‘REINVENTING THE WHEEL?': CASE STUDY OF RESEARCH INTO LINEAR/NON-LINEAR AND FRAMING PROCESSES

Adrian Robinson [1], Simon Austin[2] and Alistair Gibb[2]

[1] *Buro Happold Consulting Engineers, 17 Newman Street, London, W1T 1PD & University of Southampton, SO17 1BJ*

[2] *School of Building and Civil Engineering, Loughborough University, Leicestershire, LE11 3TU*

‘No need to reinvent the wheel’ and ‘it’s just painting by numbers’ are expressions used by designers avoiding unnecessarily complex or over-simplistic approaches to design problems. These are extreme scenarios, but practitioners are under increasing pressure to minimise design effort and rationalise designs through repeated application of standardised solutions. This paper deductively tests and analyses interview data from building design case studies against analytical, conjectural and reflective theory models for repeat design solutions. A re-framing process for both clarifying a brief and selecting a design solution is shown to best match the described designer behaviour, with instances of linear analytical and non-linear conjectural processes occurring within that framework. It is inducted that designers in a repeated design adopted a strategy for rationalising the design, which they described as ‘modularisation’, although this had multiple meanings for different members of the design team. The strategy was driven in part by the ability to use parametric CAD models to duplicate the design. The case study data is based on a series of architecturally sophisticated projects with fairly unique standardised characteristics. This may therefore limit the ability to generalise these findings to more rationalised building types. However the conclusions of this research add to the understanding of approaches adopted by designers using pre-solutions for standardisation.

Keywords: client, brief, framing, design, efficiency, standardisation, modularisation

INTRODUCTION

‘Reinventing the wheel’ describes an activity that wastes time and effort, because it creates something that already exists (OED, 1989). However, there is a presumption in the use of the term wheel, that the problem to be solved is tangible and has discrete, definable parameters. In building designs, problems are more complex and interdisciplinary, and it is sometimes necessary to adopt a more ‘inventive’ approach (Lawson 2006). Paint-by-numbers is the very opposite of invention. Devised as a process for mechanically creating a copy of an original artwork (Palmerpaint, 2013) the expression refers to an activity that is unimaginative or un-natural (OED, 1989). The ‘artist’ does not require significant knowledge of the original process or the

[1] adrian.robinson@burohappold.com

[2] S.A.Austin@lboro.ac.uk, A.G.Gibb@lboro.ac.uk

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artistic intention. Within the construction industry, when an outcome is necessarily rationalised and is repeated many times, a mechanical or industrial approach may be the most appropriate because of it offers consistency, speed and efficiency (Womack et al 1990).

This study analyses case study data considering reflective processes of design, described in literature as framing (Schon 1983; Atkin 1992), and compares these to more analytical and conjectural approaches.

The case study considered for this research is a large scale infrastructure project with several repeat designs: a series of high-speed railway stations, using a prototype station design with four specific designs developed simultaneously from the base design. The design team aimed to rationalise the process through the generic design with standardised components, sub-assemblies and pre-assemblies with parametric data using a shared Building Information Model. The team collectively described the process of prototyping, rationalisation and use of generic components as 'modularisation'.

DESIGN STRATEGIES

According to Zal & Cox (2008); p3 'Prototypical strategies' will avoid 'completely reinventing the wheel' when working with manufactured products. The same phrase is used when adopting 'typologies' from past solutions as design generators (Emmitt 2002; p122). These both suggest that there are ways of finding design solutions more quickly. As will be defined below, the use of previous solutions is just one of several methods used in design, with analytical techniques being used for well-defined problems and conjectural techniques being used for ill-defined problems.

