A problem-solving approach to value-adding decision making in construction design

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Abstract

Purpose – To illustrate the use of a Value Adding Toolbox by construction industry designers when addressing customer value expectations using problem solving.

Design/methodology/approach – Focused literature review establishes the need for construction industry design solutions to deliver customer value and a Value Adding Toolbox is proposed in response. Case studies validate Toolbox use and one illustrative example is provided. Interviews with prospective Toolbox users identify barriers to adoption and inform a recommended approach to organisational adoption.

Findings – The Toolbox is found to be effective at helping construction designers to solve technical design problems with regard to customer expectations of value. However, designers are found to be initially reluctant to adopt the new tool. Organisation learning is therefore required to establish the importance of customer value satisfaction as a prerequisite to Toolbox adoption by designers.

Originality/value – This paper provides a useful insight into the practical application of problem-solving tools by construction designers to better understand customer needs.

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Keyword(s): Design calculations; Problem solving; Structural design; Construction works; Value chain.

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Introduction

This paper discusses the development and use of a “Value Adding Toolbox” to structure and document value delivery from construction design decisions. The paper reviews established value delivery methods with reference to the project process and design problem solving. Toolbox development is presented with reference to the **Austin *et al.*'s (2001)** design chain view of collaborative design in the construction project supply chain. The principles of toolbox function are illustrated and determined to be capable of supporting value delivery by relating design decisions to stakeholder expectations.

The need to improve value delivery

Construction clients increasingly demand documented evidence of the steps taken to deliver value. Although their understanding of value varies (see **Table I**), the more sophisticated views emerging require broad and flexible measures on the part of designers to justify design decisions in terms of value delivery. The industry's current approach (see **Kelly and Male, 1993** and **McGeorge *et al.*, 2002** for examples) is characterised by value management in the project stages occurring before Final Proposals in the RIBA Plan of Work (**Phillips, 2000**).

Existing practices do not facilitate value delivery when solving technical design problems because they are constrained to briefing and conceptual design. They do not provide designers with means of investigating the relationship between their design decisions made during detailed design stages and the value expectations of project stakeholders. Instead, design is focused on fulfilling technical and performance specifications in these later project stages. This practice assumes that briefing will have adequately captured stakeholders' expectations in these specifications and that these expectations will remain constant throughout the project. However, in their “briefing as a process” view, **Barrett and Stanley (1999)** have challenged this assumption, arguing that value must continue to be considered in all design activity, irrespective of the stage in which it occurs.

Although stakeholders remain concerned with the monetary value of the buildings they procure, broader interpretations of the term “value” are gaining currency. A key element of these views address value in terms of the affect that a building has on the people influenced by it. UK Government (**Department for Culture, Media and Sport, 2000**), Professional Bodies (**Loe, 2000**; **Worpole, 2000**) and Industry/Government Review Panels (**Commission for Architecture and the Built Environment, 2003**, **2002**) are advocating address of the social implications of buildings.

Despite its awareness of the need to deliver value in this broad sense, **Saxon (2002)** notes that “the [construction] industry knows little of how it adds value to customers or society.” There is a need, therefore, to understand what is meant by “value” within each project and to reflect that insight in design decisions. The objectivist view of value embedded in traditional approaches such as value management must be complemented by a subjectivist view that accommodates the judgement of value that occurs within the relationships between buildings (and their embedded design solutions) and people. Given that the product features that inform these judgements of value are defined by design decisions, it follows that design decision making should be the primary focus of a subjectivist approach. A flexible approach to value delivery stimulated by the emerging “value agenda” must be reflected in design method.

Austin and Thomson (1999) proposed integral value engineering (IVE) to deliver value from existing, product-focused, methods and from emerging, process-focused, business models. In design, integral value engineering extends:

- the *duration* of value delivery, by linking current value management practice during inception, briefing and conceptual design to the later project stages in which most design decisions are made; and
- the *source* of value delivery, by allowing any design chain member with relevant design expertise to contribute to collaborative design.

This paper describes the development of a “Value Adding Toolbox” to facilitate and integrate the practice of IVE. The toolbox can be used by designers to relate their design decisions to stakeholder expectations using collaboration where appropriate (**Austin and Thomson, 2001**). Thus, a subjectivist approach to value delivery that validates design decisions with reference to the people influenced by them can be established as a response to clients' demand for a more sophisticated treatment of value.

