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A Methodology for Assisting Consumer Driven Design of Building Products

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ABSTRACT

The paper focuses specifically on the product development process and the importance of consumer research in getting product design requirements right. The paper demonstrates application of two generic methods of converting qualitative consumer research data into objectively quantifiable data – primarily for the purpose of creating a product design brief. The tools used include *thematic analysis* and *qualitative comparative analysis*. The application of each is set against the backdrop of a recent product development project for timber cladding (as used in the Australian housing industry). A key aspect of the example is how the two separate research tools are used in a harmonious way to distil raw qualitative data into more succinct criteria for product development purposes. The paper concludes that the methodology is suited to situations where mass customisation is required – especially where trying to change a product from being crafted onsite to a more advanced systems approach. It is also a suitable for obtaining a holistic view of consumer needs.

INTRODUCTION

Designing products that meet consumer needs whilst still meeting production efficiency criteria can create tension in any production process. One way of mediating this tension is through careful attention to product development. This has become a growing area of interest among materials manufacturers in the housing construction industry and is the central issue explored in this paper. For instance this paper focuses on a recent timber cladding product development project and how consumer needs were determined.

In the housing industry, emphasis has gradually changed from design being influenced by raw materials crafted onsite, to either value added products converted into site based assemblies, or highly standardised mass produced houses (Barlow et al. 2003). The driver of this change runs parallel with the growing emphasis on supply chain management and the related concept of mass customisation – which involves being able to customise products but deliver them at close to mass-production prices (Fisher 1997). It is asserted here, that product development is an important stage in getting the balance right between mass production and customisation.

The *product development process* can be described as "the sequence of steps or activities which an enterprise employs to conceive, design, and commercialize a product" (Ulrich and Eppinger 2000:358). In manufacturing, Cooper (1994) points out that knowledge of how products were developed and launched was fairly limited until the late nineteen eighties. During the eighties intense international competition spurred superior performance in manufacturing and along with it, the ability to describe and manage the product development process (Clark et al. 1992). More recently, authors such as Maylor and Grosling (1998) have advocated the use of specific management tools and techniques with a view to using new product development to boost market competitiveness.

In recent years, a version of *product development* has emerged in the construction industry. New areas of construction theory - such as Lean Construction - use the term *product development* synonymously with design management to describe the design inception and conception stages of a building project (Tzortzopoulos et al. 2002). In this context it focuses on being an adaptive system so as to cater for the changes that invariably occur when using standardised products and materials to make customised buildings.

Arguably, the main gap between the manufacturing and construction contexts of product development is simply the tension between standardisation of mass production versus the level of customisation required of "one-off" building projects. In real terms, the latter is literally made up of thousands of standard products put together in different ways to make a "buy to order" product. Hoekstra and Romme (1992) point out that this type of product is at the opposite end of the scale compared to the classic manufacturing scenario where standardised goods are produced and "shipped to stock". Current trends in building materials manufacture are perhaps gradually moving towards the middle ground between these two extremes. Hoekstra and Romme (1992) refer this happy medium as "assemble to order". Here, standardised components can be assembled into different configurations to suit individual needs – as is the case with computer assembly. The actual assembly process takes place as close as possible to the placement of a consumer's order, thus reducing the holding of unwanted stock. Barlow et al. (2003) emphasised that this approach is a critical enabler of mass customisation. Even so, there is little written on the conversion of relatively simple raw construction materials into more advanced “assemble to order” type products and systems.

The current study focused on this very issue by reviewing a recent product development project - the previously mentioned Timber Cladding Project - as used in the context of the Australian housing construction industry. The focus of the project was on rejuvenating the market share of sawn timber cladding boards. There was reason to think that an opportunity existed to increase a perilously small market share due to signs of recent architectural trends towards increased usage of lightweight claddings in façade designs. However, the means of increasing market share remained unclear.

Attention to design requirements was thought to play a central role in addressing the above issue but was found to be fraught with complexity regarding what consumers wanted and desired in a timber cladding product. For example, product development in this setting needed to acknowledge different consumers and different market segments e.g. end users, architects, various forms of building contractors. Building regulations and the supply chain in the timber industry had an over-arching effect on both market segments.

Since the product development project was to be for timber industry-wide benefit, there was a concurrent need to use an objective research approach for determining the above consumer segments. The method also needed to be objective in terms of converting consumer needs into tangible product design requirements.

Given the above, the paper uses the backdrop of findings from the timber cladding product development project as an example that helps illustrate a generic methodology for determining consumer needs for the purpose of product design development.

