# Development of a generic conceptual design framework [Published title: Development and verification of a generic framework for conceptual design]

# Development of a generic conceptual design framework

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**Keywords**
Conceptual phase, building design, design process, interdisciplinary, teamwork.

**Synopsis**

The rapid and dynamic information and knowledge transfer between designers during the conceptual phase of building projects can result in disorganised behaviour within the team. Team members can become frustrated by the lack of a common understanding of the manner in which the design activity is being performed and the direction in which the process is progressing. Evidence suggests that design teams are better equipped to undertake design activity when in possession of a general programme of events or activities through which they are likely to pass than when no such structuring concept is held. This paper describes the development of a structured framework, which has been generated to aid and support the interdisciplinary team in undertaking conceptual design.

## 1 Introduction

The conceptual phase of any design project is potentially the most vibrant, dynamic and creative stage of the overall design process. However, it is at present the least understood. It is at this early stage that designers from all disciplines need to interact freely in a bid to achieve optimal design solutions that eliminate or reduce the need for compromise of design at a later, more critical period of the process.

As such, there is a need to develop a working environment that promotes creative and innovative interdisciplinary design within the building industry. This, along with a deeper understanding of business and design processes in general, can only enhance the design performance and wealth producing capabilities of the industry. Yet, at present, it appears that the opportunity to gain clarity within the building design process is being squandered, with the process of design being generally poorly understood [1], which in turn leads to design teams often being poorly organised, having no real structure or common focus.

There could be many causes of these problems, one of which appears to be a lack of a shared understanding of what processes should be followed. Currently, design procedures tend to be simply lists of deliverables rather than guidance documents providing design teams with an outline of what to do and by what method it should be achieved. There seems to be an over-reliance on the 'experience' of the designers to 'know how to design', which is generally an ill-founded assumption as there is no consistent approach to conceptual design by designers in the building industry and no real model or guideline to follow [2]. At present the majority of professionals still work in accordance with the RIBA Plan of Work [3].

There can be little doubt that, during the conceptual phase of a building project, there exists great potential for taking decisions that can result in significant reductions in project costs and increased customer satisfaction. The few researchers that have studied group design activity generally agree that shared understanding between the design team members can aid the decision making process and is the key to successful collaboration. These researchers believe that a shared understanding can be achieved if all of the team members can agree on a shared design strategy, i.e. clarify and agree on the methods and processes of design to follow. It is this hypothesis, among others, that the *Mapping the Design Process during the conceptual stage of building projects* (MDP) research project, currently being undertaken in the Martin Centre, aims to test.

# 2 Modelling the conceptual design phase

## 2.1 Towards a model of the conceptual design phase

Since the origination of the 'Design methods movement' in the early 1960s, many design process models have been developed. These models can be categorised in many ways; Architectural, Engineering, descriptive, prescriptive, and consensus. However, typically these are specific to a particular application and do not represent the amalgamated process of building design.

An extensive literature review, comprising in excess of 200 texts, identified and examined the existing design process models from both within and beyond construction. This review investigated models from academia [4, 5, 6, 7, 8, 9, 10, 11], industry [3, 12, 13] and academic inquiries involving extensive industrial input [14, 15]. Those models describing the entire building design process, although few in number, tended towards a common structure, with each model: i) describing a sequence of phases which imply iteration within phases but not between phases; ii) showing progression from broad outline to elaboration of detail; iii) starting with an analysis of requirements before the generation of possible solutions; and iv) having comparable, though not identical terminology. Reference [16] provides a tabulated comparison of some of these models. However, when models representing the discrete phase of conceptual design were analysed and compared, the generalities became far less apparent, with distinct differences between architectural and engineering based models being far more evident. Generally, the conceptual design models from the engineering domain tend to represent prescriptive multi-phase procedures. Conversely, the architecture-based models tend to portray only few broadly defined stages.

These differences in approach, and the resulting lack of a shared understanding of the respective processes, could go some way to explaining the confrontational attitudes which are apparent between disciplines in the contemporary building design environment. A lack of synchronisation causes serious problems for team members in both interactions and communications, and results in misunderstandings and uncoordinated actions [17]. According to Taylor [18], an ordered approach to the design process is essential if people are to work together effectively towards common goals. To this end, it is apparent that for interdisciplinary design teams to work in a synchronised and efficient manner, an integrated design framework, sharing simultaneously the architectural and engineering approaches, is required.

## 2.2 Ingredients of an improved model

### 2.2.1 Flexibility

Hales [19] summarises the opinions of Bessant and McMahon [20] in suggesting that the way for designers and design researchers to gain improved understanding of the design process is to move toward the development of flexible and adaptable models which take account of the dynamic nature of design activity. Evidence suggests that the designer is better able to cogitate on a particular problem when in possession of a general programme of events through which the activity is likely to pass than when no such structural concept is held [21].

### 2.3.2 Interdisciplinary interaction

Design within the contemporary building industry involves teamwork, yet at present most of what is known about design activity in general comes from studies of individual designers [22]. Additionally, as has been stated previously, process models that are available to the team tend to outline technical procedures based on an individual's prescription of effective design. However, Simon argues there should be a shift away from this description of design as a technical rational process, towards that of design as ‘a reflective conversation with the situation’ [23], as descriptive studies involving design teams make it clear that design is not only a complex technical process but also a complex social process [24].