Establishing a context for value delivery

Business environment

Existing industry practice often impedes value delivery. Supply chain members are often isolated from the consultant organisations traditionally considered as the project "design team." This hinders the development of design solutions that could yield stakeholder value if they included the insights of the full supply chain. **Austin *et al.* (2001)** proposed the "design chain," in which all supply chain members are engaged in collaborative design problem solving, irrespective of their historical supply chain or procurement path position. Such collaboration recognises that organisations traditionally perceived as suppliers of components and materials also often possess specialised design expertise (**Gil *et al.*, 2001**). Within a design chain, shared resources, such as an integrated design process (**Austin *et al.*, 1999**) and the Value Adding Toolbox discussed in this paper, can provide a common basis for collaboration.

Project environment

Austin and Thomson (1999) reviewed existing value delivery methods (predominately value management) within the project process. They observed that formal consideration of value is currently biased towards project inception and early design development, and that value delivery methods are intermittent with no explicit consideration of value during subsequent detailed design. To establish the continuous consideration of value throughout all project design, they proposed integral value engineering as an approach that uses problem-solving methods to relate individual design decisions to stakeholders' expectations and requirements. This flexible approach to value delivery is in marked contrast to existing value management practice that, as commented by **Fowler (1990)**, is rigidly structured around the standard process provided by the Job Plan (**Male *et al.*, 1998**; **SAVE International, 1997**).

In contrast the practice of IVE, together with associated use of a Value Adding Toolbox, offers a variety of methods to be used to determine how stakeholders view value for a given project and to respond to that understanding when making design decisions. By extending the consideration of value into all project design, IVE follows the previous attempts to establish the consideration of value as a systematic aspect of ongoing design processes, such as those of **Kirk (1989)**, **Dell'Isola (1997)** and **Thiry (2002)**. It also provides an approach to value delivery compatible with emerging, service-based business models (**British Standards Institution, 2000**; **Davies *et al.*, 2001**; **Woodhead and McCuish, 2002**).

As a consequence of its application to briefing and conceptual design development, value management considers the whole construction project as a single design problem. IVE, on the other hand, divides the project into its constituent technical design problems and addresses the delivery of value from each. By reducing the scope of design problems in this way, IVE extends the "cut-off point" beyond which the cost of implementing a design decision exceeds its benefit (i.e. value). This allows the explicit consideration of value to continue into the later project stages in which the majority of design decisions are made (compare **Figure 1a** and **Figure 1b**).

The Value Adding Toolbox

Principles

The Value Adding Toolbox supports the practice of IVE by providing a repository of problem-solving tools. The designer uses this to assemble a process for each design problem he or she undertakes to create a framework in which the design task can be completed by traditional means. The framework is used to validate the emerging design solution against stakeholders' understanding of value. By documenting this comparison, an audit trail of value delivery required by clients can be created.

Relationship to design theory

Development of the Value Adding Toolbox took place within ongoing development of underlying design theories, characterised by vibrant debate on the cognitive, logical and philosophical aspects of the activity. With this context, the ongoing work to represent designers' processes was of particular relevance. The Value Adding Toolbox uses a problem solving approach to fully describe design in response to **Houkes *et al.*'s (2002)** observation that designers combine plans, intentions and practical reasoning to solve problems. The toolbox also responds to **Jeffries' *et al.* (1981**) planning view of design by helping designers to form problem solving processes that respond both to stakeholders' expectations and to the nature of the task at hand.

To help designers form these problem-solving processes that address stakeholder value, the Value Adding Toolbox adopted the rational action model of design noted by **Gedenryd (1998)** to characterise the activity as a series of planned problem-solving steps. These steps are generally sequenced into analysis activities followed by synthesis activities, although **Broadbent (1966)** and **Jones (1984)** extend this generic sequence to: briefing; analysis; synthesis; and evaluation. Further, by establishing that logical thinking relates design activity to problem solving activity, **Akin (1979)** validated the problem-solving approach. Despite this, the representation of design as a linear process has received considerable criticism, most notably from its original proponents (**Alexander, 1971**; **Broadbent, 1973**; **Lawson, 1980**). **Jones (1992)** summarises the shortcomings of these models by commenting “only hypothetical examples or partial results are available so far.”