I. Choosing a Methodology

One of the problems with finding a methodology to address the previously mentioned research issues is simply the difficulties in creating a mass market product while dealing with the highly individualistic nature of consumer needs. Simplification of complex needs is all important, but this needs to be balanced against the context of what consumers say and want. In getting this balance correct, the experience from the Timber Cladding Project was one of:

Step 1 – convert semi-structured consumer interviews into categorisable and quantifiable themes using *thematic analysis*

Step 2 – a) re-process the data from Step 1 into combinations of themes that contextually explain each interviewee’s views as a mini case study, then b) render the cases down into a summarised account explaining the entire set of case studies i.e. using *qualitative comparative analysis*.

The following discussion provides an introduction to each of the two steps, including worked examples from the Timber Cladding Project.

II. Thematic Analysis

Much consumer research is conducted using focus groups or face-to-face interviews to find out the subtleties of what consumers really want and desire. The Timber Cladding Project used face-to-face interviews with architects and design and construct contractors - initial research identified that these consumer segments were likely to offer the best means of increasing the market share of timber cladding. Here, the research focused on “one-off” detached housing projects (thus representing a high degree of project customisation). In total, 26 interviews were conducted, each taking approximately 1.5 hours and included additional site visits to view individual projects.

Questions to interviewees were open and exploratory so as not to impose pre-conceived beliefs. The very nature of such questions meant that responses tended to be semi-structured and were not necessarily answered directly. Instead, interviewees would expand on areas of interest or provided specific examples that explained their response. It is in this context that the concept of *thematic analysis* has the capability to excel and is the reason it was used in the Timber Cladding Project.

Thematic analysis is used to process raw and/or unstructured interview data into categories of thematic meaning. It is similar to content analysis but the focus is on categorising theme frequency rather than the frequency of the words that interviewees actually say. Analysis of the deeper level of meaning contained in themes (as opposed to words) has been acknowledged as far back as Cicourel (1964) and more recently among qualitative researchers such as Boyatzis (1998), Kuchartz (1995), Miles and Huberman (1994), and Silverman (1993). The benefit of the emphasis on deeper meaning is that it provides a more expressive and detailed tool for understanding consumer needs and therefore assists in developing more purposeful product design requirements.

Themes are patterns identified in communicated messages or observations. In this context, themes aim to make sense of seemingly unrelated data (Boyatzis 1998). For example in this research, the themes involved in reinvigorating the timber cladding market were not known and thus the very basic issues influencing consumer support or rejection for timber cladding needed to be identified.

Themes are used to make theoretical inferences based on the relationship between events and symbolic content in communicated messages (Boyatzis 1998; Holsti 1969). These inferences are underpinned by an objective method of identifying and coding themes (Holsti 1969:14). Options for creating code include *existing theory, prior research* or *inductive coding* (Boyatzis 1998:44). The first develops code definitions from variables in *existing theory* – in the case of product development this could include existing knowledge on product features, existing consumer research reports, dissection of past sales figures and details on product pricing structures. The second option is less structured because it uses concepts extracted from a variety of *prior research* sources rather than a single theory – in product development, this could typically involve a variety of disparate literature and marketing sources which could be synthesised into a central logic for undertaking a product development project. The third option develops code *inductively* by learning directly from the raw data. This typically involves categorising relatively unstructured data from interviewees. The method tends to require more analysis to make sense of what people say, because there is no existing framework of variables to categorise their responses.

In the case of the Timber Cladding Project there was no identifiable *existing theory* but there was an opportunity to utilise *prior research.* An extensive literature review of cladding systems found a number of reports on lightweight cladding materials and existing marketing and sales information. These sources helped identify potential variables influencing consumer attitudes and were used as the underlying criteria for posing open and semi-structured questions to interviewees. Responses from interviewees were analysed into specific themes using the *inductive* approach. Since this required a self made means for coding and categorising the data, it is perhaps best to describe how this was actually done in practice. Boyatzis (1998) describes the process for developing *inductive* code as separating data into groups with opposing themes – as determined by reading through responses. Sub-samples from a given group are then selected to identify key anchor criteria for that group. The resulting criteria are applied back to the whole group on a 'compare and contrast' basis. If consistency is achieved then the anchor criteria gather weight. If not, adjustments and alterations are made. From this, the finalised anchor criteria provide the basis for defining codes that can be used to separate the entire data set into objectively definable groups.

