PRODUCT CONFIGURATION IN THE HOUSE-BUILDING INDUSTRY

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The UK house-building industry has often been criticised for failing to meet the housing needs of the country with the relatively narrow range of its products. There have been calls for the sector to adopt the concept of mass customisation, which sees the convergence of the distinct approaches of mass production and custom-build industries to bring the benefits of wide-ranging product choice efficiently and economically to the mass market. For a customer to be truly involved in the definition of the product, the design process has to be extended to include the sales and service functions, and the customer interface has to be accordingly re-engineered. For a complex product like a house, effective communication of options available, the accurate and efficient capture of the choices made and their translation into build requirement can be a difficult process. The paper presents work on the development of a home configuration system to support the different stages of the house-buying process – pre-sales research by the customer, product selection and its translation into a format that the business can utilise for order fulfilment. The system aids the selection process with a flexible but robust way of navigating through the choices and with product visualisation.

Keywords: house building, customisation, information management, product configuration.

INTRODUCTION

The UK house building industry is dominated by a small number of speculative builders for whom the dynamics of land- and house-price inflation have been the main business drivers (Barlow 1993). It has been criticised for slow pace of innovation, often driven by threats rather than opportunities (Ball 1998), and for products that are excessively standardised and of relatively poor quality and expensive to build (Ball 1996, 1998, Egan 1998). Changing consumer attitude towards home-ownership and its investment value (Forrest and Murie 1994), and experiences in other sectors (Cooke 1996) are leading customers to expect a higher quality of products and services. There have been calls for the industry to address these concerns by moving from the craft production of a limited range of products to mass customisation of housing based on industrialised building methods (e.g. Barlow 1999). The concept of mass customisation sees the convergence of the distinct approaches of mass production and custom-build industries to provide a great variety of products and satisfy individual requirements at prices that are competitive with those of mass producers (Pine II 1993, Lampel and Mintzberg 1996). Customisation may involve late configuration of discrete options from a large pre-defined set, and even a degree of custom-design in the later stages of production. For the house builder, there are a number of implications. For example, product design based on the concept of ‘open building’ will be needed to simplify interchange of components (Sarja 1998). The builder will have to rethink the way it perceives its market (Barlow 1999) and re-engineer the

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interface with the customer, who will be involved in the definition of the product. The paper discusses the requirements of this new customer interface, and presents work on the development of a product configuration system to support it. It is part of a more wide-ranging study of the sector that is being carried out with a major house builder.

PRODUCT CHOICE

Speculative house-builders offer relatively few choices to their customers. Product ranges are defined primarily by type (terraced, semi-detached, detached), a small number of architectural styles, and the number of bedrooms which is usually fixed for a given plot size/price bracket. The internal layout and specification is largely fixed for a given product range. The choice offered is usually limited to fixtures and fittings (kitchens / bathrooms etc), and even then if the order is placed in time within the build schedule. Market coverage is wide - products usually range from entry level 2 bedroom houses to 5 bedroom homes specified to a higher level, but segmentation is shallow, with little account taken of the different types of trade-off decisions that various demographic groups have to make (Roy and Cochrane 1999). A growing diversity of household formation is likely to make greater product variety even more of an imperative (DETR 1997). Builders tend to put forward market conservatism as the reason for their current business strategy (Barlow 1999). However, compared to other industries there have been few attempts to develop the product through customer feedback (Ball 1998) and gather market intelligence on unarticulated needs (Barlow 1999). The second-hand market, in contrast, provides much greater choice, and a recent household survey suggests that the limited portfolio of products offered by the builders may be restricting their market penetration (Roy and Cochrane 1999).

The range and nature of choice that a builder offers its customers will be partly a policy decision, but will also be dictated by the business and regulatory environment. A bespoke service is not considered suitable for the mass market because of the associated higher costs and longer lead times for order fulfilment. The lengthy procedures for obtaining planning permission on the 'street scene' would also rule out customisation of the external features of a property. Hence, at least at present, the scope for customer input into the product design is mainly limited to the internal layout, room configuration, and décor and fittings. As the industry moves towards a mass customisation strategy and offers greater choice, it is important to put processes in place for management of the resulting increase in business complexity. A suitable framework will be needed for the succinct definition of the range of products on offer and its limits, and the controlled introduction of choice in stages.

