STANDARDISATION OF SPECIFICATION DRIVEN BUILDINGS WITH SERIAL AND REPEAT ORDER DESIGNS

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Government policy-makers are continuing to affirm the need for greater economies through standardisation. The benefits of standardisation seem straightforward: repeated designs offering economies through rationalisation and greater use of preassembled manufactured components as a result of a closer engagement with supply chains. However, a closer investigation of standardisation shows it to be more complex; individual client needs, unique site conditions, planning legislation, late contractor engagement, inadequate knowledge and intermittent manufacturer supply are some of the factors that conspire to limit the benefits of standardisation. This research, as part of an Engineering Doctorate study, examines repeat- and serial-order standardised buildings through multiple case studies where the reasons for their adoption are explored from various stakeholder perspectives. It tests existing theories from literature on standardisation in design and construction efficiency, with an emphasis on specification driven 'non-iconic' buildings. With one-off projects the benefits of standardisation are expected to be limited to efficiencies within a project, and there may be limited engagement with a supply-chain. On multiple projects, with dimensionally standard spaces, even in multi-stage tender situations, standardisation is also limited and clients are not strongly motivated to engage with manufacturing. However, there are other projects where clients, designers and contractors have taken an 'enlightened self-interest' to collaborate, particularly for repeat order projects, and this leads to an optimised process between the design team, the contractor and their supply chains. These latter projects have better defined briefs and benefit from successive refinements of more linear rationalised design processes with increased use of standardisation and preassembly, particularly for the more dimensionally standard areas of the buildings.

Keywords: client, briefing, design, standardisation, prefabrication

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INTRODUCTION

The inefficiencies of construction in the UK have been extensively documented (Latham 1994; Egan 1998; Woodhuysen & Abley 2004). In response, recent government policy continues to affirm greater economies through standardisation: rationalisation of briefs, greater use of repeated standardised designs, better integration of design and construction and closer engagement with supply chains (Cabinet Office 2011).

This research, as part of an Engineering Doctorate study, examines repeat- and serial-order standardised buildings through multiple case studies where the reasons for their adoption are explored from various stakeholder perspectives. It tests existing theories from literature on standardisation in design and construction efficiency, with an emphasis on specification driven 'non-iconic' buildings with a significant degree of dimensionally standardised spaces.

DEFINITIONS

Standardisation has been described as the "extensive use of processes and components with regularity and repetition" (CIRIA 2000). Standardisation exists in building products, standard forms of construction, procedures and techniques. The benefits of standardised designs and an increased use of supply chain manufacture through preassembly are well known (CIB 1998; CIRIA 1999; CIB 2010: Gibb 2000): predictability, reliability, efficiencies in system processes, reduced waste, increased speed of construction (CIB 1998) being the most noted benefits.

Few buildings are totally standardised, and most can be classified as being on a range of individualised and rationalised building spectra (CIB 2010; Robinson *et al.* 2011a). The building design brief can be similarly described as ranging between "Bespoke" and Standardised (Gibb 2001), with intermediate conditions described as "Hybrid" and "Customised" (Fox & Cockerham 2000b).

Figure 1: Brief, Frequency, and Design Type for Rationalised and Individualised Buildings,