Implementation of *thematic analysis* can be assisted by qualitative research software such as NVivo or its fore-runner NUDIST (details relating to the development and usage of these software research tools can be found at http://www.qsrinternational.com/aboutus/company/company_history.htm, accessed 9/2/07). For some time this software has been acknowledged as being one of the main software packages used for qualitative analysis (Fisher 1997; Gahan and Hannibal 1998; Weitzman and Miles 1995). It can be used to categorise raw data into theme groups, count theme frequency within groups, and facilitate analysis of co-relationships between groups e.g. intersections and overlaps. An advantage of using such software is its ability to manipulate data and improve coding reliability (Kelle 1995). The need for such an approach becomes more important the larger the number of interviews and data sources involved. It is also useful where the methods used for making design decisions must be transparent to others – as is often the case where mass market products are involved. However in small groups – as was the case with the Timber Cladding Project - it was considered unnecessary to go to this degree of software specialisation. For instance, in the current research a spreadsheet application was found adequate for defining and counting theme frequency.

III. Utilising the Findings from Thematic Analysis

Thematic analysis was applied to the Timber Cladding Project for open questions such as "explain the main strengths and weaknesses of timber as a cladding material". The most common theme concerning strengths was the unique appearance of timber cladding (97%). Coding this feature required a reliable basis for recognising its presence and was defined by how respondents spoke of appearance related issues such as:

- The appearance of stained, clear or natural (uncoated) timber finishes.
- The warmth, texture, grain and tactility of timber
- The thickness of timber cladding boards and the inherent ability this provided in obtaining a deep shadow line between cladding boards – thus providing different patterns and contrast to the adjacent façade elements.

Since nearly all interviewees were united in the main strengths of timber cladding (i.e. 97%) the issue of aesthetics could effectively be viewed as a fixed and important requirement in the ongoing search to identify consumer needs. This beckoned for more detail. To find out more on how the aesthetics of timber cladding could potentially fit into the design of housing facades, interviewees were asked to generically describe the facades they design and whether they tried to create a modern or traditional look. They were also asked to define their preferred "look" in terms of elements and detailing.

It was found that most respondents tried to create a modern look in the house facades they designed (89%) and importantly this included one or more the following:

i. smooth transitions between surfaces at joints,
ii. sharp rectilinear lines,
iii. a refined appearance that is minimalist in detailing (including possible use of expressed joints),
iv. use of lightweight claddings to counterbalance heavy masonry, glass, steel and other smooth surfaces
v. use of contrasts in colour, pattern and/or texture
vi. use of shadow lines in board products to effect the abovementioned texture and pattern changes in elements
vii. articulation of feature panels and façade elements

The above findings suggested that from a product development perspective, the need for a modern façade could be treated as a fixed variable that should be incorporated as a central design requirement in the timber cladding design brief. Again, this beckoned for more detail on how timber could be used in this context.

To probe further along this line of inquiry, interviewees were asked if they would ever design a facade using 100% timber boards. 97% of the sample said that this was unlikely, suggesting that the emphasis should be on using timber boards to mix and match with other façade elements. Other questions resulting in achieving an almost unanimous response included support for a hidden fixing (nailing) system and support for a more systematised kit of parts that incorporated preformed metal flashings and preformed corner moulds.

Again these areas of (almost) unanimous support meant that fixed variables for the design brief could be locked in. From a methodological point of view, once such variables are determined, the emphasis of inquiry must change to the areas of consumer need that are fragmented or unclear to the researcher. The following questions (which probed about the possible features of an appropriate timber cladding system) represented such areas:

- Preference for a flat faced board (with deep shadow line) versus a splayed board.
- Preference for a rough sawn board or a dressed board.
- Preference for a pre-stained or a pre-painted board.
- Preference for the ability to purchase prefabricated and/or modular cladding panels.
- Preference for a novel metal fixing batten which would allow simplified site assembly of cladding. The same batten would also aim to improve functional properties of the wall such as thermal ventilation and weather resistance.

Some of the above questions lead respondents to support more than one of the options. In others, they were clearly divided concerning their preferences. In general, these issues created complexity in terms of identifying the right way to go in terms of using consumer opinion to direct product design requirements. It was here that *qualitative comparative analysis* (QCA) was thought to be useful as it can be used to undertake advanced processing of the findings from *thematic analysis*. QCA can concisely summarise the main variables (or features) of a given case and provide the means for comparing, contrasting and ultimately simplifying a group of cases to find the simplest and most minimal solution for the desired outcome.