Internal Layout

Traditionally the design of the internal layout is geared towards maximising the number of bedrooms for a given plot size/price bracket. Defining the basic product (house type), instead, as a set of modular components (e.g. footprint, layout, rooms) would enable the house builder to increase the level of product flexibility without the same level of increase in its complexity. The concept of the design philosophy is based on component swapping modularity (Ulrich and Tung 1991) in which, subject to any technical constraints, different components are swapped within the same basic product, creating a large number of combinations from a relatively small range of components. If the shell of the property was designed as a separate component to that of the internal layout and fittings of the home, then a builder could develop a number of alternative products, which could be pre-designed according to the intended market

segment (e.g. single person, empty nester). The products will have to be designed to take into consideration technical constraints (location of services, load-bearing walls), and around the features of the footprint (location of the chimney, windows, doors) so as not to destroy the balance or appearance of the home. Many builders have been redesigning the portfolio of their products to eliminate or minimise the number of load-bearing internal walls (Barlow 1999), which should provide greater flexibility in the modelling of the interior of the home. Consideration should also be given to the way in which the products are marketed. For example, it might be advantageous to describe the property in terms of its area of living space instead of by the number of bedrooms. This is usually resisted by builders on the ground of customer acceptability (Barlow 1999), but is a practice common in many other countries. More of an obstacle may be the way valuation of properties is carried out in the UK.

Room Configuration

The internal layout defines only the number and size of the rooms. The functionality of a room (e.g. bedroom, home office) is a separate choice and, by designing each internal layout in a way that the rooms are modular components with easily interchangeable end functions, it would be possible to provide the customer greater flexibility in defining the product. In the case of bathroom and kitchen, manufacturers provide house builders with a number of pre-designed products, but tend to generate only one design for each house type. It should be possible in many cases to offer the customer more choice by developing a number of kitchen and bathroom styles for a given layout, as is common in Japan (Bottom *et al.* 1994).

Décor and Fittings

The options available on internal décor and fittings may be large but will be dependent upon choices already made on the internal configuration and other features, and a mechanism is required to control the selection process based on an inherent rule or prior sales knowledge; for example, a tumble dryer can only be in a room with an extraction vent in the wall. There may also be some natural combination of options that serve a particular household requirement, and it might be beneficial to market the available choices as a set of packages. For example, if a home office is selected as an option, there may be two packages of fittings to suit different household requirements - for a home worker, the configuration may include additional communication ports and a secure floor-safe, whilst for family use it may include additional storage areas and shelving for books. The house builder may also offer additional home-related products or services, e.g. white goods, security system, home networking.

THE CUSTOMER INTERFACE

For a customer to be truly involved in the definition of the product, the design process has to be extended to include the sales and service functions (Tseng *et al.* 1996). There are many opportunities for improving the current interface between the customer and the business (Fig. 1) to deliver a customer-friendly and efficient operation, and certainly it will need to be re-engineered if it is to cope with the inevitable increase in complexity as a strategy of mass customisation is implemented. The observations made here are based primarily on an analysis of the Partner Company’s operations, but are believed to be fairly typical of the sector.

Pre-sales Enquiry

In the pre-sales enquiry phase, the customer gathers information on the local area, house types, product availability and price, and this would typically involve several telephone calls and site visits. The important aspect for the customer is the ease with which information can be collected. Many large builders already have a website, and the Internet provides a convenient medium to initiate the search process. However, the business use made of the website is currently limited, primarily offering passive forms of information in what has been described as brochureware (Kiani 1998). If it were also used to capture any preliminary product selections, this will shorten the time the customer will need to spend later with a sales negotiator.