Egan [25], in the document ‘Rethinking Construction’, argues that team design activity can be enhanced by applying a framework which outlines what is being worked on and what the work involves with respect to group design practice. Various current research projects (e.g. Process Protocol [14] and ADePT [15]) have demonstrated how this conjecture is being advanced within the industry. Any realistic framework of this type must include a collection of practices that designers can use in getting the social and technical work of design accomplished [26]. Modern multi-disciplinary design demands that engineers work in teams [27], a comment which holds true for all designers involved in team design activity, as to be successful the team has to reach some shared or commonly held understanding. As such, design methodology has now to address the design process as an integration of the technical process, the cognitive process, and the social process [22].

It is difficult to achieve effective operation of a large interdisciplinary design team [20]. However a way to improve this has been found to be the implementation of a design method, because it more or less imposes group dynamical effects and interdisciplinary co-operation [24, 28]. It is this conjecture, among others, that has prompted the current research project to develop a tentative design framework aimed at addressing these issues – the details of which are outlined in the remainder of this paper.

# 3 Gathering data to develop the model

## 3.1 Introduction

The conceptual stage of the design process is particularly difficult to specify because its phases cannot be described as isolated activities. Additionally, the way in which activities are described is highly ambiguous, with individuals from various disciplines using a variety of terminology to recount the same occurrence. However, although any attempt at collecting data relating to the conceptual design process can be both a difficult and time-consuming task, the research interview is recognised as an effective means of data collection in the field of social science. To this end, a number of designers and 'Design Team Leaders' (DTLs), representing a full compliment of disciplines from across the collaborating organisations, were interviewed about how group design activity had been undertaken on previous projects.

### 3.2 Systematic interviewing

The technique of open-ended, systematic interviewing was utilised for this observational exercise based on details extracted from the literature survey regarding group design activity. The reader is referred to Brenner, Brown and Carter [29] and Gorden [30] for details regarding the interview approach and the interview environment respectively. Open-ended interview responses were followed up by structured questioning to extract further information regarding particularly fuzzy areas of the described design activity. The interviews were recorded in note form. However, to ensure that details were not lost during the course of the interview, the note taking was supplemented by audiotaping.

The interview as a method for gathering qualitative data has both strengths and weaknesses in field research. One of it's main flaws is that it is not a real time analysis technique and as such, results can be biased owing to the fact that descriptions tend to become over simplified, representing the interviewee's subjective perception of the proceedings rather the idiosyncratic activities of design that actually took place. However, as the purpose of this phase of the project was to gain a general understanding of conceptual design activity in practice, in order for any high-level generic elements of the phase to be distinguished, this factor was not seen as being detrimental to the validity of the findings.

Over the course of this period of the research nine case study investigations were undertaken (table 1). These inquiries, which involved interviewing a total of 30 design professionals, focused primarily on the examination of design activity during the conceptual design phase of the projects. However, owing to the fuzziness of the boundaries between the early phases of design, there was, inevitably, some overlap between them. As such, it is important to note that the term 'conceptual design' was never used in the interview sessions as it was felt that this title did not represent the same period of design activity for all individuals.

The case studies represented a cross section of client type, project type, project cost and phase duration and as such, they allowed the investigation of the ways in which differing factors can influence the activities involved in the conceptual design process (table 1).

**3.3 Archive analysis**

To support the information gathered during the interview sessions, the author was given access to archived data. This data, comprising various types of documentation such as meeting minutes, early design drawings, project design notes and concept design reports, had been generated over the course of each of the respective case study projects. The collection and subsequent analysis of the accumulated documentation, which amounted to over 40 individual documents, together with the information gathered during the interview sessions, allowed the elements of team design activity to be recorded in reasonable detail. Additionally, the documentation proved important as a means of confirming the reasoning behind the progression of activities described by the interviewees.

### 3.4 Designing Together Workshop

During the course of the case study period an experimental session was held, which took the form of a 'Designing Together Workshop', in which the real-time conceptual design activity of three individual teams was observed and recorded as they worked on an artificially constructed design problem.

The workshop, which involved fifteen participants from a leading multi-disciplinary practice, involved the design of a window façade system for the re-cladding of 1960s office buildings. During the design exercise detailed notes were made with regard to both the manner in which the teams progressed and the activities and phases that were undertaken. These observations were later used to develop detailed maps of the design progression of each team. Additionally, upon completion of the exercise, each team was asked to describe the manner in which they perceived they had progressed through the design activity. The data, outlined in table 3, assisted in the development of the preliminary model (figure 3). This period also served to both enhance and verify the case study findings. Full details of this, and a second similar workshop that served to validate the findings, are provided elsewhere [31,32].

## 4 Development of the preliminary model

### 4.1 The case study projects

Nine projects were examined during this research period in order to gain an appreciation of the similarities and differences in the tasks undertaken during the conceptual design of buildings.

These particular projects, which are described and contrasted in table 1, were chosen specifically to ensure that such variables as i) type of building; ii) client; iii) time periods for phase completion; and iv) cost, were accounted for.