Bamford (2002) more recently suggested that representations of design activity as a logical process were shaped by the era in which they were developed, and therefore reflect the predominance of the “scientific method” paradigm of that period. **Horváth (2004)** confirmed this characterisation and further commented that, despite its ongoing and diverse investigation – which ranges from consideration of underlying philosophy, exploration of designers' cognition and reflection on emerging artefacts, as well as the continuation of the process view – an accepted view of what design is, is yet to emerge. Given this current state of knowledge, the linear problem solving view continues to provide a useful shorthand for design activity despite its limitations in describing the iterative, non-linear and exploratory aspects of design which have been identified through empirical observations (see **Steele, 2000**; **Choueiri, 2003**; for examples) but is yet to be fully understood and explained.

Linear representations of design activity continue to abound, however. This is particularly the case for the construction industry where they are useful in describing an ideal design process (**Lawson *et al.*, 2003**). In light of this, the linear representation of design problem solving was retained by the Value Adding Toolbox to help designers form working frameworks. By making these problem-solving frameworks explicit the toolbox discourages the tendency of designers to replicate their previous solutions without considering the new application in detail observed by **MacKinder and Marvin (1982)**. Value adding tools help designers to express and follow their plans, while reflection on the characteristics of the emerging design solution (**Schön, 1983**; **Newton, 2004**) helps designers to respond to their own reasoning through some degree of iteration around the intended problem solving process. The representation of a value adding design process in a linear form therefore provides a process backbone around which designers can structure their consideration stakeholder value.

Dissemination medium

Shen and Chung (2002) established that decision making in value management workshops can be structured by using IT to share information between decision makers. The Value Adding Toolbox reflects this by using IT to share common problem-solving tools among designers within a design chain. **Huang and Mak (1999)** demonstrated the effectiveness of the World Wide Web as a medium for the dissemination of design tools to designers performing conceptual engineering design. In light of this, the Value Adding Toolbox uses the WWW as its dissemination medium.

The use of IT to support collaborative problem solving is also justified by other observations. **Kaga *et al.* (2001)** have established the ability of IT to inform stakeholders prior to design engagement, ensuring that they all share a common premise for design development. **Craig and Zimring (2000)** demonstrated the ability of IT to document ongoing design conversations, establishing the premise for capturing an audit trail of value delivery, whilst **Woo *et al.* (2001)** highlighted the use of IT itself to promote cross-discipline collaboration. Further, **Rosenman and Wang (2001)** and **Borkowski *et al.* (2001)** determined that IT tools can help designers share common data for collaborative design.

Development method

A prototype toolbox was developed with the active participation of 12 design and manufacturing organisations representing a typical design chain. These organisations comprised: building controls and systems integrators; building services installation designers, installers and maintainers; specialist contractors supplying and installing clean rooms, ductwork, ventilation installations, and roofing installations; and an international architecture, engineering and construction (AEC) organisation.

A predominately deductive approach to toolbox compilation was adopted to investigate the hypothesis that the provision of a Value Adding Toolbox would help designers address stakeholder value in design development. After initial development, inductive work was undertaken to incorporate validation findings in further development (**Buckley *et al.*, 1976**; **Gill and Johnson, 1991**). Following **Bresnen and Marshall's (2001)** reformist approach to introducing new knowledge to organisations, the toolbox was introduced as an additional resource to augment, rather than replace, existing design methods and tools. Toolbox development did not address the social dimension of innovation diffusion identified by **Rogers (1995)**. The issue of establishing a project ethos in which the delivery of value is considered implicit to all activity was left as a subject for subsequent research[1]. The full development method is presented in **Table II**.

Stages 5 and 6 of **Table II** were cycled through several iterations to bring the toolbox to a state of development that designers were willing to adopt in practice. As such, development cycled through several deductive and inductive iterations. For example, the issue of toolbox customisation became apparent during development, with designers requesting linking of the toolbox to design tools and practices already used by their organisation or design chain. This necessitated the development of a generic toolbox for general dissemination to industry and customised toolboxes for individual organisations or design chains.

