the CODP positioning for a product architecture is aligned against customer preferences, there is a need for further research to test our findings beyond a single case study and into other industry sector contexts.

Key words

House building, participatory research, customer survey, product architectures, decoupling points.

1. Introduction

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 manner (Tang, 2010). Many researchers therefore highlight the importance of the careful management of the marketing and operations interface as this will ultimately align these two key functions towards common goals (e.g. Walters, 1999; Pero et al., 2010; Tang, 2010).

The reward for a successful alignment will be an improvement of the competitive performance of organisations (Zanon et al. 2012). There are, however, conflicts in the marketing and operations interface because of different interests (Hill and Hill 2012). Therefore, Wortmann et al. (1997) 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. This paper addresses this challenge, incorporating concepts associated with customer preference measurement and operational strategies.

An important part of any efforts towards alignment is to debate and agree the markets in which to compete, while also putting in place the right production system and supply chain to serve the market (Fisher 1997; Hill and Hill 2012). In terms of understanding the market, it is often argued that customer satisfaction can only be achieved if the degree of choice offered matches customer requirements. However, if customers are offered too much choice there is a risk of confusion rather than satisfaction (Huffman and Kahn, 1998). Conversely, 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).

A well-established approach to the alignment of customer demand and operational strategies can be found in the body of work surrounding Customer Order Decoupling Points (CODPs), highlighting that a range of different operations strategies exist to achieve alignment, from pure standardisation (where there is no customer input) through to pure customisation (where the customer is engaged in the design process). By considering the positioning of the overall product and its respective components within this continuum, it is possible to evaluate the degree of alignment and whether any mismatches occur and need addressing.

This paper focuses on the house building industry, and particularly prefabricated house builders, where the major structures for the buildings (such as walls) are built 'off-site' and final assembly takes place at the customer's desired location. Such producers primarily offer attractive, affordable housing, but also manage customer specific requirements with a high degree of client involvement (Gosling and Naim, 2009; Schoenwitz et al., 2012). Hence, it is a very interesting sector to consider the alignment of customer choice and operational strategies. Previous research has highlighted that meeting customer needs can increase customer satisfaction and market penetration. In this regard, clever product architecture is vital and can give the impression of a fully customised house by using standard components in the production process (Gibb, 2001).

The CODP has been used to analyse the strategy of such companies, for example the case studies of Toyota Home and Sekisui Heim (Barlow et al., 2003), but research has concentrated on the building level, rather than on the component or even attribute level. Given customer choice penetrates on all levels, such an approach over-simplifies the analysis considerably, links marketing and operations on a superficial level, and could lead to mismatches between products and operations structures (Schoenwitz et al., 2012).

Bringing together the above themes, the motivation for this paper is articulated as follows. Firstly, there are calls for more systematic approaches to the alignment of customer preferences and operational strategies to support them. This is particularly important for industries that offer highly customised products, such as those in engineer-to-order sectors including construction. Secondly, within the context of house building, the majority of approaches that currently exist have concentrated on the building level rather than on the component or even attribute level. A more detailed and systematic approach is required, which is informed by the broader literature on understanding customer preferences. Therefore, the overall aim of this paper is *to develop a systematic approach to the alignment of customer preferences and the levels of customisation offered through the operational processes within the context of the prefabricated self-build housing industry.* This aim is decomposed into the following objectives:

1. Determine the appropriate product architecture for a customised, prefabricated house.
2. Ascertain the priorities of customer preferences in the configuration of a prefabricated house.
3. Establish the position of the CODPs within the product architecture for a customised, prefabricated house.

The paper proceeds by firstly summarising the main literature relating to product architectures, customer preferences and process alignment, reinforcing the aims and objectives above. The research method is described, before the results for each stage of this process presented. Consequently, the discussion puts forwards a framework for how product, process and preferences can be aligned, before final conclusions are drawn.

2. Literature Review

In the literature on the marketing/operations interface, there is clear evidence that these two aspects need to be considered in conjunction, rather than as independent activities and that this should be an iterative process (Tang, 2010). For any product, the design phase is the starting point. Authors such as Fine (2000), Lambert and Cooper (2000) and Piller (2013) highlight that the appropriate design of operations is a result of the product and process combination. In doing so, the constitution of the product, also known as product architecture, needs to be known. Our proposition, which we explore in the section, is that the product architecture, once itemised, can indicate the number and configuration of components, but can also be used as a basis for analysing customer preferences.

2.1 Product Architecture

Ulrich (1995, p.419) defines product architecture as the “scheme by which the function of a product is allocated to physical components” while Fujita (2002, p.945) 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”. Fixson (2005) proposes that the product architecture includes the number and type of components and interfaces, giving the fundamental structure of a product. This is often viewed as a prerequisite for developing modular or platform products (Baldwin and Clark 2000; Ethiraj and Levinthal 2004). Claims have been made that an effective product architecture can offer very significant annual cost savings, resulting from component sharing, streamlining and platform based systems (Dahus et al 2001).

Schoenwitz et al. (2012) offer a hierarchical view of product architecture, clustering house elements into categories, components and subcomponents. A category would relate to a major product family or segment of the product, where it would be possible to identify component and sub-components that are required for the category. For example, the façade (category) of a house needs doors (components), which is made up a lock, door handle and other features (subcomponents). Choice can be introduced at each of these levels. This hierarchical perspective helps to determine relationships between different clusters of products, and through an analysis of historical data relating to customer preferences, they highlight the different levels of choice at these hierarchical levels. This model of product architecture was mobilized by Gosling et al. (2016) to show that product architecture, as defined in this way, can be used to facilitate production planning and supply chain decisions in projects.

2.2 Customer preference

Customer preferences are a complex combination of individual characteristics and it is a challenging task to determine preferences when customising products (Jobber, 2004). Consequently, 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). This has often manifested itself in high number of variations within a single product group. For example, Nissan tends to offer low variety within its product range (of the order of 10^3) while BMW and Mercedes have high levels of variety, with the number of variants being of the magnitude of 10^{17} and 10^{21} respectively (Pil and Holweg, 2004, Hu et al., 2008). 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 a main priority in many industries such as, for example, the car and fashion industries, with customers willing to pay a premium for a customised product (Tseng and Piller, 2003). In doing so, it is important to exactly know clients' preferences in order to deliver new product variety at a price that is acceptable (Stäblein et al., 2011).