As can be seen, the projects varied in a number of ways. This variance in the nature of the projects was seen as being beneficial to the research as it ensured that a realistic cross-section of design approaches was considered. However, the nature of the projects available for study was constrained to some degree by the fact that there were only six industrial collaborators directly involved in the research.

| Project | Project type | Client type | Phase duration | Building cost (budget) | Method of study | No. of tasks described |
|---|---|---|---|---|---|---|
| A | Airport pier | Airport authority | 12 weeks | £21.5m | Interviews; Archive analysis. | 36 |
| B | Airport terminal (refit/extension) | Airport authority | 12 weeks | £51m | Interviews; Archive analysis. | 41 |
| C | Airport terminal (refurbishment) | Airport authority | 8 weeks | £12m | Interviews; Archive analysis. | 30 |
| D | Office building refurbishment | Pharmaceutical organisation | 6 weeks | £16.7m | Interviews; Archive analysis. | 32 |
| E | Laboratories, offices (new build) | Pharmaceutical organisation | 20 weeks | £137m | Interviews; Archive analysis. | 58 |
| F | Laboratories, offices (new build) | Pharmaceutical organisation | 12 weeks | £30m | Direct involvement; interviews; archive analysis. | 40 |
| G | Corporate offices (new build) | Property developer | 8 weeks | £28m | Direct observation; systematic interviewing; archive analysis. | 42 |
| H | Operations centre | Rail company | 5 days | £20m | Interviews; Archive analysis. | 27 |
| J | Production facility/ office headquarters | Private client | 2 weeks | £2.5m | Interviews; Archive analysis. | 45 |

**Table 1** Comparison of case study projects

### 4.2 Observations from case study data

The various sources of data, relating to each case study project, were compiled and cross-referenced. A synopsis of each case study was generated, in addition to a list of the design tasks that were involved in each of the respective projects. Subsequently, each of these documents was passed to those individuals who provided the information for verification of data. In this manner, errors in the descriptions were highlighted and amended quickly and efficiently. This procedure allowed the generation of a robust and detailed description of the various design tasks involved during the conceptual phase of each of the projects. This allowed a number of general observations to be made, the most germane being:

- There was a variation in the number of tasks that were identified in each project (table 1). This difference was recognised as being the result of either i) individual perception and subjective interpretation of the situation; or ii) differences in the processes involved. However…
- Within the high level details of tasks it was apparent that some were common to all projects, while others were very much project specific. There was no evidence of correlation between these similarities and differences in terms of project type, duration, or cost.
- There was little, if any, explicit recognition of iteration within or across the identified tasks, with descriptions tending to be systematic and linear representations of design progression. Interviewees acknowledged that iteration had occurred across tasks however, they could not recall the manner in which this

iteration had occurred. As such, only basic progression through tasks could be identified (a recognised problem in historic investigations).

- It was apparent that each project involved a period of understanding the project requirements prior to any generation of concepts. This implies that conceptual design activity involves high-level phased progression to some extent
- It was possible to compile tasks into a number of discrete groups (activities), with each group having a similar objective across every project (see section 4.5). Although the tasks within each project contained similar and disparate tasks, the objective of each activity could be described in generic terms.

In addition to these direct observations, the interviewees were asked to divulge information regarding any problematic areas they had encountered during the conceptual phase of the projects (table 2).

| | | **Project** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | H | J |
| **Problematic areas** | Confusion regarding direction of progression | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Team members rushing ahead of one another during design process | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Late changes in requirements and design aspirations causing difficulties | ✓ | | ✓ | ✓ | | | | ✓ | ✓ |
| | Construction not directly considered in concept development | ✓ | | | | ✓ | | ✓ | | |
| | All team members not told about design changes | | | ✓ | ✓ | | | | ✓ | |
| | No consistent level of detail to be reached for concept proposal | | | | ✓ | | | | | |
| | Little user involvement during conceptual design activity | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Expectation that all requirements can be satisfied equally | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Lack of cohesion between design stakeholders | | ✓ | ✓ | | | | | | ✓ |
| | Wrong people involved in initial briefing sessions | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Table 2** Problem areas in conceptual design phase

These details were required to allow a further understanding of the nature of the phase to be gained. Predictably, there were several distinct problems that were common to each project:

- There is a need for each design team member to understand what others are doing as they progress through the phase. Without this shared understanding the team becomes inefficient. Consequently…
- There is a tendency for individual members of the team to try and 'rush ahead' in design terms, with designers tending to try and develop some elements in detail before many other issues have even been discussed broadly.
- There is little user involvement in design meetings. This is critical as it would allow them to participate actively in the concept development and ensures that the final proposal meets their requirements. This involvement would improve the decision making process and reduce the problem of having to wait for client input and changes before the design activity can progress.
- At present, initial briefing sessions tend to involve the wrong people. Instead of the client outlining what is required, the design process would be simpler and contain less iteration if the building users were involved from the outset. However…
- It is very difficult to accommodate the requirements of everybody involved in a project not least because some requirements conflict. This also leads to problems when trying to provide different people with robust information; 'they must appreciate the fuzziness of this stage of design'.

### 4.3 Designing together workshop observations

This first experimental session provided the opportunity to gain an appreciation of the similarities and differences in the activities undertaken during the design of a building component. As described previously, this designing together workshop involved three teams of five industry professionals working on the design of a window façade system.