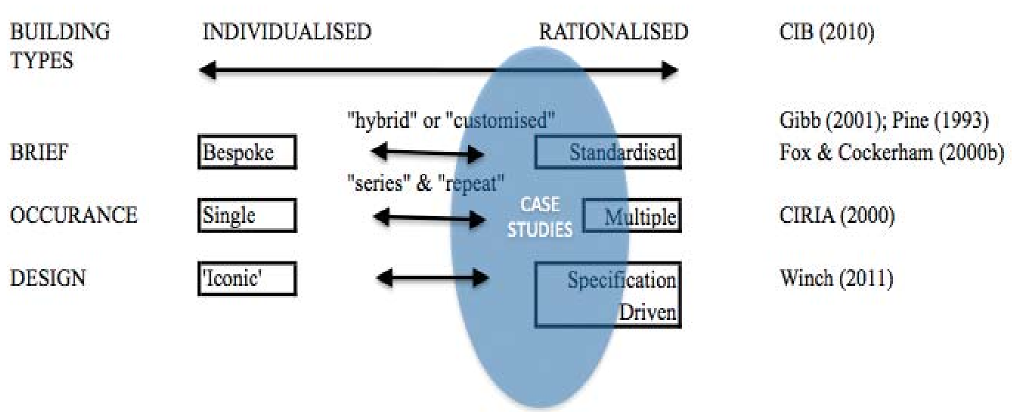

Figure 1 shows a generalised model for building type, brief, design and project frequency. Highly individualised buildings occur less regularly (CIRIA 2000) and have more bespoke briefs, possibly with a strong cultural significance, and are therefore classed as "iconic" (Winch 2011). Similarly multiple projects tend to be more rationalised, suiting more a standardised brief, and having a “specification driven” design (Winch 2011). Furthermore, site issues in culturally significant and individualised buildings may be highly specific, whereas specification driven buildings by their nature may tend to have significant elements that are less site specific.

The principal focus for case studies in this research as highlighted in figure 1, is for rationalised buildings with more standard briefs, with specification driven designs for repeat- and serial-order clients. On these projects the motives for standardisation are more easily isolated and less prone to cultural issues.

The proposition of this research is that standardisation is limited, even for specification driven, and is strongly dependent on stakeholder behaviour. This is a rival scenario to the case implied by government where standardisation will naturally follow-on through more rationalised briefs (Cabinet Office 2011).

The reasons for different degrees of standardisation in buildings are compound; they are based on a combination of individual client needs (Gibb 2000), unique site conditions and planning legislation (Fox & Cockerham 2000a), timing of contractor engagement (Groak 1992), technical knowledge (CIRIA 2000) and reliability of manufacturer supply (Gann 1996). All these factors to a greater or lesser extent conspire to limit the benefits of standardisation. With bespoke ‘one-off’ projects this could be predicted, but for repeat projects a client and their design and construction team could be expected look for economies of scale and increased predictability through repeat processes when working on similar buildings (CIRIA 2000), particularly if the building has standard, repeated spaces.

RESEARCH DESIGN

A case study approach has been chosen because there are many variables in the data for an accurate experimental method (Fellows & Liu 2003, Yin 2003). Using case study methods (Yin 2003) this research identifies the project and stakeholder conditions for when standard designs are repeated and optimised. It takes a pragmatic theoretical perspective (Creswell 2003) with a qualitative strategy of inquiry (Fellows & Liu 2003, Cresswell 2003).

Research is achieved through multiple case studies, looking at the different stakeholder positions. Three groups of projects have been examined, each group having two or more projects with the same client and design team and in some cases the same construction team and supply chain.

During data collection, the multiple case studies were used to establish a chain of evidence on the characteristics of standardisation to construct validity, both in terms of internal causal relationships between the data and the overall proposition on the limitations of standardisation, and external validity in terms of the generalisation of the findings for different projects and stakeholder groups.

From the development of a model based on existing literature, it looks for trends in repeat projects. The processes being examined are the brief development, the design, procurement, manufacture and construction (CIRIA 1999). In its analysis, the research attempts to isolate variables from the data that could not be used as a generalised model of standardisation to apply to other projects. For example, data relating to the effects of local market (Gann 1996), and team behaviour (Emmitt & Gorse 2003) are ignored.

The individuals/organisations involved are the clients, designers, contractors, and manufacturers. Where possible, the different stakeholders were interviewed for each of the projects. Initial interviews during the exploratory phase used a semi-structured technique around themes. A proposed later phase of the doctorate research will review the conclusions from this research with the key informants to verify the chain of evidence between the project data on the use of standardisation and the initially hypothetical conclusions concerning its limited use and effectiveness.