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 initially 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, as a result of the increasing dissatisfaction of customers (Ozaki, 2003). 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; Hofman et al., 2006). A house is a complex product consisting of many components (Cox and Goodman, 1956), the risk of confusion is evident and choice in itself may not be beneficial. Offering an overly high degree of choice can cause confusion rather than satisfaction (Huffman and Kahn, 1998) and may have an influence on customers and their purchase decision. 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.

The difficulty with customisation is trying to capture individual data for each customer and configure the product accordingly. However, this is essential in housing design customisation with the benefit of increasing customer demand (Leishman and Warren, 2006). 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.

The importance of understanding the nature of customer preference in prefabricated housebuilding has resulted in the second objective for this study, with the recommendation of Blecker et al. (2004) influencing the approach taken.

2.3 Product and Process alignment

It is important for companies to align their own operations with the needs of their customers to achieve customer satisfaction along a continuum between standardisation and customisation (Lampel and Mintzberg, 1996). Otherwise, there is a risk of mismatch which can ultimately result in processes being inefficient or simply not meeting customer requirements. 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 CODP in general is a concept that decouples operations into two parts: forecast (upstream) and customer order (downstream). Although there are many definitions of CODP (see, Hoekstra and Romme, 1992, Naylor et al., 1999, Olhager, 2003 and Rudberg and Wikner, 2004), it is generally defined as the point in the value chain for a product where the product is linked to a specific customer order. The positioning of the CODP resulted in 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).

The strategic positioning of the CODP is a balancing process between market, inherent product properties and process related factors (Olhager, 2003). Hence, there are a range of factors that may lead to 'shifting' either forwards to a more standard offering, or backwards to allow more customer interaction (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 the context of the construction industry, Barlow et al (2003) show the trade-offs between different competitive dimensions when shifting between CODP positions. As the decoupling point moves closer to the customer, we typically find increased customization, but with increasing lead times and costs. As the decoupling point moves further away from the customer, we typically find reduced customization, but with decreasing lead times and costs. Wikner (2014) develops decision categories within a decoupling theory to further our understanding of how to make decisions about balancing these trade-offs.

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 (Figure 1). When client's requirements penetrate all the way through to the concept stage, the project is a purely customised Engineer-to-Order (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. Although the model provides a good conceptual overview of the characteristics of house building specific supply chains, it is on an aggregate level i.e. it only considers customer choice for the house as a whole and ignores the potential for choices to be made for the various categories, which may lead to different locations of the decoupling point.

Within the CODP literature, the number of papers focusing on the house building sector is few. 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.

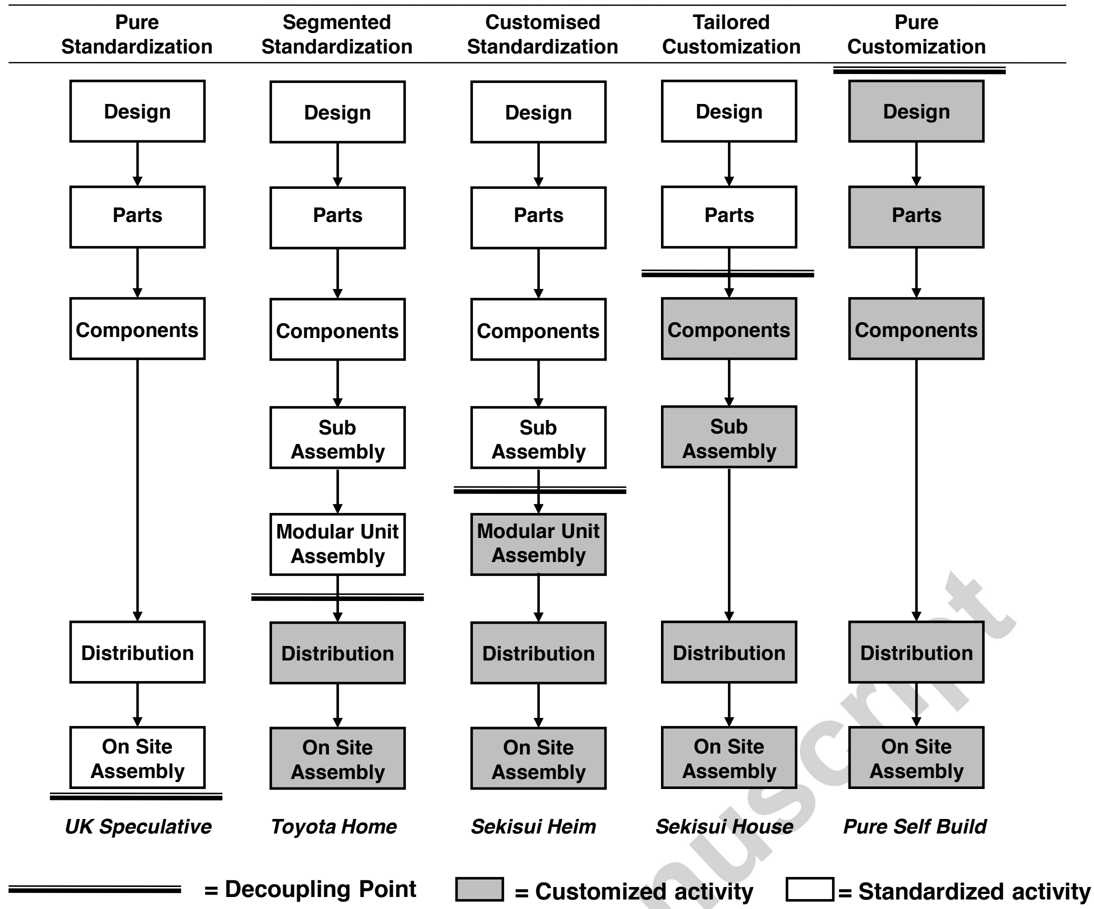


Figure 1: House building supply chain types (source: Barlow et al., 2003)

All of the aforementioned literature considers the CODP 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. 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. It is therefore important to be aware of the practical implications of the multitude of CODPs within a supply chain for products with complex product architectures.