Customisation was primarily concerned with the construction of interfaces that reflected corporate values and identity and which differentiated between existing problem solving processes and those introduced by the toolbox. The affinity between designers and their organisation which necessitated this customisation had been predicted by **Rogers (1995)** and **Griseri (1998)**. It resulted in customisation of the type illustrated by **Figure 2**.

To compile the toolbox, value-adding tools were gathered from value management and value engineering practices (in the construction and manufacturing sectors), generic problem solving, project management methods, and product development techniques. Many were common across these fields and were found by designers to be useful in both individual and collaborative design. Trial application demonstrated that some of the tools initially proposed were not suitable due to their inability to assist in the consideration of value or their inflexibility. Consequentially, the toolbox content was rationalised during development as illustrated by **Table III**.

Toolbox application

Deployment

The Value Adding Toolbox presents several tool selection methods to the designer. Tool descriptions are drawn from an unstructured repository for presentation through the user's selected interface. This format simplifies toolbox extension and adaptation as the tools contained in the repository can be readily changed, as can the tool selection methods.

The Value Adding Toolbox contains both dynamic content generated in response to designer input and static content describing the value adding tools. Tool descriptions contained links to examples of their use, other related value adding tools, relevant resources outside of the toolbox, and, where the toolbox was customised for use within a specific organisation, links to related design processes and tools already established in that organisation or design chain.

The World Wide Web was used for toolbox dissemination, bringing the following benefits:

- The toolbox can be deployed in several formats, facilitating deployment within a single organisation, or as a shared resource within a design chain.
- The web interface is familiar to designers, simplifying adoption (**Dalton *et al.*, 2002**).
- The toolbox content can be stored in one location to simplify maintenance and to ensure that that content is consistent throughout the organisation (**Drucker *et al.*, 1998**) or design chain.
- Maintenance of a single, shared toolbox within a design chain can provide a common basis for collaborative design.
- Designers can explore the toolbox. The act of seeking out, selecting and using value adding tools increases designers' buy-in to the tools they select for use.

Selecting value adding tools

The designer assembles a problem-solving process for the completion of design tasks by reviewing:

- Characteristics of the design problem to which they will be applied (**Figure 3**).
- The stage of the problem-solving process to which they will be applied.
- The stage to which the project in which the design problem occurs.
- Keywords or phrases in tool descriptions.
- The position of the tools in an index of all available tools.

Each tool procedure was illustrated in a standard format to aid comparison (**Figure 4**) during selection. These procedures were also provided in a format suitable for printing for use in a workshop or setting where the toolbox can not be accessed electronically.

Case studies

The role of case studies

Case studies were used to establish the effectiveness of value adding tool use. Evidence was required to validate the ability of value adding tools to help designers consider stakeholder value and to illustrate their use to future toolbox users. This evidence was therefore sought from observations of actual designer practice rather than from experimental scenarios or testing. With these requirements in mind, case studies were initially identified as an appropriate non-interventist method of gathering such evidence.

The selection of case studies to observe use of the Value Adding Toolbox arose from consideration of alternative social inquiry devices. The need to gather evidence of the toolbox in use necessitated an empirical, rather than experimental, validation method. It was further considered that the observations would more usefully inform future designer applications of the toolbox if they were intensive, rather than extensive (**Sayer, 1992**). This view was substantiated by the requirement to gather detailed evidence of instances of toolbox use without the need to generalise observations. These requirements suggested that case studies would be appropriate as their flexibility, even when deployed using a consistent structure between cases (**Yin, 1994**), would support the exploratory review required.

Final validation of case study use was provided by considering alternative observation methods previously to study design. **Galle (1996)** noted that two variations of protocol analysis have been used to study design and require designers to verbalise their otherwise internal thought processes. From these, design protocol analysis was rejected because the need for verbalisation interferes with designers' communication regarding the design task itself. Further, **Davies (1995)** found that the need to verbalise causes designers to adopt problem solving strategies suited to the need to verbalise, rather than to the design problem at hand. **Galle's (1996)** replication protocol analysis was also rejected because it was considered inappropriate for one group of industry-based designers to attempt to replicate the thought processes of another.