| Initial proposal for activity terminology | Team A | Team B | Team C |
|---|---|---|---|
| Understanding the briefs requirements | Task debate | The Task<br>Brainstorm design features (introduced by brief) | Common understanding of brief |
| Generating a mission statement | Vision statement<br>Mission statement | Mission Statement | Mission statement |
| Identifying design process to follow and allocate time periods to each phase | | Time Evaluation | Identify activities to be undertaken<br>Order activities chronologically<br>Allocate days, times, responsibilities |
| Assessing and developing design factors/ requirements | Critical success factors (What are the issues?) | Existing methods of fulfilling the design brief | |
| Identifying design drivers and constraints | Design Basis/ constraints | | |
| Prioritising factors/ requirements | | | Weight factors from brief |
| Generating design concepts/solutions | Concept drawings | 5 Concept solutions | Brainstorm concepts to address factors: -External visual impact Internal considerations |
| Grouping/combining solution concepts | | Evaluation (of preliminary proposals) | Group factors to allow scoring of schemes |
| Selecting suitable options | | 2 solutions | Identify broad options |
| Evaluating/choosing options | Select design | Detailed review of solutions<br>Preferred scheme | Use 'pros and cons' to assess options<br>Choice of option |
| Developing, improving and reviewing of final option | Resolve issues with design<br>Assign tasks for deliverables<br>Generate deliverables<br>Final internal design review<br>Final amendments | Detailed design review | Develop option |
| Presenting final proposal | Present design proposal | | |

**Table 3** Comparison of design processes outlined by the teams

Upon completion of the exercise the design teams were asked to provide a presentation outlining not only their proposals but also the processes involved in reaching them. These processes, which were described both graphically and verbally, represented each team's own interpretation of the design activities they had followed during the course of the exercise. Details of these descriptions are provided and compared in table 3.

As can be seen, although the terminology is different, the elements of design activity can be clustered with respect to their common purpose (the proposed terminology for each being shown in the left column of the table). This is an observation that reinforces the findings of the case study descriptions.

## 4.4 Type of modelling approach

The observations made during both the case study and experimental investigations highlighted the fact that generic activities were apparent across the projects. A subsequent investigation of available modelling techniques concluded that structured representations of design activity based around information flow between tasks at the conceptual phase were overly complex and cumbersome. However, by representing only discrete sections of the information flow between tasks rather than the whole, design activity could be simplified. Unfortunately, once reduced to this level the models become fragmented and as a result, provide little, if any, understanding of the sub phases through which the design activity should progress. As such, a choice needed to be made as to the most appropriate modelling approach to utilise in developing the preliminary design model. Bearing these factors in mind, three modelling approaches were considered: project specific, global, and categorical.

### *4.4.1 Project specific*

A project specific approach would require the collection and archiving of models from individual projects, which would then be referenced and examined as a means of predicting and defining the tasks involved in a project of the same type. This type of approach has both advantages and disadvantages:

***Advantages***

- True and accurate representations of previous projects can be generated.
- A store of these projects could be generated from which the most applicable could be chosen as a basis for predicting design activity in future projects of a similar nature.

***Disadvantages***

- To produce models of all permutations of all projects likely to occur in the design of a building would be both time consuming and unrealistic [33].
- Large parts of each model would be similar with only small differences distinguishing individual models. However, there would be differences and these would have to be accounted for.
- Projects evolve from the unique environments in which they are developed and are a result of the personalities of the participants and the social conditions. As such, applying a specific model of a successful project to a new environment would not guarantee a successful result.

### *4.4.2 Global*

A global approach would involve representing all possible design occurrences on all types of building design project in a universal model. The major advantage of using this approach is that a new project could be represented by simply removing those elements of the model that were not applicable to the particular project at hand. However, this approach too has a number of recognised disadvantages:

- It would be practically impossible to represent all possible eventualities that could occur during the course of the conceptual design phase of all projects. This owes much to the fact that the conceptual design phase cannot be viewed as a history of various responses to one and the same problem but as the history of a problem which is evolving and whose solution is changing with it [34].
- The model would be awkward and unmanageable, possibly with large parts being redundant for each proposed project [33].

#### *4.4.3 Categorical*

A categorical approach would involve the development of a tool kit model comprising two basic elements: i) a standard framework describing the various phases that are generic from one project to the next; and ii) at the lowest level, it would provide a structured set of activities. This level of the model would enable project specific knowledge, data and models to be stored rationally. This type of approach allows flexibility and adaptability to particular types of project, client, and design environment while offering a structure to which project specific sub-models can be connected. As such, this type of approach has several distinct advantages over both the project specific and the global approaches:

- It would allow sub-models developed using the structured modelling techniques to be integrated into the wider picture and their interfaces to be aligned across the generic phases.

- It would describe the phases of design activity that will be undertaken by the design team, albeit at a high level of abstraction, without constraining the manner in which they are undertaken.
- It structures the conceptual design period without over systematising the details of the actual design activity involved.

Nevertheless, this approach also has a recognised flaw:

- The user must generate sub-models of design activity and insert them into the framework if an increased level of detail is required. As such, the users must generate their own project-specific models as described above.

However, considering the above factors, the categorical, or tool-kit, approach was chosen as the most suitable means of developing the preliminary model of the conceptual design phase. Owing to the nature of this type of modelling approach it was considered appropriate to classify the product as a framework rather than a model. This decision was taken after referring to the definition of the two terms; with a model being defined as a simplified representation of a system or complex entity and a framework being described as structural plan or basis for a project. As such, from this stage on the product will be defined as a framework: that being a structure in which project specific models can be located.

### 4.5 Generation of the preliminary design framework

The development of the framework involved a bottom-up approach to grouping the design tasks from the various case study projects in the light of the results from the literature search. In essence the approach involved the generation of a framework hierarchy, with the project-specific tasks acting as the basis of development, and the clustering of these tasks in relation to their combined objective representing the generic group characteristics (figure 1). These groups of tasks have been termed activities. Once defined, the nature of each activity was referenced against the conceptual design activity described at the end of the designing together workshop. The combination of these two individual sets of descriptions allowed the bottom level design activities to be identified.