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. 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.

Verdouw et al. (2006) 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. Similarly, Banerjee et al. (2012) postulate that it is increasingly difficult to identify a single strategic CODP due to the following developments: increasing costs, uncertainty, margin pressure, globalisation, modularity, complexity and competition.

A further dimension adding to the complexity of product architectures is the information flow. Mason-Jones and Towill (1999) explicitly define and formalise the information decoupling point concept, applying decoupling point thinking to the order information flow pipeline. They suggest that this is the point at which marketplace orders penetrate the pipeline without modification (Mason-Jones and Towill 1999). They also suggest that information is typically distorted upstream of the decoupling point.

The above literature provides insights for the development of the third objective, determining the CODPs for the components within a prefabricated house.

2.4 Summary of the literature

The above literature review has denoted that there exists only minor understanding of what customers prefer when configuring a house. 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, thus not appreciating the complexity of the product. Moreover there seems to be no research that links the identification of customer preferences with the required alignment of the production process in the house building industry. If customer choice can penetrate on all levels of the product architecture then it is important that the appropriate supply chain reflects this degree of choice. These gaps in the extant literature have resulted in the development of the overall aim for this study, as outlined in the introduction.

3. Research Method

The research presented in this paper builds upon two empirical research streams: a case study and a customer preference survey. On the basis of the case study, a view of the house as a system of categories and components has been developed. Furthermore, the location of multiple CODP for the categories and components has been identified. A preference measurement survey applying a pairwise comparison questionnaire based tool was conducted so as to define the level of choice expected by customers for the components. Combining these two streams allows consideration of the alignment between operational processes and customer requirements.

3.1 Case study

A German prefabricated house builder was identified as the case company. The main criterion for this was that this business manufactures self-build homes, that is, deals directly with clients who want to design and build their own 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). German prefabricated house builders account for 16.2% of all new build houses in their domestic market, over 13,000 houses per year (BDF, 2015).

Furthermore one of the authors was actually based in the collaborating company and provided considerable access including personnel and archival data. This facilitated data collection considerably as access to information sources was readily given. Ottoson and Bjork (2004) argue that when dealing with complex systems, such as engineering and product development projects, researchers should consider 'insider' and 'participatory' approaches to research.

A focus group was chosen to gain rich data with regard to the architecture of the product, in line with Ulrich (1995, p.419) and Fujita (2002, p.945). During a focus group discussion with the major stakeholders in the internal operations (sales manager, production manager, fit-out manager, purchase and technical manager) the different components within the product architecture were identified. A further outcome of the focus group discussion was a three-level hierarchy, building on previous research in house building (Schoenwitz et al., 2012) with the top-level being the product itself, the second level labelled as categories and the third level called components. The hierarchy can have lower levels but to avoid making the exercise too complicated for the focus group, sub-components were not analysed.

Verification that these parts of the house were customised was undertaken through the review of a random sample of house building projects undertaken by the case company. This confirmed that each component of the architecture was offered as an option, and also the extent to which customers chose to customise these.

Subsequently, an interview with the production manager as well as observation and process mapping of the material and information flows made it possible to position the CODP for each category and as a consequence for each component as well. This was an important task as it enabled a categorisation according to the current level of customisation for each component on the option list. Olhager (2012) points out that market information can be forwarded further upstream of the supply chain in order to enable advance planning. However, no evidence of a separate information penetration point could be found in this case and, hence, the information and material decoupling point coincides.

3.2 Questionnaire design and data collection

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.

Reflecting 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.

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. The 9-point bipolar scale with the appropriate values for the determination of the preference weighting is illustrated in Figure 2. In this particular example, the weighting determines the preference for window attributes in the facade of a house.

The paired comparisons for the preference measurement were set up using the above mentioned software and following the determination of a three layer product architecture in the case study, as will be shown in the Findings section. Not all components were included as otherwise the questionnaire would have been too long. Based on the case study results, only components with a high probability of being known to respondents were selected. Otherwise it would have been difficult for respondents to indicate their preference. Furthermore, the selection reflected the range of CODP locations (per Barlow et al., 2003) and the frequency that each component was customised, based on the examination of previous projects. While this may represent a limitation in understanding the full product architecture of a prefabricated house, the main aim of the paper is to develop a process for evaluating alignment. Therefore, the random selection enables effective testing of this.

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	Conside-rably preferred	Weakly preferred	Equal	Weakly preferred	Conside-rably preferred	Strongly preferred	Absolutely preferred	
Material of main door handle (handle or knob)	o	o	o	o	o	o	o	o	o	Locks with normal or higher security
Material of window and door handles (stainless steel or plastic)	o	o	o	o	o	o	o	o	o	Material of main door handle (handle or knob)
Material of window and door handles (stainless steel or plastic)	o	o	o	o	o	o	o	o	o	Manual or automatic window or door opener
Material of window and door handles (stainless steel or plastic)	o	o	o	o	o	o	o	o	o	Locks with normal or higher security
Manual or automatic window or door opener	o	o	o	o	o	o	o	o	o	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 2: Example of paired comparison question in questionnaire (source: authors)

Having finalised a draft version of the questionnaire, a pilot was tested with a group of three experts in prefabricated housing and two randomly selected members of the public. This testing was important to ensure that the questionnaire is 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.

A non-probability sampling method was applied. 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). A limitation of this approach is that bias in the choice of respondents can be introduced, although de Rezende and de Avelar (2012) observe that this does not necessarily mean that the population's view is different. An initial sample of 34 respondents were identified and contacted by e-mail with a hyperlink to the survey. However, in order to increase the number of responses it was specifically mentioned in the accompanying text that the link can 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 the above mentioned potential respondents. Following another four weeks the survey was closed and the link was deactivated. In total, 120 responses had been received. 33 responses had to be removed from the results spreadsheet due to biased responses. These included unrealistic responses to questions where for example 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. Consequently, 87 valid responses were further analysed. A demographic profile of the sample can be found in Table 1. During the questionnaire pilot, the experts were asked as to the profile of the customer base for prefabricated housing. Their view was that typical customers were couples (with or without family living at home), aged 40 to 70 and with a strong financial background. The data in Table 1 is reflective of this.