Problem-solving Design Theory

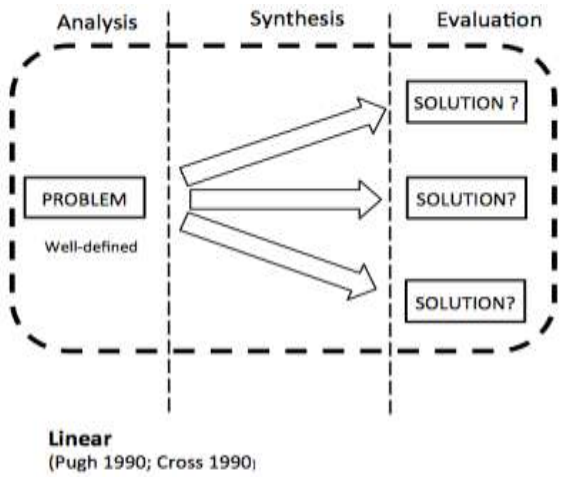

Figure 1: Linear problem solving

Concept, feasibility and detailed design are dynamic and creative phases of a design process and many models have been proposed (Austin et al 2001). Designers follow sequential steps and iterative cycles of design, although others argue (Lawson 2004) that a reflective process is more accurate description. Design methods and design science have been subjects of research since the 1960's (Bayazit 2004). Described as a separate discipline - a 'designedly way of knowing', thinking and acting (Cross 2001) - designers are trained heuristically to evolve processes to solve problems that have not yet been encountered (Lawson 2006). Designers tend to be solution focussed accumulating knowledge they may use in later designs. Furthermore, the process from problem to solution is not consciously followed or straightforward (Lawson 2006).

Usually working to a time limit, designers aim to generate a satisfactory solution rather than instigate a prolonged analysis of a problem (Cross 1982). The more experienced rely on skilled behaviour reviewing many levels of design simultaneously, tacitly ignoring non-important issues (Cross 1982) knowing that it is impossible to assimilate all the constraints (Cross 1982). Solutions may emerge through intense team deliberations (Macmillan et al 2001) and therefore, as a result, designers do not necessarily 'know' how they design.

Linear and Non-linear processes

For well-defined problems, a linear process with cycles of analysis, synthesis and evaluation, (Pugh 1990, Cross 1990), is the most common model. In complex designs several competing solutions are investigated (Harper 1990), and an objective assimilation of the options is used to find the best solution (Figure 1).

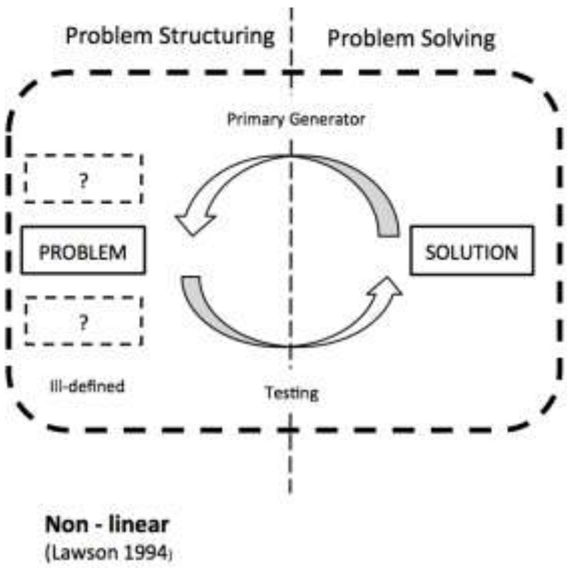

Figure 2: Non-linear problem solving

If problems are ill-defined, designers tend to use a more conjectural process: a cyclical non-linear model with problem structuring and problem solving (Lawson 1994), using a primary generator and testing process as shown in figure 2. The primary generator or 'proto form' is a way of short-circuiting an otherwise complex activity.

It has been recognized that, even in a linear design process, building design solutions may consist of overlapping and conflicting systems and sub-systems of components and assemblies (Groak 2002) further complicating the design process.

Schon (1988) questions the positivistic view on design, noting that most designers are responding to ill-defined problems, using intuition to deal with uncertainty and conflicting demands (Cross 1981). Therefore, the model of assimilation, synthesis and evaluation may be an inadequate description of the process (Lawson 2006) and, in any case, is not practiced widely (Atkin 1992).