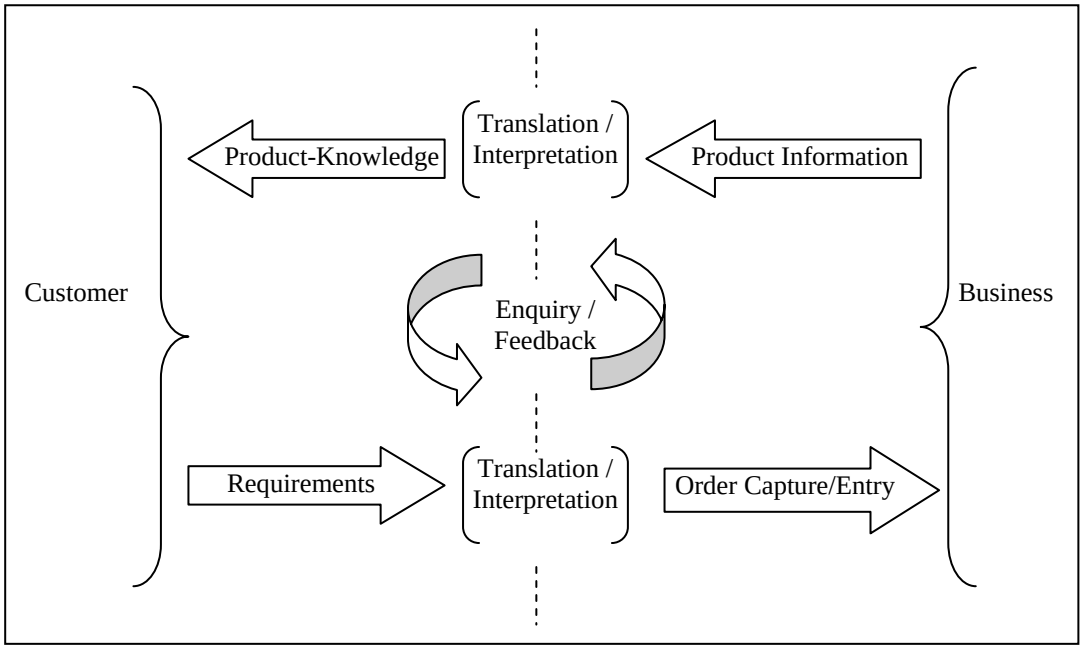

Figure 1: The Customer Interface

Product Demonstration

Currently product demonstration material is mainly paper-based and focuses on the architectural style and décor of the finished product, whilst the spatial layout is represented with a 2D floor plan. This is usually an inadequate form of visualisation, and most builders have a show-house on site to demonstrate a standard product range. To demonstrate fixtures and fittings, sample products (e.g. kitchen tiles and worktop selections) are mounted onto to a product carousel. As product variety and complexity increases, new, more flexible methods will be needed to demonstrate product choices. The use of computer-based visualisation tools is a solution (Whyte 2000) but, on their own, they do not focus on all the five senses (Ryan 2001). A better solution may be to use it in conjunction with other mediums such as video and, as currently, with paper-based brochures and physical samples to provide a more complete experience. An example of an effective use of a video would be the demonstration of the workings of an expensive locking mechanism for a garage door.

Product Selection

The current product selection process takes place over a number of days at the site office and may involve extensive communication between the sales negotiator and internal departments to establish the technical feasibility of certain permutation of choices made. Lack of integration of commercial and engineering software systems is a common problem in the industry; access to computers is also usually limited at the

building sites. Often customer queries are left unresolved between meetings and communications are prone to errors. The problems will only increase with greater product variety, as it becomes difficult for the sales team to provide the customer with information that is clearly defined, relevant, up to-date and accurate. Great care is needed in the design of the process and any supporting system to ensure a customer-friendly and efficient operation. The selection mechanism itself has to present information in a logical and structured manner and resolve customer queries efficiently. It should provide an appropriate level of flexibility in the decision-making process, and robustness to avoid lengthy duplication of data entry when changes to the product specification are required. It should also be designed to assist the customer in the decision-making process by allowing them to try out a number of possible permutations prior to committing to any purchase.

Order Translation
The sales team is responsible for defining and maintaining a record of each plot specification. The current, manual process that is prevalent is prone to errors and inefficiency due to the amount of administrative overhead of maintaining plot, product and customer data; it is estimated to account for around 40% of a sales negotiator's time in the Partner Company. With an increase in product variety, it is important that the order-fulfilment process and any supporting system be designed for efficient translation of the (sales orientated) product selection data into a build specification that can be used in the construction of the home.

Customised Output
The builder usually provides the customer fairly limited documentation of the selected property/ product. The hand-written forms are of a generic format and are identical to that used by the building contractor. With mass customisation, personalised documentation will be needed, which should be designed to be more meaningful to the buyer than the builder. Care needs to be taken to provide a description of the home that complies with the Property Misdescriptions Act 1991 (HMSO 1991).