Table 1: Demographic profile of sample

		% of respondents
Age	20 years and younger	1.15
	21-30 years	11.49
	31-40 years	35.63
	41-50 years	13.79
	51-60 years	19.54
	Over 60 years	18.39
Size of household	1 person	5.75
	2 people	56.32
	3 people	17.24
	4 people	19.54
	5 or more people	1.15
Household Income	Less than €40,000	11.49
	€40,001 to €60,000	20.69
	€60,001 to €80,000	11.49
	€80,001 to €100,000	12.64
	€100,001 to €120,000	8.05
	€120,001 to €140,000	2.30
	Over €140,000	10.34
	Not stated	22.99

3.3 Preference measurement method

In order to determine customer preferences and find out how the identified components are prioritised by home buyers configuring a house, a customer preference measurement was undertaken. In general this is complex and difficult as many customers are not able to exactly specify the importance of product attributes. Moreover the perception of an attribute independently 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, where each attribute and level is evaluated separately;
- Decompositional, considering attributes and levels jointly; and
- Hybrid, which combines compositional and decompositional.

There are a number of techniques within these categories that have been used to measure customer preferences, for example: Quality Functional Deployment (Cherif et al., 2010), Analytic Hierarchy Process (Scholl et al., 2005) and Conjoint Analysis (Green and Srinivasan, 1993). 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 (Scholz et al, 2010, Meißner et al., 2010). PCPM uses paired comparisons where the respondent indicates a preference of an element over another element. 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 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).

One advantage of the PCPM approach is that it takes into account the Number-of-Levels Effect. In AHP 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 (Liu et al., 2009). The PCPM approach tries to balance this effect by multiplying the respective preference weights by 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).

Hence, the PCPM is used in this study as it has been successfully applied in complex product environments (e.g. Scholz et al., 2010). Moreover, it is critical for the success of a preference measurement that apart from the actual technique 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. For a customer preference measurement this means that questions need to be visualised effectively as given in Section 3.2 utilised the AHPlab software.

3.4 Customer preference and process alignment

The final stage of the research was to evaluate the alignment between customer preferences and CODP positioning. A matrix was developed, shown later in Section 4.4, with the x-axis showing the weightings given to each category and component in the product architecture. These have been grouped as high, medium and low, with thresholds identified using a class interval calculation (Silver, 1997) based on the take up of options observed in the case study. Thus, weightings from 0% to 30% are rated low, 30% to 60% medium and 60% to 90% high. No option was customised in over 90% of the sample of houses examined. The y-axis is adapted from Barlow et al. (2003) and differentiates between the different categories of customisation shown in Figure 1. The categories and components were then plotted on this matrix to identify areas of alignment and mis-alignment between customer preferences and the operations processes. Triangulation between the data sources was used to verify the positioning, along with further feedback from experts in prefabricated house building (Patton, 2002).

4. Findings

4.1 Conceptualisation of product architecture

The case study analysis yielded a product architecture tree diagram as shown in Figure 3. Three levels were identified. The top level is the house itself, as the finished product to be made. The case company itself undertakes the complete build. Next come categories, which are made up of clusters of components that reflect the overall category. Façade, construction design and internal design reflect the main physical structure of the house and are undertaken by the case company. By contrast, home technology, heating and sanitary relate to the fitting out of this physical structure. These are separated into the three main systems found within a house – electrical (termed home technology), heating and water (termed sanitary) and are all procured via one of the case company's subsidiary organisations Finally, additional services are listed. This category reflects components that may not exist with every house building project and depend upon the requirements of the buyer. The case company undertakes basement, garage and carport in-house while all others are fully outsourced.

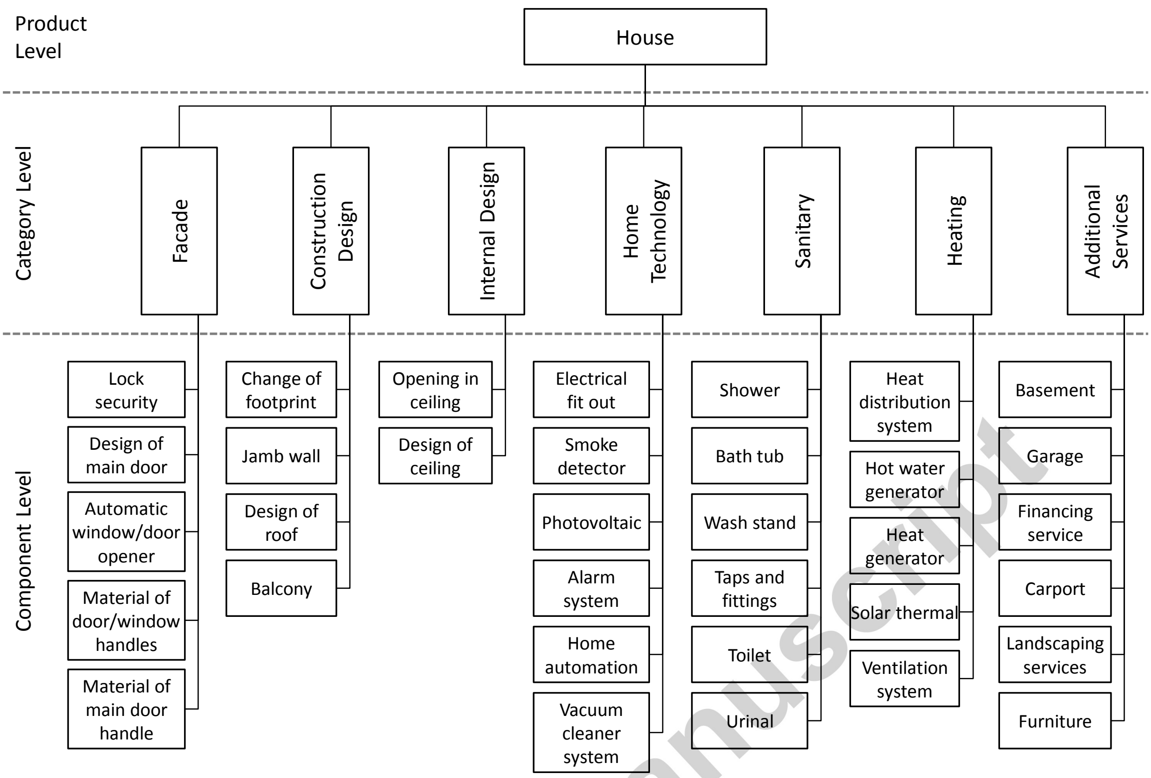


Figure 3: Product architecture matrix of a prefabricated house (source: authors)