Table 1: Breakdown of Project Case Study Groups and Interviews

	No. of Projects	Project Type	Client	Designers	Contractors & Manufacturers
Group A	4	Series of projects with same client & design team	0	14	0
Group B	3	Series of projects with same client & design team	1	4	0
Group C	3	Repeat order projects with same client, design and contractor team	1	7	3

EXISTING STAKEHOLDER POSITIONS ON STANDARDISATION

The following theoretical models have been developed through literature. The models look in turn at the perspectives of clients, designers, contractors and manufacturers on standardisation and the accompanying tendency towards preassembly.

Client's Perspective

Clients are end-product focused (Gibb 2000) and therefore less concerned with process; they are looking for individuality (Pine 1993) and will often maintain some degree of 'design authority' (Fox & Cockerham 2000a) throughout the construction process. Clients lack knowledge about what manufacturers can do (Gibb & Isack 2002), and they may tend to overestimate product performance (Blismas *et al.* 2005).

Although quality and the ability to individualise are stronger drivers for preassembly than economic considerations (Gibb 2000, Gann 1996), clients are strongly motivated by initial cost (CIB 1998).

Clients understand the benefits of early contractor engagement, but they will often use competitive tendering up until the later stages of the design to drive capital cost down. The whole-life and operational costs are unlikely to be quantified: life cycle costs, savings through reductions in programme, cost of snagging and health & safety improvements add value to manufacture-led offsite solutions. Preassembly often appears to cost more in capital terms, but performs in a more predictable way (Blismas *et al.* 2005; CIB 1998, CIRIA 2000) and many of the real cost benefits are hidden.

'One-off' building clients will benefit most from the standardisation of smaller-scale standard products, while 'serial building' clients with several sequential projects may benefit from the advantages of customised preassemblies (CIRIA 2000), but it is the 'repeat order' clients who choose to use the same strategic partners in all their projects, that benefit most from standard procedures, products, and close relationships with suppliers (CIRIA 2000). Furthermore, standardisation of products may increase reliability during operation and maintenance (CIB 1998).

Designer's Perspective

Designers use standard templates for briefing documents, reports, surveys, design drawings, details, specifications and product selections to reduce design effort and therefore design cost on a building projects (CIRIA 1999). They will also design buildings with standardised grids and components to maximise the benefit of repeat details (CIRIA 2000).

More recently, Building Information Models (BIM) have been used to generate and manipulate building information using 3D parametric data for geometric components and their layouts, allowing building information to be generated automatically. BIM works by using data with object orientated representations that can be extracted and manipulated to show the best building arrangements and therefore improve the decision making process (AGCA 2006). BIM have been cited as tools that can assist a more integrated design process by encouraging the earlier resolution of design coordination issues to improve cost control (www.hokrenew.com 2012)

Designers' knowledge of preassembly may sometimes be limited (CIRIA 2000), but those who are familiar with preassembly techniques are more likely to use them again and know that early design freezes are needed to give reasonable lead-in times to manufacturers especially for prototyping and to allow the architect to inspect the works in the factory.

Site factors will influence the ability to standardise (Fox & Cockerham 2000a), but standardisation increases predictability and quality (Gibb 2000; CIB 1998; CIRIA 2000), and a development of generic solutions leads to continuous improvement particularly for more common interfaces and simplified joint designs (Fox & Cockerham 1999, Egan 1998, CIB 1998, CIRIA 2000).

However, standardisation may limit design options (Gibb 2000) and off-the-shelf solutions can lead to less innovative solutions over time. As a result, customisation is used to produce variety through varying standard or modular components (Gibb 2001, Pine 1993, Kieran & Timberlake 2004, CIB 2010).

Designers and builders will bring forward knowledge and ideas from previous projects, albeit usually on an ad hoc basis (CIRIA 2000). Designers are in a unique position to improve compatibility between construction systems (Fox & Cockerham 2000a). Design and construction process is a complex system of mostly non-hierarchical parallel and layered activities (Kieran & Timberlake 2004, Groak 1992) and construction industry products are complex due to the high degree of user involvement and the many interconnected elements: a small change in one element can lead to large changes in another (Winch 1998).