Once these bottom level activities had been distinguished, the procedure was repeated. However, this second stage of development grouped the activities in terms of their overall phase objective as a means of developing the next level of generality. This procedure was repeated until the only way in which the components could be grouped was under the objective; ‘Undertake conceptual design’. Thus, the framework was at the required level of detail in generic terms (figure 2).

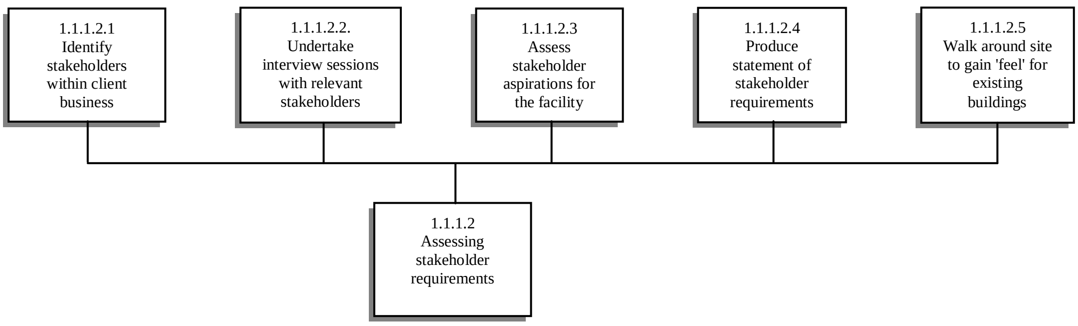


**Figure 1** Section of bottom level of project specific framework hierarchy

Once complete, this hierarchy represented a generic building design framework in which each of the case study projects and the designing together process descriptions could be contained. The framework comprised four levels of definition; with the second containing two stages, the third containing five phases, and the fourth and final level containing some twelve generic activities (table 4).

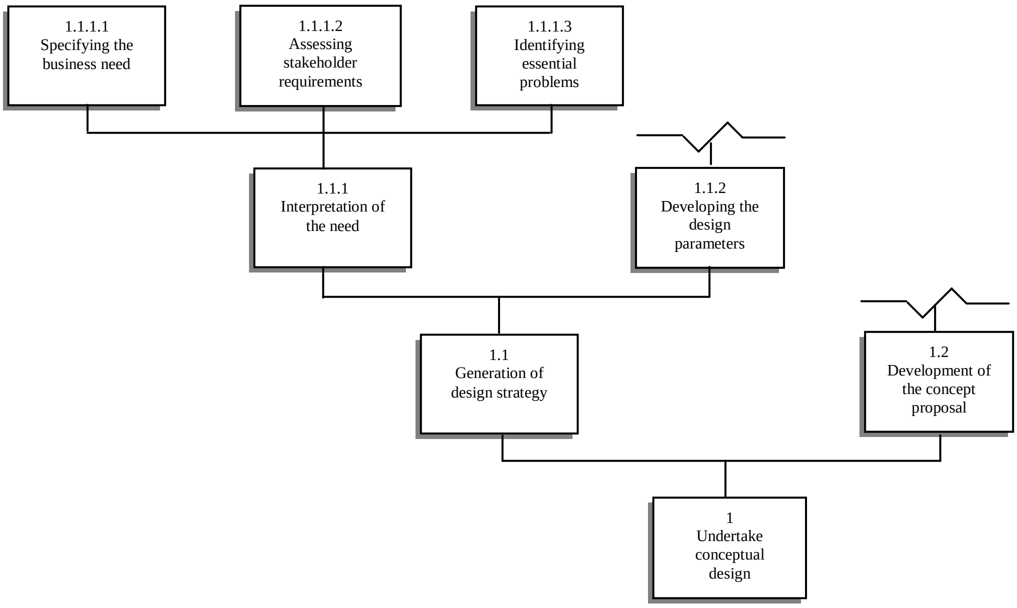


**Figure 2** Section of the conceptual design framework hierarchy

| **Level 1** | **Level 2 (stages)** | **Level 3 (phases)** | **Level 4 (activities)** | **Level 5 (tasks)** |
|---|---|---|---|---|
| Undertaking conceptual design | Developing the business need into a design strategy | Interpretation of the need | Specifying the business need | Specific to project |
| | | | Assessing stakeholder requirements | |
| | | | Identifying problems with existing solutions | |
| | | Developing the design parameters | Developing requirements | |
| | | | Setting requirements | |
| | | | Determining project characteristics | |
| | Developing the design strategy into a concept proposal | Divergent search | Generating initial concepts | |
| | | Transformation of concepts | Transformation/combination of concepts | |
| | | | Selecting suitable combinations | |
| | | | Firming up into concept proposals | |
| | | Convergence to proposal | Evaluating and choosing proposal | |
| | | | Improving detail and costing proposal | |

**Table 4** Basic framework structure

## 4.6 Definition of level four activities

The fourth level activities had to be defined in a manner which outlined the nature of the group without being over descriptive of the actual tasks involved. It was recognised that, without defining the activities of the framework, it would be impossible for it to be implemented in either a live design project or an experimental workshop; two exercises that would enable validation of the framework and lead to its subsequent improvement. Thus, the tasks involved in each of the activities were considered in some detail and a generic definition of each was produced (table 5).