To get the most out of QCA one should consider the outcomes. In the Timber Cladding Project, separate groups of questions aimed to clarify certain design oriented outcomes. One outcome concerned attainment of the previously mentioned modern façade aesthetic. Another concerned attainment of a set of appropriate timber cladding features to suit the context of modern facades. The idea of using QCA was to determine the most minimal and therefore most simple design solution. This could then form the core basis of the product design brief.

IV. About Qualitative Comparative Analysis

Qualitative comparative analysis (QCA) was developed by Charles Ragin (1987) for social sciences research (in this case consumer attitude research). His approach works on the basis of re-structuring categorical data into 'outcome' and 'condition' variables. The logic is that the presence or absence of certain 'conditions' will explain the presence or absence of specified case 'outcomes'.

To implement the method, categorical data is converted into numeric data by signifying a present variable as '1' and an absent variable as '0'. From this, combinations of 'outcomes and conditions' can be mathematically quantified and compared as configurations of '1s' and '0s'. An example is shown in Table 1 and is presented in the form known as a "truth table" (Ragin 2000).

Ragin (1987) developed the approach after seeing the way *Boolean algebra* was used to mathematically simplify electrical circuitry in complex switching situations. Principally, the system provided a means of reducing a complex number of variables to the minimum necessary to create the desired switching requirements. Ragin argued that the outcomes of case studies could be simplified in a similar way. In essence, the objective of his approach is to determine the minimum number of what he refers to as "Prime implicants" that explain all the cases studied.

The system relies on applying Boolean addition and multiplication. This differs from arithmetic concepts and is instead akin to the operators of 'OR' and 'AND' as commonly used in logic algorithms. On this basis many different empirical combinations of conditions can cause an outcome. The number of combinations can be reduced by applying a minimisation rule that asserts:

If two Boolean expressions differ in only one causal condition yet produce the same outcome, then the causal condition that distinguishes the two expressions can be considered irrelevant and can be removed to create a simpler, combined expression.

(Ragin 1987:93)

For instance in Table 1, it can be seen that combination 1 and combination 2 differ in only one condition variable but cause the same outcome. As a result, the differing variable can be removed and a minimised expression created that explains combinations 1 and 2.

Combination	Condition 1	Condition 2	Condition 3	Condition 4	Outcome	Combination frequency
A	1	1	1	1	1	20

B	1	1	0	1	1	6
C	1	0	0	1	1	4
D	1	0	0	1	0	2

Table 1: Example of combinations of conditions and outcomes presented in 'Truth table' format

Ragin also applies other logic to reduce combinations down to the minimum set of prime implicants. He utilises De Morgan's Law (Ragin 2000) which involves reversing all values on the combinations (e.g. "1s" become "0s" and visa versa) for testing and minimising negative cases. This method can be subsequently used to resolve any inconsistencies in logic between positive and negative outcomes. For instance illogic similarities between the two cause a conflict in logic and could cause such combinations to be removed from the minimised solution.

There is considerably more to the QCA approach than can be dealt with in this paper and so the main purpose here is simply to make readers aware of its main features and then point them in the right direction to find out more. With this in mind, QCA is assisted using free software developed by Ragin (http://www.u.arizona.edu/~cragin/fsQCA/, accessed 5/2/07). It contains an interface for applying the algorithms necessary to compare and minimise case configurations using the previously discussed principles. In preparing the data for the software, it is common to first input the numeric version of the categorical data into a spreadsheet. Rows define cases and columns define variables. The spreadsheet data is then loaded into the software for sorting of identical configurations of '1s' and '0s' into "Truth Tables" and so on.

As can be seen in the right hand column of the Table 1, many cases may conform to a single combination of conditions causing an outcome. As appropriate, this enables the researcher to progress and simplify the analysis by assigning greater importance to high frequency combinations compared to low frequency ones. For instance in the Timber Cladding Project, all case configurations that occurred less than twice were excluded from the ongoing analysis because they were not considered to be sufficiently representative of the broader population of responses, to merit further attention.

In general, it has been found through experience that using too many variables in running an analysis creates too many permutations and creates confusion. As Ragin (forthcoming) points out, a range of 3-8 variables should be seen as the upper limit and this can be achieved by breaking down large sets of variables into groups of individual issues. In addition, QCA can be used at various levels of complexity. In the current study, there was an emphasis on the use of truth tables to quantify and compare common configurations. The software also allows "Fuzzy set" analysis which offers a more advanced analysis tool. For instance Ragin (forthcoming) describes how the Fuzzy Sets analysis method enables variables to be coded at values between 0 and 1 to signify partial presence or absence of a given variable (rather than being dichotomously opposed at "0" or "1"). This is also useful where interviewees respond to some sort of scale. For instance a value of "0.25" could be used where an interviewee responds as being "unsure" about something, or "0.5" could signify a response of "maybe". Finally, a value of "0.75" could be reserved for responses such as "probably". This greater degree of detail is then rendered down into truth tables and minimised using the same principles as discussed previously.