Framing Process

Framing theory proposes that each building design is a mental frame (defining size, layout, architecture etc.), which acts as reference for future development of ideas (Atkin 1992). Architectural design is a form of experimentation (Schon 1983); the framing of a problem is like a hypothesis to be solved through the design process. Framing defines boundaries and situations and is used as a way of describing generic perspectives (Schon 1983; Atkin 1992), leading to framing also being used in establishing building types.

However, research on design thinking and framing (Atkin 1992) has shown that this approach can lead to stereotyping. Atkins asserts that most designs are limited to a small number of generic design options, and 'experimentation involving conjecturing and rigorous refutation is not popular amongst designers' (Atkin 1992); p129. Usually working to a time limit, designers will settle on a familiar and satisfactory solution (Ball et al 1998) rather than instigate a prolonged analysis (Cross 1982) and may even be aiming for a final solution in the first attempt (Atkin 1992). This broad generalisation for design practice deserves further scrutiny to determine if on more evolved design projects this process of stereotyping is still followed.

More recent work on framing focuses on the interrogation of client briefs (Paton & Dorst 2011) as a method of clarifying a design commission shows that different stakeholders have their own perspectives of a brief and re-framing is used to form a common view. During the briefing process, designers confirm back to the client their opinions on the building by re-framing the brief to propose a solution that is realistic.

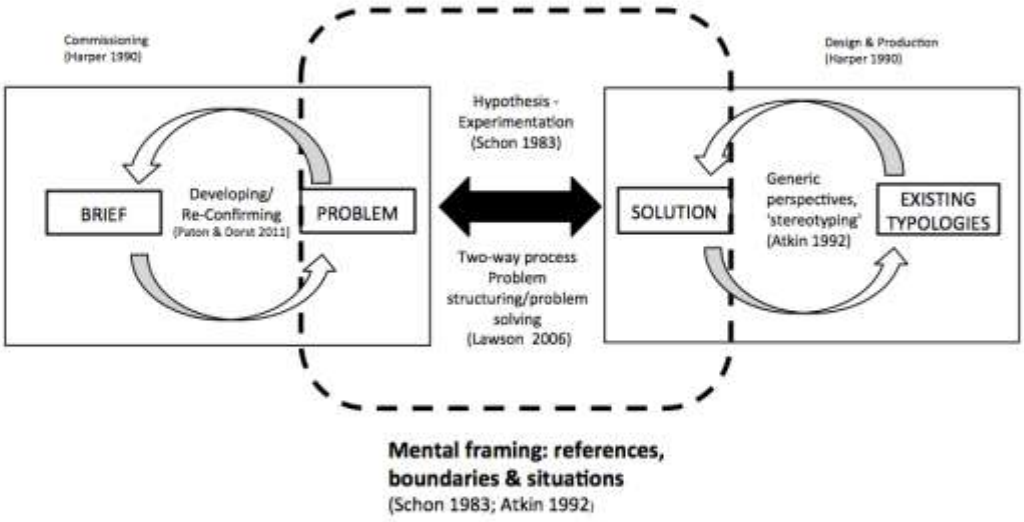

Figure 3: Framing of a design problem and solution

Figure 3 graphically summarises and collates the two current theories on framing activities for evaluating and reconfirming the brief (Paton & Dorst 2011) and framing of the solution with pre-existing typologies (Atkin 1992). The combined outcome of these two processes is a problem structuring/problem solving activity (Lawson 2006), defined through common boundaries (Schon 1983). Schon's experimental process of hypothesising is a testing, rejecting and refining using this mental frame of the project design.

These processes are non-sequential: the process of confirming the problem through the brief, exploring existing typologies and refining the solution, occur in a loosely structured relationship as shown in this diagram. The research will test out this framing model and also look for the presence of linear and non-linear processes, which are known to occur. Under this model they are proposed as episodes of design activity occurring within the framing events.