Thomas and Carroll (1984) offered further research devices for studying design activity. Their “controlled free response experiment” methods were rejected because, as discussed above, practical evidence was sought from application in real-world situations on live construction projects. Use of their “controlled experiments with restricted responses” was further rejected due to the same need to observe tool application on live projects. Within their taxonomy of design investigation approaches, **Thomas and Carroll (1984)** classified case studies as “expert experiments” because they represent the observation of design activity – without influencing it – for subsequent analysis. This provided further evidence that case studies were appropriate for studying toolbox use.

With the above review in mind, case studies were accordingly considered the most prudent research instrument for observing designers' use of the Value Adding Toolbox. Data were gathering during the performance of these case studies in the form of observer notes, detailing the activities undertaken by designers, including their resulting insights. The problem-solving processes formed were recorded as were the activities performed within each stage including the barriers designers encountered and how the designers overcame them, together with details of the emerging design solution itself.

The use case study compilation

Case studies illustrating examples of previous toolbox use guide designers in the application of value adding tools. They illustrated the application of the toolbox at different positions in the design chain and at different stages in the project process. Following standard practice (**Yin, 1994**) each study was compiled with the same structure documenting:

- the scope and objective of the problem-solving process developed and applied by the designer in response to the characteristics of the design problem at hand;
- the framing problem-solving process assembled from the value adding tools by the designer and its application to a design problem; and
- application of the framework relate the design problem solving to stakeholder value.

Five case studies were compiled, illustrating the following situations:

1. by a mechanical engineer to relate the selection of a chilled water distribution system to stakeholders;
2. by a mechanical engineer to relate the selection of an air conditioning system to stakeholders;
3. by a mechanical engineer to investigate the background to a problem encountered when designing a swimming pool plant installation, the solution to which would influence stakeholders' judgement of its value;
4. to help a group of engineers consider whether it is appropriate to install a combined heat and power system in a new hospital building; and
5. by two civil engineers to rigorously select a method of applying intumescent paint to steelwork.

The case studies demonstrated that toolbox effectiveness (measured by the ability of the designer to consider the value delivered to stakeholders in the design process) was dependent on two key factors: the buy-in of all designers in collaborative situations, to structure a design task in terms of problem solving; and a willingness of designers to develop customised problem-solving processes for each design task they complete. Without this, designers were observed to become familiar with a subset of the value adding tools available and to then either assemble new problem solving processes from this subset of tools or to simply reapply prior processes to future problems, irrespective of the problem's characteristics.

Example of toolbox use

This section summarises one of the case studies contained in the Value Adding Toolbox which illustrates its use to structure consideration of stakeholder value in design decision making. The case study presented concerns an example of the design decisions made during the detailed design stage of projects by technically-oriented designers. It is typical of those contained in the Value Adding Toolbox to illustrate how consideration of value can be introduced to situations in which design would traditionally be concerned solely with technical performance.

At the time of toolbox validation, designer “X” was faced with the problem of selecting a chilled water distribution system. He wanted to use the Value Adding Toolbox to structure and document his assessment of the influences on that decision so that he could demonstrate its provision of stakeholder value. Reviewing the full content of the toolbox, he sought to develop a problem solving process that would allow him to document his understanding of stakeholders' expectations and demonstrate how that understanding had informed his decision making. To achieve this, he assembled the process shown in **Figure 5**.

X began to address the design problem by using Information Gathering Techniques to first understand it. He quickly sketched out the two basic methods of assembling chilled water distribution systems to be compared: a system based on a 3 port valve and a system based on a 2 port valve. To simplify the assessment, he included only those parts of the two systems that varied between them (**Figure 6**).

Using Brainstorming, X characterised the influences on stakeholders' judgement of the value of his design solutions. Because this case study was developed during the validation of the toolbox, full toolbox deployment had not begun and direct stakeholder access was not available. Hence, X used his perception of the stakeholders' expectations formed in his prior engagement with them during preceding project stages. In a full deployment, X commented that he would prefer to engage stakeholders directly in this stage to accurately elicit their requirements at the time of making the decision. X used Affinity Diagramming to undertake the second, structuring, stage of Brainstorming. As commented by X, it “mapped things out to structure the problem environment.”