The final level is components. These are individual parts of the house that could be customised, and in total 110 different components were identified. Some cover the physical appearance of the overall building, such as the overall footprint and the types of glazing in the window, while others relate to fixtures and fittings, e.g. bath tub or fireplace. Furthermore, attributes for each component were identified to inform the preference survey. Comparison with completed projects showed that all of the identified components were offered as customisable options, although the level of take up by customers varied widely. Because of the large number components, and the technical nature of some of them, a rationalised list was used in the preference measurement survey, and only those included are shown in Figure 3. Despite this, the figure indicates that a house is a highly complex product consisting of many different components and categories, often with interdependencies between them.

4.2 Customer preference measurement

An early question in the survey was 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 this is rather important or very important. 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 or where unnecessary options can potentially be reduced.

Thus the respondents were asked to assign an importance to the categories as identified in Figure 3. This is the first indicator with regard to customer preferences. The respondents indicated particular customisation interest as shown in Table 2.

Table 2: PCPM results on category and component level (source: authors)

Category	Weighting	Component	Weighting
Façade	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%
		Financial service	20.21%
		Carport	11.75%
		Landscaping services	9.61%
		Furniture	6.33%

The desire to customise is relatively high in categories construction design (18.31%), home technology (16.94%) and heating (18.01%), whereas in categories such as internal design (12.85%) or facades (12.60%), sanitary (13.67%) and additional services (7.62%) it is relatively low. However, this does not mean that within these categories customers do not wish to have a high degree of choice for certain components. In the third column of Table 2 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 for 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. Hence, 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.

The results not only show where choice needs to be offered but they also show which categories and components can be neglected. This is probably more important than to know what needs to be offered as every option that does not need to be offered any more reduces variety, complexity and cost.

4.3 Identifying the CODP

In Figure 4 the CODP for each category have been mapped in the standardisation-customisation model originally introduced by Lampel and Mintzberg (1996) and further refined by Barlow et al. (2003) as previously presented in Figure 1. This shows a number of strategic options. On the left hand side there is the 'Pure Standardisation' operations strategy which means that products made using this strategy will not be customised at all. On the right hand side there is the 'Pure Customisation' operations providing products make-to-order (Barlow et al., 2003). The positioning in this model has been completed using the case study data.

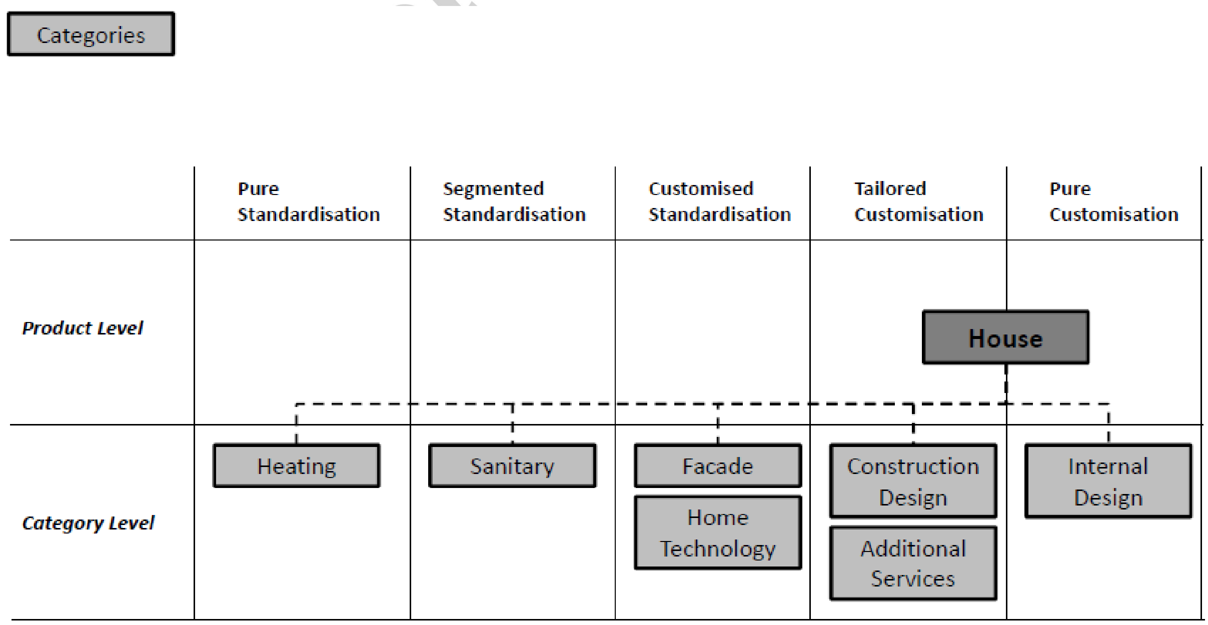


Figure 4: Determination of CODP position at category level (source: authors)

Furthermore, in Figure 5, as an example, the category 'Construction Design' has been decomposed into its components. This is presented because, as shown in Table 2, it is the category that the survey respondents had most preference for customising. The components have then been mapped using the same form of representation. As can be seen, although a category can be classified as per the Barlow et al. model (2003) with one level of customisation, the components and sub components can be classified completely differently. This highlights the importance of decomposing a product before making decisions with regard to the order fulfilment strategy. The remaining categories according to Figure 3 have also been decomposed and are presented in Table 3.