RESEARCH METHODOLOGY

Epistemologically, the research is testing and revealing a condition that already exists and is therefore empirical realist in nature. The ontological position is predominantly objective, but recognises that organisational behaviour will influence this study and therefore is open to constructivist perspectives. The chosen research method for collecting and analysing this data is a case study approach (Yin 2008). Using a theoretical statement to enable an explanation or prediction of theory the approach is deductive, using linear techniques for analysis. However, as found in many studies, the distinction between inductive and deductive research is blurred as both approaches may occur during different stages of the same research process (Bryman & Bell 2007). Bryman & Bell propose a variant of the deductive empirical research model, which ends with an inductive phase: a hypothesis is deduced from literature and preliminary data and is scrutinized in the normal way to see if the main findings confirm or reject that initial hypothesis and, depending on the outcome of those research findings, the theory is further revised through an inductive process.

Data was collected from 25 interviews (40 hours) as part of a set of end-of-project 'After-Action' reviews (AAR) (Morrison & Meliza 1999), a hindsight process (Bartholomew 2005) intended to increase a group awareness of tacit knowledge. The team used memoranda and design models to communicate the design and these were interrogated along with project reports and drawings. The interviews were organised as structured conversations (Bryman 2007; Cresswell 2008) based around the topics of the AAR process.

Thematic analysis was used to extract data from the interview transcripts; a coding frame was developed for the analysis by:

1. Exploring themes and recurring topics, identifying repeated words and phrases
2. Sampling data from the interview transcripts based on descriptive statements referring to the design process
3. Sorting data under the key categories:
    a. brief development/problem structuring (Patton & Dorst 2011)
    b. problem solving/use of previous typologies (Atkin 1992),
    c. framing of the problem and solution (Schon 1983; Lawson 2006)
4. Sorting this data under sub-categories:
    a. analytical linear *(Pugh 1990; Cross 1990)*
    b. conjectural non-linear *(Lawson 2006)*
5. Drawing inferences from connected quotes, repeated topics, and occurring phrases

The design team followed a prototype-design approach because of the scale of the station project (>2 billion USD) and its repetition of designs. The modularisation approach created a philosophy for the team of 150 architects and engineers to follow. The case study is treated here as a singular project because the four stations were developed simultaneously from an initial prototype design. Being a unique example of its type it has justified a singular detailed case study investigation (Yin 2008).

Figure 4 shows a typical section through the station platform and concourse. Although two of the stations were through-stations and two were arranged as terminus stations, they all had common repeated elements: linear platforms and canopies of varying length and arrangement, based on a repeated modular design.

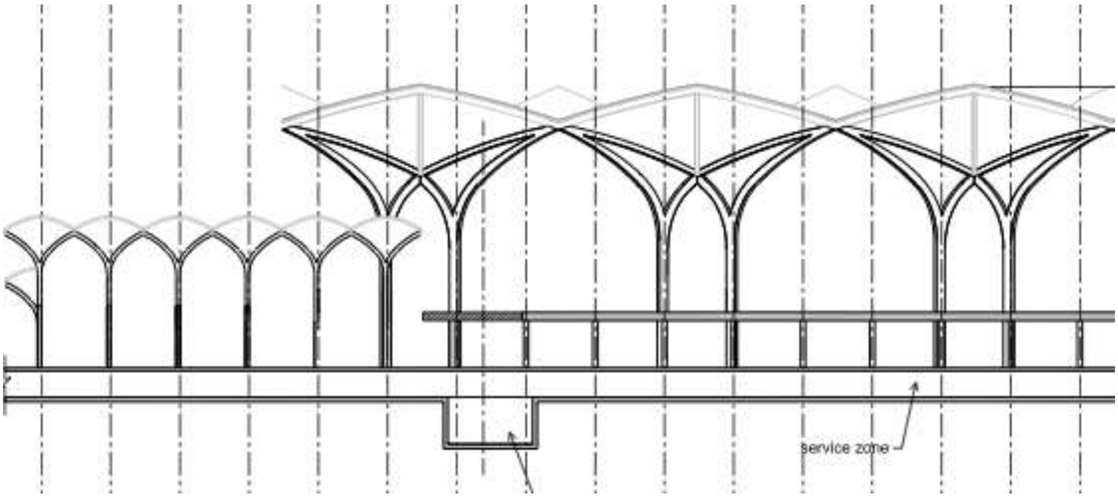

Figure 4: Typical cross section of similar building elements in stations.