The influences on the decision were identified in the Affinity Diagram as clustered brainstormed issues. These were entered into a Decision Matrix (**Figure 7**). Analysing the Decision Matrix, X found that a chilled water distribution system using a 2 port value would be the most appropriate in the current project circumstance, as defined by the stakeholder expectations.

X concluded toolbox use by reviewing the decision resulting from its use against the decision that would otherwise have been made intuitively, per current practice. He commented that the decision would have been the same although without application and documentation of a structured problem solving process, he would not have been able to confidently demonstrate his consideration of stakeholders. Consequently, X concluded that he would make use of a Value Adding Toolbox should it become available in his design chain.

This conclusion was typical of the case studies. It was therefore concluded that the validation had proven the hypothesis that the provision of a Value Adding Toolbox would help designers address stakeholder value in their design development.

Lessons learned

Establishing toolbox use in design practice

Designers who had been engaged in the toolbox development were interviewed to determine their willingness to integrate it into their personal design methods. When first introduced, it was found that designers considered reference to a toolbox to be an interruption to the flow of their design activity. In the early stages of adoption, the toolbox would have to be actively promoted by means such as including it in organisational definitions of procedure or by management instruction. In the longer term, individual designers would gain experience of the toolbox's ability to assist in their address of value in design. These beneficial experiences, together with advancement of the value agenda generally, will help advance designers' professional values to a point at which consideration of stakeholder value is considered a key part of good practice. In this circumstance, toolbox use would be spontaneous, as designers' values would align with those embedded in the toolbox by its developers. The authors believe that formal procedures are insufficient to integrate the toolbox into design practice. Instead, the “buy-in” of individual designers must be sought. This can only be achieved gradually through the gaining of experience and the general advancement of the value agenda within the construction industry.

Linking the Value Adding Toolbox to organisational development

By stating that “the carrying forward of lessons learned from one project to another may be difficult if mechanisms for capturing and codifying that knowledge do not exist,” **Bresnen and Marshall (2001)** highlighted the barriers to organisational learning created by projects in construction. A Value Adding Toolbox can perform a role in both the capture and dissemination of corporate knowledge regarding value adding tool use, forming links between projects. Functioning continuously, the Value Adding Toolbox could self-validate its content as those value-adding tools found useful will be highlighted through their repeated application. However, to avoid the stagnation of an organisation's or design chain's approach to value delivery, a balance must be struck between this self-validation and the need to introduce new tools to the toolbox (and to remove those found not to be useful). In this way, a Value Adding Toolbox can bring business value (by developing business competencies) in addition to end user value (by validating design output against stakeholder expectations). When shared among organisations within a design chain, it can contribute to the co-ordination of their combined service delivery. Further, the long-term strategy of encouraging the evolution of individuals' values to relate them to the values embedded in new working practices is an established means of encouraging the update of new working practices (**Rogers, 1995**).

Conclusions

This paper presented an approach to value delivery that continually relates individual design solutions to project stakeholders. This represents an advance of both method and scope of value delivery in construction projects. In addition to the methods used at the project level, the role of design collaboration within a design chain to encourage and frame that problem solving has also been described. The role of a Value Adding Toolbox as a common device for cross-organisation collaboration has been described, and the potential of the design chain and integral value engineering in facilitating that collaboration has also been outlined.

Value management has been observed to be a well-established team-based practice that addresses value in functional terms during project briefing and conceptual design. Integral value engineering complements this existing practice by using resources such as the Value Adding Toolbox introduced by this paper to structure and document individual designers' assessment of stakeholder value throughout project design. Further, by relating design decisions to stakeholders, the use of a Value Adding Toolbox provides a first step toward establishing the subjectivist treatment of value required in response to clients' growing demand and the growing value agenda of the construction industry.

Via case study review, toolbox validation exercises have proven the hypothesis that the provision of a Value Adding Toolbox can help designers address stakeholder value. Given these findings, the development of a Value Adding Toolbox is recommended. Ideally, this would occur in a managed design chain (where design collaboration between supply chain members will be more forthcoming than with traditional practice) and in support of the practice of integral value engineering (to extent the scope of project design within which value delivery is explicitly considered).