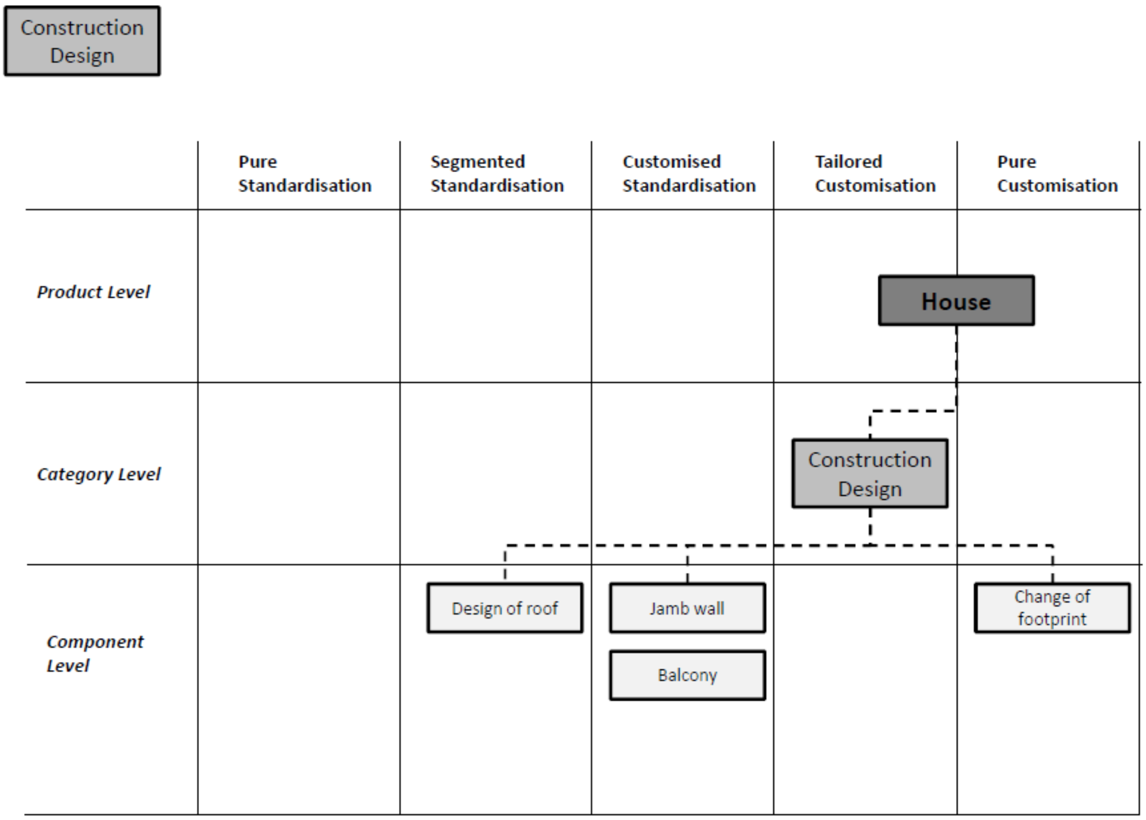


Figure 5: Determination of CODP position at component level using "Construction Design" as an example

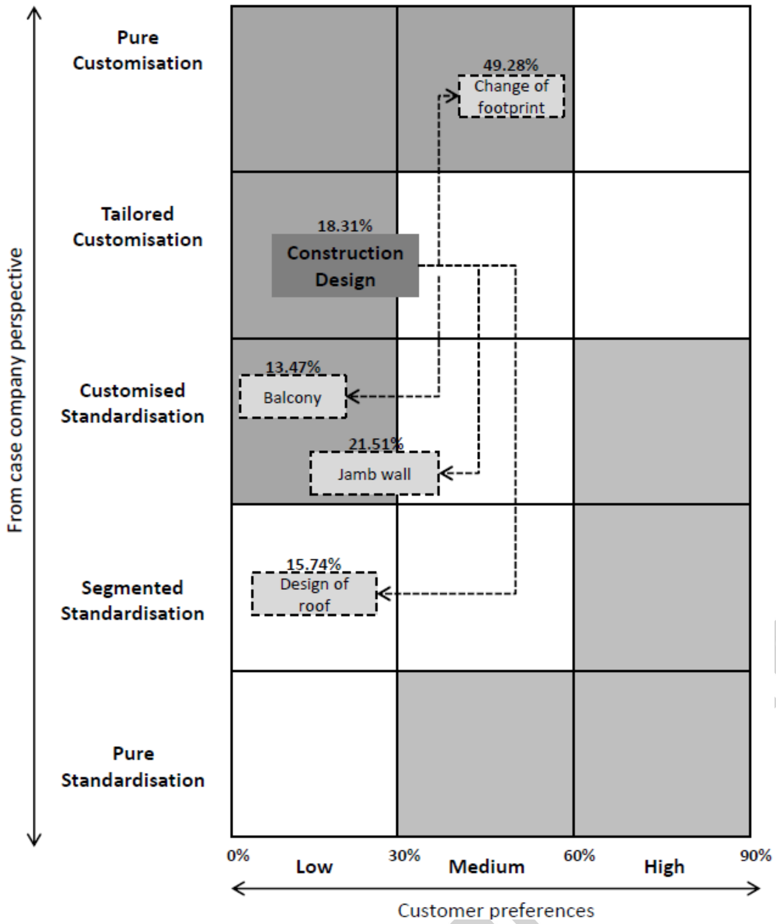
Table 3: CODP positions for components (source: authors)

Operations Strategy	**Component**
Pure standardisation	• Lock security, automatic window/door opener, material of door/window handles (Facade) • Alarm system (Home Technology) • Bath tub, wash stand, taps and fittings, toilet, urinal (Sanitary) • Heat distribution system, solar thermal, ventilation system (Heating) • Smoke detector
Segmented standardisation	• Design of roof (Construction Design) • Photovoltaic (Home Technology) • Shower (Sanitary) • Hot water generator, heat generator (Heating)
Customised standardisation	• Design of main door, material of main door handle (Facade) • Jamb wall, balcony (Construction Design) • Vacuum cleaner system (Home Technology)
Tailored customisation	• Opening in ceiling, design of ceiling (Internal Design) • Electrical fit out (Home Technology) • Garage, carport (Additional Services) • Home automation
Pure customisation	• Change of footprint (Construction Design) • Basement, financing services, landscaping services, furniture (Additional Services)

Although the CODP for each category and component has been positioned by determining the degree of customisation based on the case study results. However, from a process point of view it needs to be highlighted that there are interdependencies between some of the components. Therefore, within the operations strategy there also needs to be a time-line showing when which decision is required in order to avoid a negative impact on lead time.