The central concourse structures were of different scale, layout and number of levels, depending on their site and nature (terminus/through). The buildings had several other rationalised components and similar cladding treatments.

RESEARCH FINDINGS

The interrogation of drawings, reports and interviews was aimed at detecting the different strategies being used during the different phases of the project. The research findings are grouped under the three headings:

1. Brief development/problem structuring,
2. Problem solving/use of previous typologies,
3. Boundary framing of the problem and solution.

Brief development/problem structuring

Although the project started with the brief development, the observed evaluation/confirmation process continued throughout, including during the detailed design stages. Design outputs were presented to the client at each stage to reconfirm the way that the design was meeting the brief.

The client's brief was found to be under-developed; it contained a list of areas that the client would need for running and controlling the station, but there were no detailed requirements.

"It describes what the entrance should encompass etc.… but (there are) no standards" (Designer O; 2010).

The design team created a document to re-state the brief back to the client. "Our objective was to convert the client's brief into a working document, as well as telling him what we were going to do" (Designer O; 2010). This document contained specific design criteria and design proposals. With the client only having a partially formed idea, the design team were taking on the role of 'expert/artist' (Paton & Dorst 2011), with the framing process being largely led by the design team.

The report shows evidence of a detailed analysis of the brief including a deliberation and selection of design options. The reports also conveyed design ideas: "we would add in design criteria and sketches to show him what systems we were using"

(Designer O; 2010). The use of sketches suggests that these designs were preliminary and conjectural as to what the final proposal would contain. The designers were using their professional knowledge, including schemata and guiding principles (Patton & Dorst, 2011), to reframe the design problem.

Without full information on the operation of the railway, the JV appointed a sub-consultant as a proxy operator: "we all realised that we needed a rail operation specialist" (Design Manager AC; 2010). These separate consultants invented a virtual rail operation with a timetable, with generated passenger flows and station staffing levels in order to re-confirm assumptions about the size of the station concourse, platforms and accommodation. This process required both invention and detailed analytical processes to create the necessary data for understanding the design and operation. This situation confirms the need for a cyclical process of developing and re-confirming of the brief with the client (Paton & Dorst, 2011).

The client later appointed academics to assess the architecture. "The introduction of the professors post-concept, caused a delay to approvals as the design team needed to re-justify the design principles". This indicates that a continuing process of deliberations and approvals was taking place during and beyond the brief definition phase. "…once on-board, their (professors') subsequent endorsement of the scheme became useful later" (Architect AB; 2011. This shows that a building of relationships with the client body was helped through the framing process, and through the professors role the client team became more of a 'collaborator' with the architect (Paton & Dorst 2011).

Problem solving/use of previous typologies

For the layout of the public spaces and the architectural roof forms, the design team drew inspiration from their previous projects and airport buildings in particular. In the concept design documents, comparisons were made with repeating roof systems used in airport departure halls, as well as using local contextual references to forms such as arches and colonnades. Notwithstanding, there was little indication to suggest that design 'stereotypes' (Atkin 1992) were being used beyond the concept stage as idea generators. The airport precedents were closer to an initial framing technique using a primary generator for conjectural analysis (Patton & Dorst 2011). The options report detailed variations in repeating roof forms, with variations in pitch and grid spacing, showing a significant degree of analysis and synthesis with evaluation of these options. This process was "architect led", being "really about what worked spatially and for operation" with the structural engineer "helping (the architect) to see what worked as a column grid" (Designer M; 2010). Therefore the solution structuring process, which initially drew on other building typologies solutions, continued to be re-framed through a consideration of parameters (structural grid, jointing, vertical supports, optimisation of spanning structure) and within this process there were cycles of linear analytical design work.