There is a need for many other changes in the order fulfilment process. The way the construction process is managed, for instance, will have to change to maximise the scope for mass customisation (Gann 1999, Roy and Cochrane 1999), e.g. separation of the construction of the structure of the house (or ‘support’) from its fit-out (or ‘infill’). The relationship with the customer and the process of customisation will also have to be managed in a way that minimises the risk to the builder of being left to sell a non-standard product if a customer fails to proceed with the purchase (Barlow 1999).

A PRODUCT CONFIGURATION MODEL

Product configuration tools emerged from primitive ‘expert systems’. The range of features provided can be categorised by market sectors, which defines the complexity of the task (Lundstrom 1997) - pick to order from stock; assemble to order; configure to order based on specific customer application and performance needs; engineered configure to order requiring a degree of product engineering; engineered to order for products that are very application specific. For reasons discussed earlier, the scope for customisation is limited in the case of the speculative house-building industry in the UK, and configuration to order is the most realistic option. The work presented here towards the development of a Home Configuration System (HCS) has three main objectives – communicate product information in clear and concise terms from a customer, not technical, perspective; provide a simple and flexible, but robust

approach to product selection; translate customer orders in a form that can be utilised by sales, construction, purchasing and other business functions. The system has been developed using a knowledge-based configuration platform, Knowledge Builder (Cincom 2000), and has the following main features.

PRODUCT SELECTION

Location / plot selection. In this stage the customer is involved in gathering field-based information regarding the local area and the selection of a basic product range (architectural style / footprint). HCS assists by recommending sites and products based on the following criteria - geographic location (region / county / town), number of bedrooms, price range, and structure type (terraced / semi-detached / detached). The customer can select either the plot or the location first; the system filters out the available plots with the selected product in a given locality (e.g. town). The system also can direct the customer to the builder's web-site (if one exists) to view or print a textual description of the local area and marketing information regarding the plot, as well as leave contact details and arrange a site visit.

Internal configuration. This stage allows the buyer to define how the floor space is used in terms of the internal layout and functionality of rooms (e.g. home office, bedroom). Each option is predefined and packaged to suit different household requirements. The available options are governed by a series of rules to ensure that the configuration produced is always valid for a particular construction phase and product combination. Images of the floor plan / room are displayed along with dimensional data and a marketing description to assist the selection process. Although not yet implemented, it should be possible in the future to allow the location of some internal walls to be varied within predefined boundaries. The internal configurations selected are used to personalise the remaining options on décor and fittings.

Selection of décor and fittings. This stage allows the customer to select the internal décor, fittings and home-related products (e.g. white appliances, security system). The selections are categorised on a room-by-room or themed basis (e.g. kitchen, bathroom) and governed by the knowledge base to ensure compatibility and availability. The system allows the display of an image and a description of a selected product, or additional marketing material, e.g. a video, through a hyperlink.

Visualisation. To create a visualisation of a room, an advanced room planning and real-time visualisation design package, Virtual Worlds (Logicom 2000), has been incorporated. Visualisations are created by importing and positioning detailed 3D objects into a customisable room layout. The software allows the completed scene to be output as a high quality photo-realistic render or as a panoramic view in a file format suitable for web integration. In the current version of HCS, library files of digital photos, rendered images, videos and panoramic models, and links to web sites can be called up for display to demonstrate a product option; a reference to the appropriate file is stored as a parameter of the product in the database. True integration of Knowledge Builder and Virtual Worlds will be required to enable data sharing for real-time interior design or creation of models based on selected product options. This will require additional work on the part of the software vendors.

Marketing profile. Not all product options will be relevant to every customer group, e.g. a retired couple is unlikely to be interested in a child's playroom. In HCS, marketing profiles provide a mechanism for packaging product options into different views depending on factors such as price, customer lifestyle or regional preferences.

SYSTEM OUTPUTS

Order portfolio. During the sales process a number of outputs are available that document the product selections and the progress of the purchase. The portfolio includes a property reservation form, marketing material and plot specific information detailing the home and product selections.

Order quote. In HCS, there are two options for generating a quote. The first option displays a figure in real-time during the product configuration; as selections are made the quote increases or decreases. Alternatively the cost calculations are carried out in the background, but used to restrict the customer selections to a predetermined budget; a warning message is displayed if the total value is close to the budget or exceeds it.