| Activities | Definition |
|---|---|
| **Specifying the business need** | Once approval from the client is received that the only way to satisfy a certain business need is to construct, this basic need must be recognised. The manner in which the need is specified, be it formally in a design brief or verbally through a brief conversation with the client and his representatives, is irrelevant. The nominated interdisciplinary design team must fully appreciate and understand this need before any attempt can be made to address it. This can usually be achieved by gathering the information available and then generating a project mission statement to define broadly what is required. |
| **Assessing stakeholder requirements** | This phase involves taking the specified business need and attempting to elicit information from the client or the client brief concerning aspirations for the project in terms of requirements for functionality. The search space must be given boundaries. The first step in achieving this is to assess the client's own requirements. If these are not met, the design solution will be unacceptable. The client’s requirements should be extracted and recorded. |
| **Identifying problems with existing solutions** | Here the design team should develop some idea of the constraints of the problem at hand. The client's need and requirements have been assessed and the problem should be gaining some clarity. The fact that a new design is required shows that there are problems with the products or systems already available. As such, these problems should be identified and used to guide the design by setting some design drivers and constraints. |
| **Developing requirements** | Once the client's aspirations have been acknowledged and the task clarified, the design team members must attempt to extend the acceptable solution boundary. This can be achieved by identifying the 'real' users of the facility or system and questioning them as a means of understanding their value requirements. This phase also provides the design team with the opportunity to introduce their combined experience and expertise into the design environment. The client's requirements must still be adhered to, but the introduction of more innovative requirements may force the designers to uncover more innovative and fresh proposals. This phase allows the design team to contest both convention and the client's wishes as a means of developing a function structure. |
| **Setting requirements** | Produce a list of all the requirements that have been both stated by the client and introduced by the design team. Each of these requirements should then be defined in a few words. The definitions should be defined narrowly enough to give the design team direction, while still being broad enough to ensure that a wide search space is apparent. Similar requirements should be combined while those that are unrealistic should be discarded or reassessed. The requirements that remain should be set as key to the project. |
| **Determining project characteristics** | The pre-set requirements define the boundaries of the search space. At this stage of the process the requirements list needs to be developed in to a value tree. This will require the group to rank the requirements in order of their perceived value, and thus importance, to the success of the project. This value hierarchy will define the project characteristics and will set the value datum against which the conceptual design proposals will be assessed. |
| **Generating initial concepts** | This phase is where initial attempts are made to generate solutions. These solutions can be developed based on requirements or abstract ideas. Designers must be creative and uninhibited in proposing solutions. The key here is to use creative thinking in conjunction with experience and prior knowledge as and when they are required. Once externalised the ideas should be recorded in a structured manner to ensure that no scrap of ingenuity is lost, however useless or unrelated it may initially appear. Several 'creative' tools have been developed to assist in undertaking this phase. |
| **Transformation/ combination of concepts** | At this point a number of concepts should have been generated that address the problem holistically and/or at sub-system level. These solutions however, may well be unusable in their present form, having being generated as the result of uninhibited thought. As such, this period of design activity should concentrate on developing, transforming and combining individual proposals in a bid to mould them in to a number of usable proposals, at an holistic and/or sub-system level, that more realistically address the functional requirements. |
| **Selecting suitable combinations** | Having generated several possible solutions, their number must be reduced as early as possible. However, care must be taken not to dismiss valuable concept principles before the opportunity to combine them with other concepts, to generate an advantageous overall solution, has been missed. There is no fail-safe procedure that facilitates this choice, but the decision must be democratic. Firstly, elimination of totally unsuitable proposals must be undertaken. After this, it is a matter of giving preference to those remaining solutions that are patently better than the rest. |
| **Firming up into concept proposals** | Those concepts that remain may satisfy the requirements superficially. However, the generation and selection procedure to date may well have revealed gaps in information about important elements of the design that mean that not even a rough and ready decision, let alone a reliable evaluation, of the proposals is possible in their present state. In building design this tends to manifest itself in the co-ordination of the disciplinary components. As such, important aspects of the working principles in terms of performance, space requirements, pinch-points in structure and services co-ordination etc. must be known at least approximately. More detailed information need only be gathered for promising proposals. |
| **Evaluating and choosing proposal** | In this phase the solution proposals or concept variants must be evaluated by the interdisciplinary design team so as to provide an objective basis for decisions. The subjective views of the individuals must be introduced into a democratic decision making mechanism. There are several evaluation procedures that have been developed to satisfy this phase of design, all of them developed to allow objective evaluation of concept variants as well as of solution principles in every phase of the design process. The evaluation procedures allow the concept variants to be gauged against one another, an imaginary ideal and/or the pre-set value hierarchy of design characteristics and requirements. |
| **Improving detail and costing proposal** | This phase requires the improvement of details and the costing of the proposals. The costing of proposals should be an ongoing exercise throughout the design activity, but at this juncture a detailed costing of the proposals is imperative. This phase actually involves developing the chosen proposal to a level that allows the critical unknowns to be improved to the point where they pose little or no risk to the subsequent development and success of the project. The pinch points should be detailed enough to ensure that co-ordination can be facilitated in the later stages of design. This phase, along with the entire conceptual design phase, is complete when the chosen proposal is documented in a way that the client can fully understand it and as such, agree that with further development it will sufficiently, if not optimally, satisfy his need |

**Table 5** Definitions of level 4 framework activities

# 5 Verification of the preliminary design framework

## 5.1 Verification versus validation

Verification represents an internal check of both model integrity and logic based on the projects studied. This involved checking that each of the components of the preliminary framework were representative of the conceptual phase of building design and that, in combination, they characterised the elements of design activity described during each of the case study projects.