However, the design team, led by the architects, operated a robust reviewing process called a design review board, occurring shortly before final design resolution at each stage in the project. As a result of these reviews, agreed detailed designs were frequently rejected, leading to re-designs.

The timing of these was chosen to make sure that the design leadership endorsed the design presented to the client. The review boards were also helpful in identifying the critical issues for the design, giving the lead architect and his the team fore-knowledge on which aspects of the scheme to push more strongly with the client, and which areas where they could show more flexibility. However, for many in the design team the results of these reviews appeared unpredictable and the process highly conjectural. In effect, some non-linearity seemed to be self-imposed through the architect's review processes. Major design revisions would be made at these reviews: “they decided to punch a hole all the way through, to connect to the platforms of the two through stations…. but we had a fire compartment between the station and the platforms (Designer P; 2010). Internal design meetings also had unpredictable results. The architect’s team “would change designs the day after the meeting where decisions were made” (Designer M; 2010). “The frustrating thing from our point of view was that we were committing to delivering Stage E and beginning of stage F” (Designer Q; 2010). Stage E & F are detailed design and contract production stages; these accounts show that conjectural design activity was occurring at the same time as more focussed linear and analytical processes associated with delivery of information.

Boundary framing of the problem and solution

The project was of sufficient scale to appoint senior designers to oversee each of the key disciplines; their role was separate to the delivery team in order to maintain an over-view of their own discipline. They were also required to be able to contextualise the technical requirements of their discipline from the overall project perspective. This became important for the design board, because discipline leaders needed to be able to “articulate a design concept or story” in negotiations with other disciplines. They also needed to have a clear picture of the overall context “making it clear why certain choices are made’ (Manager AF; 2010).

The use of design notes was also considered an “absolutely crucial tool” (Designer Q; 2010) for defining the design thinking and process for all the stations. These instances of technical oversight and communication are evidence that mental frames described through a set of boundary criteria (Schon 1989) were being defined to manage the detailed design of the buildings and the framing activity was instrumental in assisting collective team knowledge and understanding of the design problems being tackled (Atkin 1992).

Figure 5: Concourse ‘kit of parts’ structure

For the concourse layouts the prototyping team had developed a ‘kit of parts’ for the structural components (figure 5). Simplified analysis models were sent to the station teams, who then worked them up into station specific models. The standard ‘kit of parts’ approach was also adopted for the drawings, with elements built-up piece by piece. This process was “tricky at the start, knowing where all the pieces went” and stations designers “needed to know design assumptions made for all the elements” but eventually it “became an incredibly fast tool” (Designer T; 2010).

"The most efficient way of doing this was to design the stations simultaneously. When we ran models, the same person would look at the same part on the other station, applying learning from the first station straight away" (Designer T; 2010). This shows that the framing of design problems was instrumental part of the evolved design solution using standardised components and sub-assembly designs.

CONCLUSIONS

To conclude that 'a structured design generation and synthesis is little practised by designers... and future designs are more likely to be combinations of previous designs…than representing a new line of thinking.." (Atkin 1992); p129, has not been evidenced in this study. The designers appeared to be using a structured approach to the design, they were synthesising problems associated with the brief, and developing original designs.

Reframing as a design theory is a convincing model for representing the overall process of design as shown in this case study; the design process is a non-sequential series of reflective mental activities grouped into loosely structured stages of briefing evaluation, solution testing and problem structuring/problem solving. The occurrence of each stage was interrelated with other stages; the brief process was negotiated, the testing out of building typologies was a conjectural and analytical process of testing and rejecting options, and the definition of framing boundaries for problem/solution was formally defined to become an important structure from which the detailed design emerged.

The modularisation process, based on an initial prototype was a predetermined strategy, in effect an evolved type of framing, with design parameters being defined through the prototype and then reconfirmed in the detailed design of the individual stations. Framing through modularisation as shown here is a productive technique for structuring and developing a standardised design.

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