Contractor's Perspective

Contractor-led construction using industrialisation techniques is more prone to using standard solutions with standard building shapes with little variation (Groak 1992), and standardisation provides efficiency benefits though greater familiarisation by the operatives on site. Preassembly eliminates complex interfaces, increases speed and provides more programme certainty, particularly for sties with severe constraints (Blismas *et al.* 2005, CIB 1998, Gibb 1994, CIRIA 2000). Preassembly also reduces waste on site, and reduces the number of operations and operatives on site, freeing up areas of storage and improving quality and site safety (Blismas *et al.* 2005, CIB 1998).

However, building complexity on site often limits the degree of manufactured components (Groak 1992, Gann 1996), and construction uses ‘formless’ material to build interfaces between elements (Fox & Cockerham 2000a), making it difficult to predict and therefore standardise.

Manufacturer’s Perspective

Manufacturer-led construction uses standard components, modular frameworks and ‘kit of parts’ approaches with proportional systems and dimensional coordination (Groak 1992, CIB 1998, CIB 2010). An increase in individuality of designs reduces the ‘series’ size of components (CIB 2010) and client design authority that continues during manufacture will reduce their productivity (Fox & Cockerham 2001).

In preassembly, working conditions are more easily controlled away from the point of installation. Preassembly allows optimisation of work through increased use of specialised equipment (CIRIA 2000), although automation is limited due to the complexity of the parts involved (Gann 1996). Buildings are closer to complex systems than volume manufacturing; elements are rarely made to forecast (Kendal & Sewada 1997), and almost always operate on a ‘pull’ basis, designed and built to order (Winch 2003). This means they cannot be easily improved by process re-engineering (Winch 2003).

A major limit on the size and extent of preassembly is the ability to transport subassemblies. Manufacturers will adjust factory to suit individualised solutions, many off-site factory are set-up as building sites under a roof, with pre-assemblies created to a size that can be reasonably transported to site (Gibb & Isack 2002, Winch 2010). Cost of products will be adjusted to suit market, rather than to reflect true economies. Working within a modularity or platform will increase costs (Pine 1993) and may therefore reduce design flexibility, as a result mostly lower ‘levels’ of preassembly are used (CIB 2010).

ANALYSIS OF CASE STUDY DATA

Data was collected through 30 semi-structured interviews with stakeholders on ten projects in three case study groups. The interview discussions were focused on topic themes based on literature on project brief, design strategy, commercial issues, construction and manufacturing strategies. Data has been extracted and mapped against the stakeholder positions established from the previous published research.

Findings for the different stakeholder positions are identified below.

Case Study Client’s Perspective

The case studies confirmed that clients are more interested in the outcomes of the building process than the building process itself. However, as found in case study B, end user clients, working on a series of projects became increasingly sophisticated in their understanding of operational needs, and this influenced their decisions on building solutions being offered to them.

The multiple repeat projects in case study group C were lower specification buildings, and tended to have more standard briefs compared to the other case study groups. Groups A and B had higher specification buildings and more individualised design needs.

All the clients preferred to appoint contractors later in the design process, or to use a two-stage tender process to involve the contractor gradually. A two-stage process can give the client a degree of design control, while still being able to transfer risk to the contractor during the negotiated second stage. The other advantage of early engagement should be to allow construction process to be discussed. However, in all the case studies with a two stage design & build tender, financial negotiations dominated discussions at the first stage, and the construction process was not considered in any detail until the second stage, when suppliers were on board.

Case Study Designer's Perspective

In case study groups A and B, the standardisation of approach rather than standardisation of layouts and elements was a more valuable outcome for building design, but in case study group C, where there were larger numbers of repeat designs, this was reflected in design product as well as the process. In all cases, there was progressive learning through several sequential projects, with the refinement of the process and products tending to happen on live projects, not through a prototyping process

Building elements in group C with standard dimensions for rooms, stairs, lifts, and car parking were the areas most consistently standardised. It was possible to rationalise the production of these elements with increased levels of industrialisation either off or on site. On projects in groups A & B, when offsite techniques were used, these were less successful, and were not attempted or scaled back for follow-on projects.