Requirements generation. Completed customer selections can be translated into a list of materials with part codes. With appropriate software integration with other business systems/ modules, the output data can be used to generate, for example, a build specification. In HCS, product translation is achieved using a component hierarchy tree. The hierarchy defines the product structures and the relationships between components, and includes functions to calculate quantities of material and cost. Each node in the tree is interpreted individually, which allows the list of components to be generated from user inputs or inferred through product knowledge. The Bill of Material generated is directly used to populate a pre-designed purchase order form that can be faxed or e-mailed to the appropriate supplier.

SYSTEM DESIGN

Data/ knowledge representation. There are four main types of data used in HCS – customer/ order details, plot data, layout and room information, and component data. The database is structured for ease of maintenance; for example, a list of layouts is stored in one table, and the list of their attributes (technical specifications, marketing description, pointers to images) stored separately as parameters to enable attributes to be added without having to add fields to the database. Information on components is also similarly structured, and individual components (e.g. plug, basin, taps) can be grouped into a higher order product/ component set (e.g. washbasin) with a many-to-many relationship between the two data items. Typically a set is used to describe the product in terms of its features in a sales-friendly language rather than part numbers.

The knowledge base contains rules that are used to check the product selections (at the point of sale/ enquiry) for their availability and marketing/ engineering compatibility. The rule representation in HCS knowledge base can be classified into four categories. *Constraint-based rules* are the most commonly used type, which restrict the product options based on known facts and/or previous selections, often a particular attribute of the product; for example, the type of fuel (gas / electric) supplied to a plot is used to restrict the customer's options when selecting cooking appliances (oven / hobs) to products that only use the pre-selected fuel type. *Case-based rules* provide a method of expressing knowledge by storing examples of a decision in a table that can be maintained by the data owner, e.g. colour choices for kitchen appliances; if a product is selected, the case-based rule is invoked and the user is restricted to the colours that are stored in the decision table (a valid outcome). *Decision trees* are typically used in the matching of a component or ‘off-the-shelf' product to a customer need, and make recommendations based on a set of known facts or attributes related to previous selections and/or specific plot details. If an attribute used in the rule is not already specified and is required for the recommendation, then the system tracks the missing

information through inference or prompts the user for it; for example, if the customer has selected a kitchen range, the manufacturer and, through inference, the selection of the fascia and cooker hood are known. *Procedure-based rules* provide a mechanism for declaring a relationship between attributes using, for example, simple calculations; the procedure is defined using a proprietary scripting language in Knowledge Builder. An example of its use is in restricting customer selections to a predefined budget cost.

System maintenance. Maintaining the knowledge base must be a simple task that does not frequently require the intervention of a knowledge engineer (Duffell 1998). In HCS, individual rules are stored as separate sets of knowledge and a graphical interface (available in Knowledge Builder) is used to develop, structure and test the knowledge base; this makes the model easier to maintain than with a conventional text based system. Facts (data) have been carefully separated from the rules governing their use to simplify maintenance of the knowledge base and integration with external systems, sharing of data across the organisation and their maintenance by the appropriate data owners (e.g. sales, technical, costing departments).

Sequence of events. In HCS, events are controlled using control trees, which consist of a number of objects (e.g. a procedure or dialogue). Control trees are processed only when required, which allows the product selection process to be personalised or made flexible, if appropriate. For example, a house type has to be selected before a choice of layout can be made, but the customer may choose to select the type of kitchen before they have selected a plot; in the latter case, the system would restrict plot availability to accommodate the selected kitchen. Control trees may also be used for the gradual introduction/ control of the level of product choice made available, starting with simple options on fixtures and fitting as is the current practice; the necessary changes to the system will be a relatively simple task for a knowledge engineer.

Selection history. During the product configuration process, the customer selections are automatically encoded into a (Complete and Unambiguous Description) string, which is then stored in the database. A stored string can be decoded and the selection restored for future use, allowing a customer to engage and disengage in a dialogue without having to restart the selection process from the beginning. However, since the continuous encoding and updating of the string for each selection could potentially reduce the efficiency of the system, the updates are limited to only key stages in the configuration process. The string is stored in the database as a temporary record, and does not indicate a commitment to purchase. If the customer decides to proceed with the sale, the selections are taken from the history file, the system makes a final check of their validity and commits them to the database.