Validation involves an external check of correlation between the model and reality. This activity involved applying the framework to real-time design activity as a means of confirming its applicability to building design. This would allow both the ratification of the existing framework components and provide critical feedback for the subsequent development and improvement of the preliminary version.

## 5.2 Verification

To enable the framework to be verified among the collaborating parties it was transformed from the early hierarchical form in which it was derived initially. This revised version was based on the initial hierarchy, however the subtle modification served to smooth its appearance and reduce the overly-structured appearance of the framework hierarchy. This alteration to the model was made owing to the belief that, for any model of the conceptual design process to be realistic and widely acceptable to industry, it should not appear overly systematic [31]. The revised framework model is shown in figure 3.

This revised framework, along with the activity definitions (table 5), were sent to those design professionals who had been involved directly in the collation of the case study project data. Short interviews were held with each individual, both face-to-face and by telephone, to elicit their opinions on the appropriateness of the framework as a reflection of their respective descriptions. The result of these sessions was, without exception, very positive across all the interviewees. A synopsis of the key comments is provided below:

- All interviewees agreed that the design activity undertaken during the conceptual phase could be classified and grouped into the proposed activity and phase structure. However…
- Although the framework could be used to describe the case studies, it did not indicate the order in which the activities were undertaken i.e. No representation of the way the design actually advanced is provided.
- The phase description (level 3 in table 4) was deemed more appropriate as a means of guiding design progression in practice, with this sequence of progression being more akin to the way the design had actually advanced during the design activity.

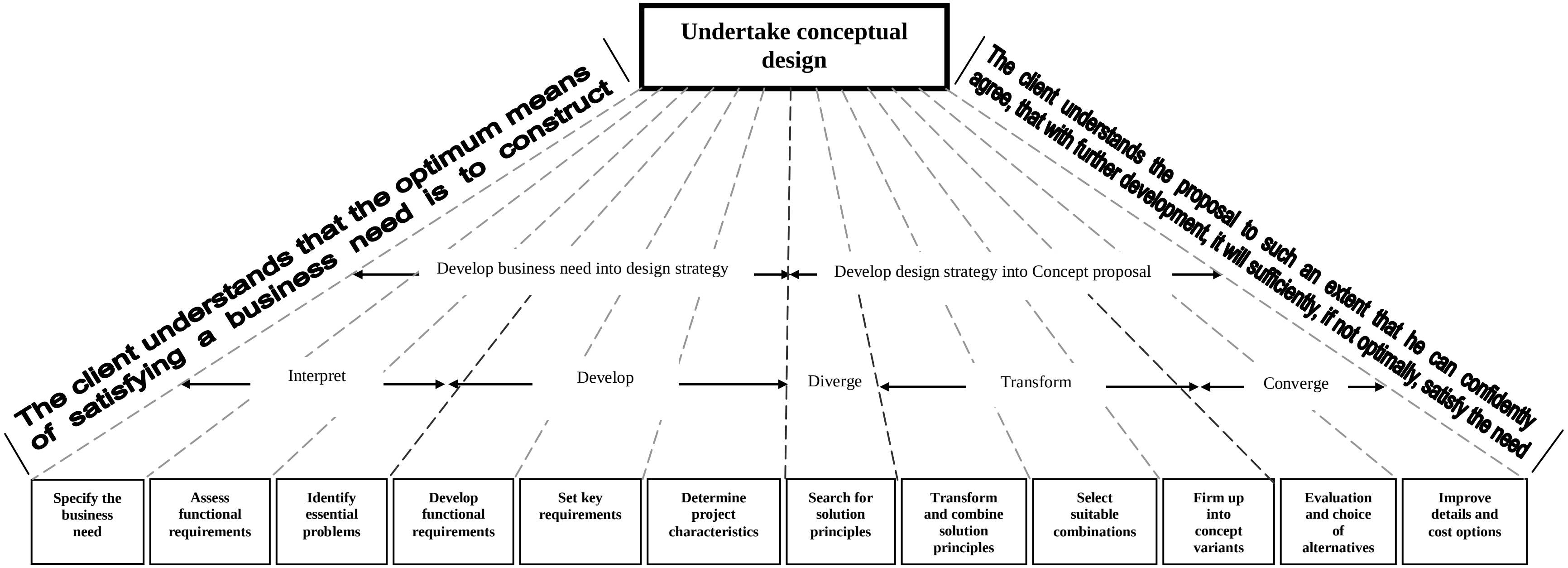


**Figure 3** The revised version of the preliminary conceptual design framework

In order to reinforce and further verify the remarks of the case study interviewees, the revised framework was sent to each of the lead contacts from the collaborating organisations who were asked to check that: i) the nature and structure of the framework hierarchy was applicable to conceptual design activity from their individual disciplinary perspective; and ii) the framework components were representative of the manner in which their respective organisations undertook conceptual design at a generic level.

These individuals then participated in a half-day round table discussion of the framework's validity. The extensive discussions resulted in several points of agreement being reached:

- As with the case study interviewees, the participants agreed that, in general, the design activity undertaken during the conceptual phase of building projects could be classified and grouped into the proposed framework.
- The phases outlined in the framework were described as being 'understood intuitively by professional/expert designers'.
- In this respect it was suggested that the framework phases could be utilised as a training aid for new designers; with the model being used to develop graduate understanding of how design is actually undertaken. (It should be noted that the architects among the group considered this to be already understood among graduates within their discipline).
- The framework's focus on outlining activities and phases would make it more acceptable to designers working in practice as, rather than structuring conceptual design systematically, it suggests a direction for progression. However, …

- There was a split of opinion between the activities and the phases with regard to the most appropriate/acceptable level to utilise in directing design activity.