In the higher specification projects in groups A & B, the architects were more comfortable with the standardisation of small size components, such as discrete building elements. Spatial layouts appear to be driven by a complex number of needs, and a rationalisation of structure would be over-ridden by operational needs on the non-standard spaces. The differences in the site and programme for all the case studies influenced any standard designs being rolled-out over several sites.

Even on a series of specification driven buildings, such as in case study group B, the complexities of some of the legislative and operational requirements were not realised until the plan was fully developed for the scheme, and this led to some re-design.

Case Study Contractors' Perspective

Unlike group C, for every project in group B, the client engaged a different contractor team. These contractors were brought on board for a two-stage tender, but they did not appear to place much importance on construction methods during the early stages. They focussed mostly on cost negotiation during the first stage, and started discussing construction methods at the second stage when a supplier was being selected.

Contractors have preferred supply chains, which will influence their choice of construction methods as well as project type and site conditions. In the case study group C, where the same contractor was engaged on repeat projects, this led to significant economies in the design process. In case study groups A and B, it was difficult for the design team to anticipate the likely construction method until the contractors were fully appointed. Contractors appointed late in the design process working on more individualised designs will work most efficiently on a 'pull' basis, and they will treat the site as the factory using 'lean' techniques to maximize efficiency and minimise waste. They will drive-down cost by ordering as late as possible, and include manufactured solutions only where there is clear responsibility and realistic possibility of timely installation. Due to late ordering, the scale of these assemblies for major building fabric such as the supporting structure may be necessarily quite small.

Case Study Manufacturers' Perspective

The manufacturers in group C who were involved earlier in the design process were offering a 'kit of parts' (Groak 1992) approach to building design as a tool for rapid design.

Individuality in building designs is a major challenge for manufacturing, and even in very linear, repeated building elements as found in case study groups B & C, there were changing criteria linked to the layout and functioning of the building. The design and manufacturing team had to work very effectively to develop building layouts and details using manufactured systems that could be adjusted to suit different scenarios. Transportation can also be a major shaper in the design of large assemblies, and as routes and their accompanying constraints vary for each project, these become difficult to optimise except through an improved process that looks beyond manufacture and installation.

Due to the intermittent nature of construction, full scale manufacturing facilities that maximise the benefits of offsite assembly are challenging to maintain, with investment in plant. Factory production is associated with quality, so when the output does not meet expectations of a superior product to onsite construction, this can be very disappointing for the rest of the construction team. Combined with the issues of individuality in case study group B, this led to an abandonment of larger preassemblies as a solution for later projects.

However, the process of involving manufacturers early through a partnering process can lead to more streamlined and integrated designs leading to economies and process efficiencies through repeat projects. Elements that would be traditionally separated in standard construction become integral with the structure.

CONCLUSIONS

The research identifies motives for using standardisation from the different stakeholder perspectives of client, designer, contractor and manufacturer.

The client is most interested in the design outcome in terms of cost and operational performance, which is achieved through discussions with the design team and single or multiple stage tender process with the contractor. In most projects the negotiations with the manufacturers were delayed until the later stages of the tender process, and this significantly limited the degree to which standardisation techniques could be used to optimise the design. The three repeat-order projects investigated were part of a much larger construction programme, and under a more collaborative approach, where all stakeholders had an 'enlightened self-interest' (Winch 2011) to collaborate. As a result the designer, contractor and manufacturer were able to make more significant contributions to economies through standardisation. In these three repeat-order projects, where contractor and manufacturer were engaged early in the process, there were more benefits in terms of standardisation through repetition and refinement in the products as well as the process.

As found in case study groups A & B, if the contractor did not have a long-term motive to improve the production process through sequential or repeat projects, they tended to maximise profits through late ordering of materials and manufactured components, leading to increased on-site assemblies rather than extensive off-site manufacture. On the rarer occasions, when the contractor and their supply chain are allowed to offer design savings through a shared process with the client and design team, a more rationalised standardised design can be achieved through repeat projects, by eliminating separate elements, and generally more efficient standardised processes.

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