4.4 Aligning case study with customer preference measurement results

As discussed earlier, the alignment evaluation made use of a matrix based upon the level of preference of customers on the x-axis and the Barlow et al. (2003) supply chain structures on the y-axis. Two examples of the matrices, for construction design and sanitary, are shown in Figure 6. The appropriate percentage reflecting the particular customisation interest of respondents can be seen above the category and components.



Pure Customisation
Tailored Customisation
Customised Standardisation
Segmented Standardisation
Pure Standardisation
From case company perspective
49.28%
Change of footprint
18.31%
Construction Design
13.47%
Balcony
21.51%
Jamb wall
15.74%
Design of roof
0%
Low
30%
Medium
60%
High
90%
Customer preferences

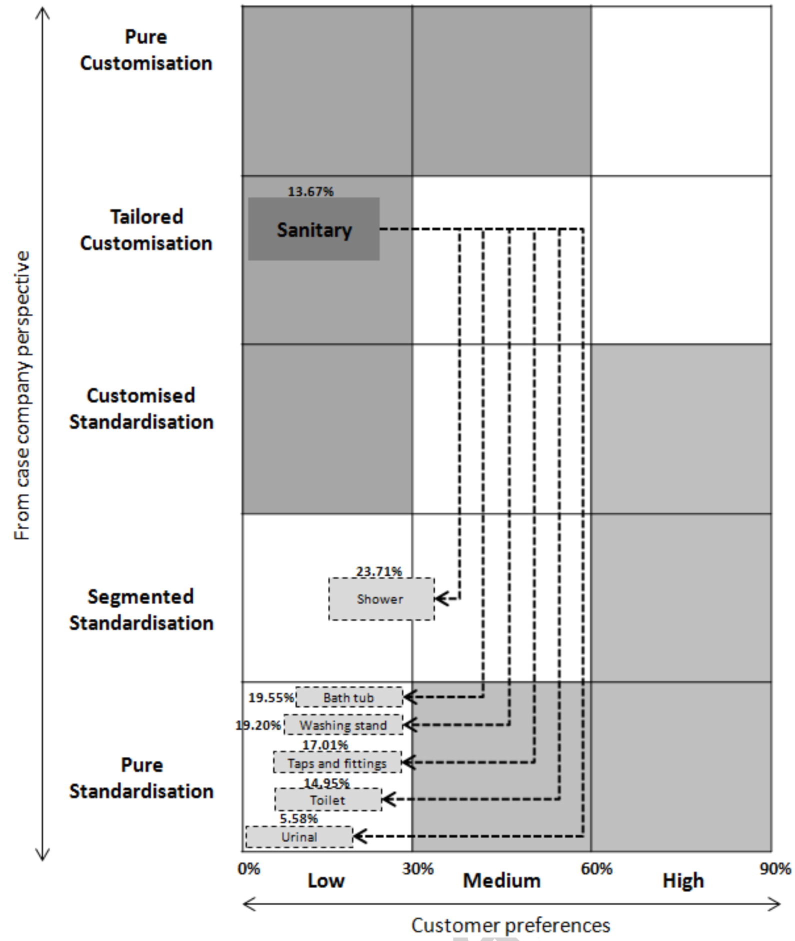


Figure 6: Alignment of strategic options and customer preferences (source: authors)

Figure 6 suggests that the unshaded boxes represent areas of alignment, so where 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. Interestingly, the majority of components are located within this region. In the example in Figure 6, the roof design aligns with the level of customer preference. Customers generally have a low preference when it comes to customising the roof, such as by including a dormer. These are considered segmented customisation because the house builder has standard modules for a dormer which can only be customized to a certain degree. Furthermore, the design and colour of roof tiles are also included in this category as there are not many options for this.

Categories / components that are positioned in the upper shaded areas are of particular concern for the house builder; customers only require low choice according to the preference measurement but nevertheless the company offers a relatively high degree of customisation indicating time, effort, resources and costs. Although not shown here in order to ensure succinctness, we found that all of the categories are located within this region, with 10 of the components also found there. Typically costs in customisation systems occur both in sales and customer interaction as well as in manufacturing (Piller et al., 2004).

As can be seen in Figure 6, the category (construction design), as well as three components (change of footprint, jamb wall and balcony) are in this upper shaded area signifying a lack of alignment between the operational strategy and the customer preference. In terms of the footprint of the house, this is largely left to the customer to define, subject to some constraints to ensure the building is structurally sound. However, the preference measurement suggests that customers may prefer slightly less choice in this area. A solution would be to provide some standard configurations from which the customer could then adjust to suit their requirements. With the balcony, customers are offered a range of materials from which the balcony could be made, and the size of the balcony reflects the design of the house. However, there is low preference for this, suggesting that maybe a limited range of standard balconies could be offered. Alternatively, given the low preference, a price premium could be charged for those customers wishing to have a balcony.

As another example, the sanitary category also is in this upper shaded area, with the operational strategy reflecting tailored customisation but the overall level of customer preference was found to be low. However, for each of the components within this category, there is alignment, with low preference scores and generally pure standardisation (the exception being shower, with segmented standardisation). Here, customisation is offered through a large catalogue range of components available on short lead times. The combinations of these provide the tailored customisation, yet individually they are effectively standard products.

The categories / components in the lower shaded areas could also require some investigation by the house builder. Although being very important for customers in requiring 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, long 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. In this research, only one component was found in this lower area.

Customers expressed a medium preference for locks with either a normal or higher security level, yet the operational strategy was pure standardisation. In this case, these components are available on a very short lead time, relative to the whole house building project, and therefore the operational strategy does not need to be adjusted.

5. Discussion

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.

Figure 7 is a visualisation of a managerial framework that reviews the gap between customer preferences and the degree of choice offered. The light grey shaded boxes reflect the steps presented above, leading to the gap analysis presented in section 4.4. 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 (Sanchez, 1999, Shieh et al., 2008). This means that a product's redesign is a direct response to customer needs and will entail due consideration of the reconfiguration of the product architecture (Sanchez, 1999). In this regard, it is important that the customer preference measurement is conducted in the appropriate target market. However, there is also another influence that drives product redesign: introduction of new technologies, new regulations 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 lower level of heat loss from the building. This improvement had a direct effect on the product architecture as new materials were introduced.