V. Applying QCA in Practice

In the Timber Cladding Project QCA was used to simplify a variety of issues such as the simplification of features associated with attaining a modern façade aesthetic. The results are shown in Table 2.

The minimised solution for the cases in Table 2 provides two solutions, which have been summarised thus:

Solution 1: Requires only 1 feature to be present after minimisation to explain a modern façade. It is "Mixed use of contrasting façade elements".

Solution 2: Requires 2 features to be present after minimisation to explain a modern façade. These include "Mixed use of contrasting façade elements" and "Attention to clean and refined articulation of facade joints".

With regard to these solutions, Ragin (forthcoming) points out that even though QCA reduces solutions down to the minimum set of configurations required to bring about an outcome, it does not provide a single correct answer. As a result, there is a need to interpret which of the above scenarios best suits the researcher's needs. In this case, the second scenario was given preference in terms of directing on-going product development. It could be concluded that timber cladding has potential for market success if it can be one of the mixed façade elements that architects prefer to use. But it must do so with attention to the way its joints are articulated (i.e. within individual panels of timber cladding, and where it abuts adjoining facade elements).

No.	Conditional features	Outcome	Combination frequency

	Variation in colour of façade	Strong use of lightweight materials	Strong use of glass	Strong use of materials with natural appearance	Clean and refined articulation of façade joints	Mixed use of contrasting façade elements	Modern façade aesthetic	
A	0	0	0	0	0	1	1	4
B	0	0	1	0	1	1	1	4
C	0	0	0	0	1	1	1	3
D	0	0	0	1	0	1	1	2
E	0	1	0	0	0	1	1	2
F	0	0	0	0	0	0	0&1	2

Table 2: 'Truth table' for features contributing to a Modern façade aesthetic

The same analysis process was employed in determining appropriate timber cladding features to suit modern facades – as listed earlier in the paper. Questions pertaining to this list (such as questions about preference for flat faced boards or splayed boards) aimed to find out about preferences for various aesthetic effects obtainable with timber cladding. In addition, the questions aimed to determine how much potential there was to convert timber cladding from being a purely site crafted material to one that offered a more systematised "assemble to order" approach.

On this basis, the QCA analysis indicated that the features that must be present in the minimised solution for an appropriate timber cladding system included: a "flat faced board (with deep shadow lines)", "prestained boards" and "preference for a novel metal fixing batten". Though other features from the list may be present or absent, these are the minimum solution requirements.

The findings about minimum requirement for a modern façade and for appropriate timber cladding features can be added to the fixed (or must a have) features mentioned earlier in the paper. Collectively, these can be used to form a design brief for ongoing product development.

CONCLUSION

This paper has provided an account of a methodology for distilling consumer product needs from semi-structured interview data. It can be used to develop a targeted design brief for the purposes of product development. A two-step analysis process was used. The method involved utilising *thematic analysis* to distil semi-structured data into specific themes classified into definable categories. Themes that were present in a strong majority of responses were treated as fixed variables. Where appropriate, these areas were analysed in greater detail to explicate physical details relevant to product design. Where complexity and fragmentation in consumer responses were observed, the *thematic analysis* was further processed using *qualitative comparative analysis* (QCA). This served to identify the most minimal combination of variables for explaining consumer needs, which served to act as the core basis for ongoing product development.

From this research, the abovementioned method is considered to be especially appropriate where there is a need to take qualitative interview data from a sample of consumers and gradually convert it to an objectively quantifiable and minimised set of outcomes. It is considered that such a situation may typically arise where mass customisation of products is involved. Secondly, it may occur where the drivers explaining the success or failure of a product are unclear – hence the need for qualitative inquiry. Thirdly, it may occur where there is a desire to gauge the potential for changing a product from say a basic "buy to order" product - that is predominantly crafted onsite - to an "assemble to order" product that uses advanced and systematised componentry. As with most research methods, the method described in this paper have both advantages and disadvantages. For instance, QCA does not provide a "single correct solution" thus there is still a degree of subjective interpretation required of the researcher. Even so, such problems afflict many research methods and management of shortcomings is the main emphasis in the implementation of this method.

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