System deployment. HCS can be deployed in either a client-server or web-based mode; however Virtual Worlds software is currently not web-enabled, but is expected to be soon. HCS can be used either by the sales negotiator in conjunction with the customer, or on the Internet directly by the customer. In the latter case, some restrictions are likely to be placed on its available features (e.g. commitment to sale). Although fully functional as a stand-alone application, HCS has been designed to be incorporated within an integrated order fulfilment process. The Partner Company has plans to make Intranet access available to all its building sites, which should make this possible. Design of the database in HCS is based on an analysis of requirements of key business processes in the house-building sector (product design, configuration and sales, etc). A schematic overview of the system architecture is shown in Figure 2.

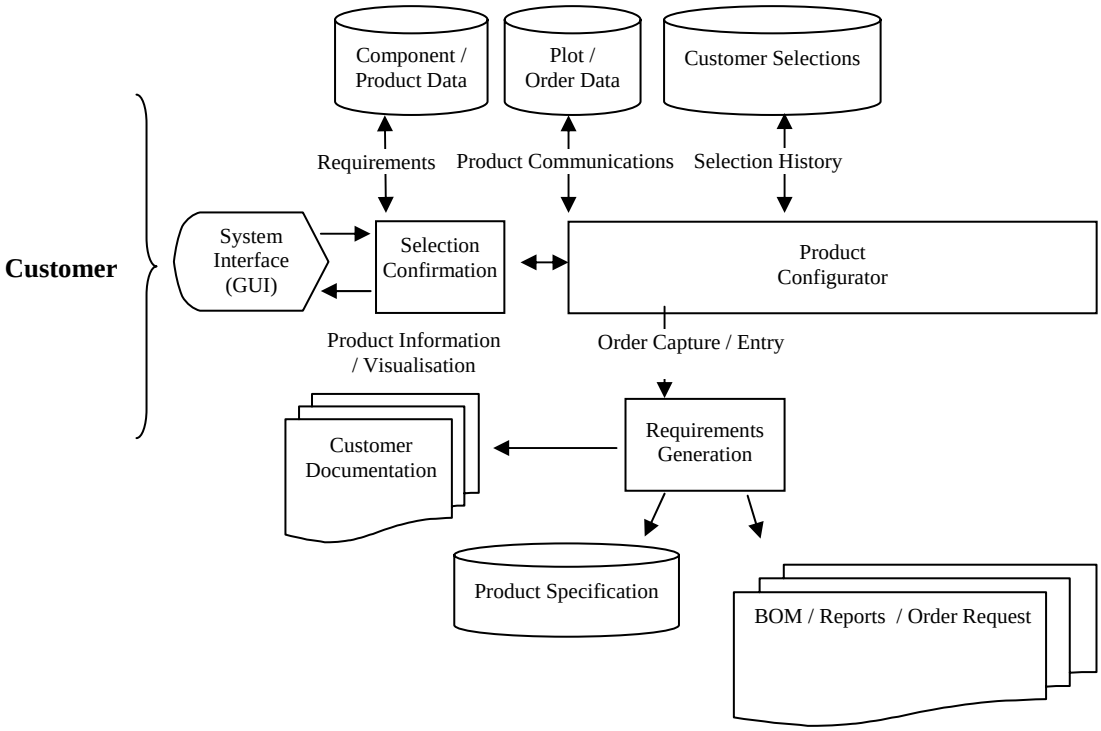

Figure 2: Schematic Overview of System Architecture

CONCLUSIONS

Mass customisation is increasingly being recognised as an important business concept in the development of a more customer-focused housing industry. Amongst its many requirements is a product configuration system for managing the inevitable increase in business complexity, controlled introduction and effective communication of product offerings to customers, and the capture and translation of the selections made into build specifications. There are a number of important considerations in the design of such a system. Product information must be presented in a logical and structured manner so as not to confuse the customer with a large volume of choices, and in a flexible, but robust, manner to make the decision-making process simple. The customer interface must be carefully analysed to make the order fulfilment process efficient and error free. The system should also be designed to make the house-buying process itself simpler; for example, the search and negotiations for a new home do not all have to be centred on the development site, which is often remote from the customer's current location. The system that has been developed (with some modifications to take account of a different, but related, application) is to be piloted in a new business venture of the Partner Company.

A product configuration system is only one step in the deployment of the concept of mass customisation. All construction and business processes have to be re-engineered for greater efficiency, customer focus and ability to manage greater product variety. For example, products have to be redesigned to maximise the scope for customisation, and supply chain performance will need improvements to enable rapid configuration of houses to individual orders.

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