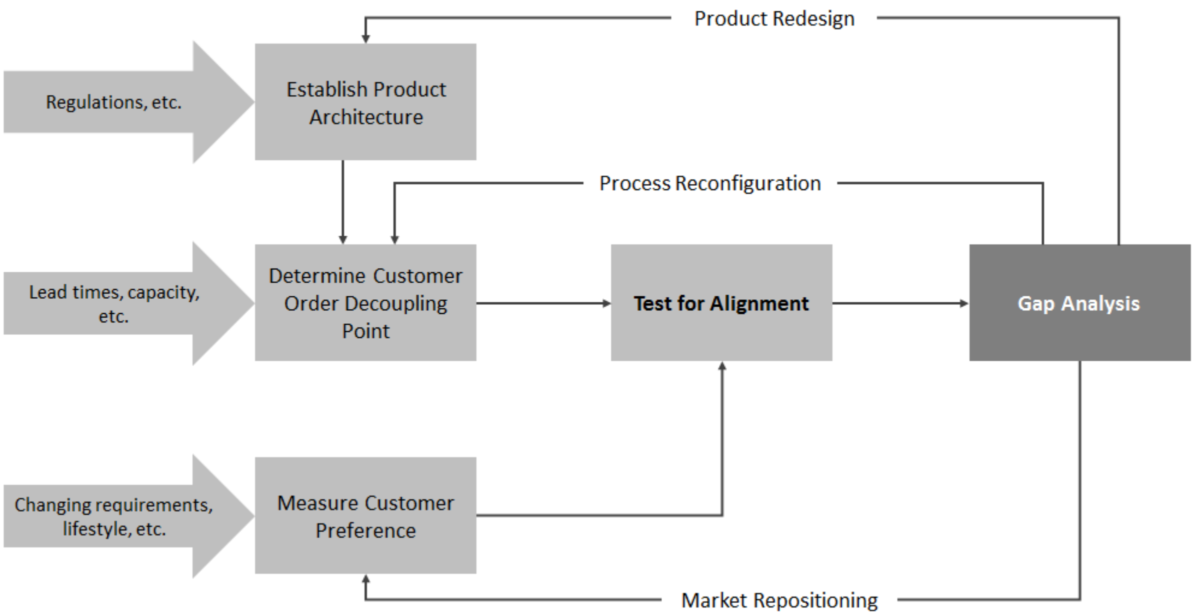


Figure 7: Product, processes and customer preferences alignment framework (source: authors)

Secondly, if the gap analysis results in a misfit between the customisation strategy applied and the requirements as determined in the preference measurement, processes can be reconfigured. A good example of a Japanese house builder that has done this is given in Barlow et al. (2003) and is commensurate with the three-dimensional concurrent engineering concept proposed by Fine (2000), that is, concurrently redesigning product, manufacturing process and the supply chain. As seen above, the house builder could benefit by reducing the choice for certain components and providing standardised offerings instead.

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 was the launch of a new house type after the case study data was collected. This offered 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. Figure 6 demonstrated a lack of alignment for the footprint of the house and this new development could address this.

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 component list. Only this ensures that there is constant alignment between the customisation strategy and the customisation requirements. Combining product, process and customer preferences in a meaningful and integrated way will result in competitive advantage (Piller, 2013).

6. Conclusions

This paper has addressed the challenge of better understanding how to make what buyers want. This was operationalised by considering product, process and marketing concepts in order to analyse customer preferences and the operational strategies used to satisfy them. The study was informed by an in-depth case study of a German pre-fabricated house builder and a customer preference survey, which yielded 87 responses.

The first objective of the paper was to determine the appropriate product architecture for a customised, prefabricated house. Based on the case study elements of the research, a product architecture for a prefabricated house was proposed which decomposes the product hierarchy into 3 levels: product level, category level and component level. The second objective was to ascertain the priorities of customer preferences in the configuration of a prefabricated house. Based on a customer preference measurement survey, Table 2 presented PCPM results showing preferences for categories and components. This shows that customer preferences vary between different categories and components. Customer desire was higher in construction design and home technology and lower in sanitary and additional services.

The final objective was to establish the position of the CODPs within the product architecture for a customised, prefabricated house. Based on the customer preference measurement results and case study evidence, Figures 4 , 5 and 6 presented a CODP analysis for product categories in the case study. Different levels from the product architecture were classified according to the CODP categories proposed by Barlow et al (2003), giving a more comprehensive understanding of the range of operational strategies employed in the case company.

The overall aim was to develop a systematic approach to the alignment of customer preferences and the levels of customisation offered through the operational processes within the context of the prefabricated self-build housing industry. A framework was developed to consider alignment options in figures 6 and 7. Adopting a class interval approach, this positions current customer preferences indicated by the survey with CODP strategies utilized by the case study company. Using construction design as an example, the analysis shows that some of the current strategies are misaligned. If such a misalignment arises, three different routes are proposed for alignment: product re-design, process reconfiguration or market repositioning (see figure 7).

A number of contributions are made in the study. The customer preference measurement survey, based on the PCPM approach developed in (Meißner et al. 2010) translates a technique developed in a mass consumer products context into a one-of-a-kind customised building setting. The analysis of CODP positions in the case study applies concepts from Barlow et al. (2003) in a new empirical environment. In doing so, the paper expands the focus of CODP research by considering component and attribute level of the product architecture. This better reflects the complexity of customised products. Overall, the study adds to the theory testing of the general body of knowledge relating to alignment of operations and marketing strategy (Hill and Hill 2012; Pero et al. 2010). The practical implication is that companies need to avoid committing resources into customisation activates that are not valued. The process of alignment outlined in the paper may act as a template for companies to analyse and consider their options.

A cautionary note must be added, as the findings are based on a single case study within a particular market sector. 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. It would be interesting to see further research being undertaken by other industries that produce customised products.

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Highlights

- Determines the product architecture for a customised house.
- Ascertains that the customer order decoupling point (CODP) for a house as a whole.
- Different CODPs exist for various constituent elements of a house.
- Customer wants for choice vary for each element.
- A method is given for testing customisation offering versus customer preferences.