All told, the response confirmed that the framework was both concise and clear and, more importantly, that the combination of phases and activities within the framework were acceptable to a sample of the professional design community.

### 5.3 Validation

The optimum means of validating the framework was to apply it to a real-time conceptual design project. However, it was wholly unrealistic at this stage of its development to expect the collaborating organisations to endorse the use of an as yet untested research model on a live design project. Likewise, introducing the preliminary framework to practising designers in the high-pressure environment of a live design project, while expecting them to apply it with full conviction and enthusiasm, was impractical. Additionally, it is questionable whether anything useful could be gained from testing a preliminary version of the framework without first developing and refining it in an initiatory session. As such, it was decided that an initial validation of the model could be achieved to an acceptable level by applying the framework in an experimental environment.

This experimental workshop, which is described elsewhere [32], enabled the preliminary framework to be validated and, after some detailed analysis of the varying levels of dependency between phases and activities, subsequently reinterpreted (figure 4).

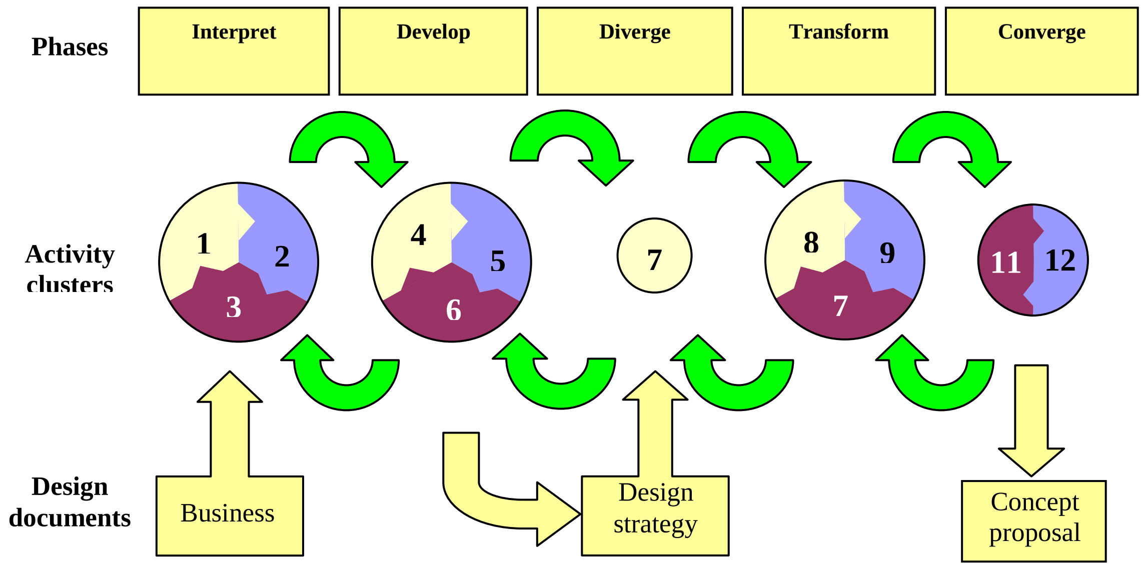


**Figure 4** Reinterpretation of conceptual design framework

## 6 Conclusions

The early sections of this paper identified that there is no model available at present to guide an interdisciplinary design team through the conceptual stage of the building design process. Additionally, for any such model to be realistic and widely acceptable to industry, it should not prescribe a systematic procedure, but be a contingency model that can be adapted to suit the team and the project.

A number of case study investigations have been described which involve a variety of project types, costs, and client. The most pertinent of the case study conclusions were:

1. A number of problems encountered by design teams were common across all projects, while others were specific to the project in question.
2. Similarly, some tasks were common across all case studies, although many others were project specific. However…

3. The tasks identified in each case study could be grouped with respect to their combined objective; these have been defined as generic activities.

4. After an investigation of the available modelling approaches, it was decided that the optimum means of delivering the framework would be in the form of a categorical (or toolkit) model. A model developed using this type of approach not only allows the team to decide at which level they work, it also permits them to define their own pattern of progression through it.

5. Additionally, this system provides a structure in which more detailed and constrained project specific models can be stored and aligned.

6. A generic conceptual design framework has been generated and verified. The authors believe that this model is adaptable and flexible to fit the needs of all teams and all project types, and it structures conceptual design activity without prescribing a systematic procedure.

The next stage of the research employed an experimental approach as a means of validating the preliminary conceptual design framework [32]. This session, which was the second of two, involved a range of the relevant design disciplines from across a number of professional organisations. It allowed a cause-and-effect experiment to be undertaken to provide hard evidence concerning; i) the validity of the framework phases and activities; ii) the applicability of the design framework in practice; and iii) its effect on team performance and effectiveness. This work also provides insights into the manner in which conceptual design activity is actually undertaken by teams of practising designers.

## 7 Acknowledgements

This work has been undertaken as part of a project entitled 'Mapping the Design Process during the conceptual phase of building projects'. The research is funded under research grant GR/L39292 by the EPSRC and industry (AMEC Design; BAA Plc., Hotchkiss Ductwork Ltd; Hutter, Jennings and Titchmarsh; Matthew Hall; and Pascall & Watson). Loughborough University is also contributing to the project.

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