Figure 1 Comparison of the problem solving scope and timing between the practice of value management and integral value engineering

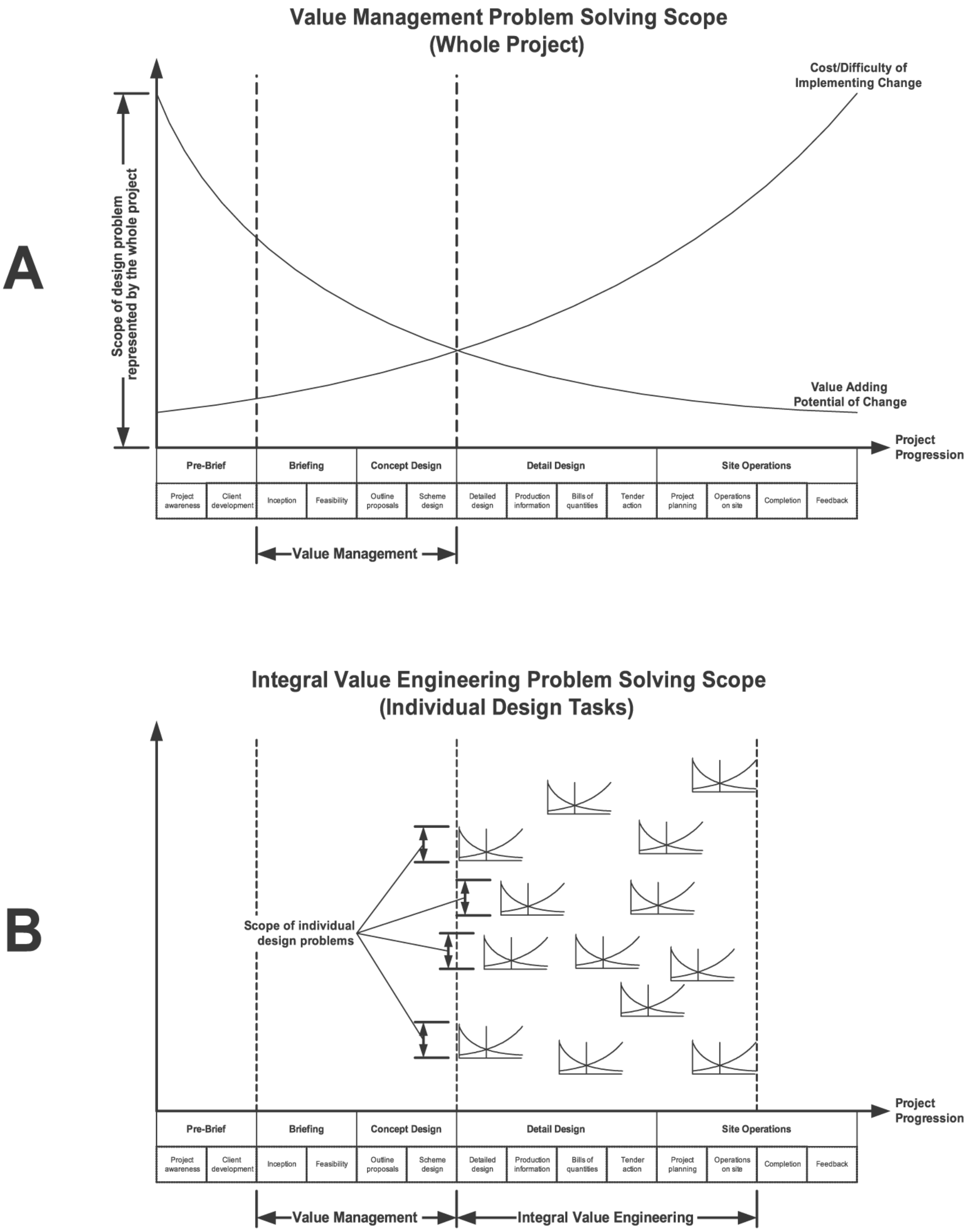

Figure 2 A customised value adding toolbox screen (note the use of icons to differentiate between new and existing design practices)

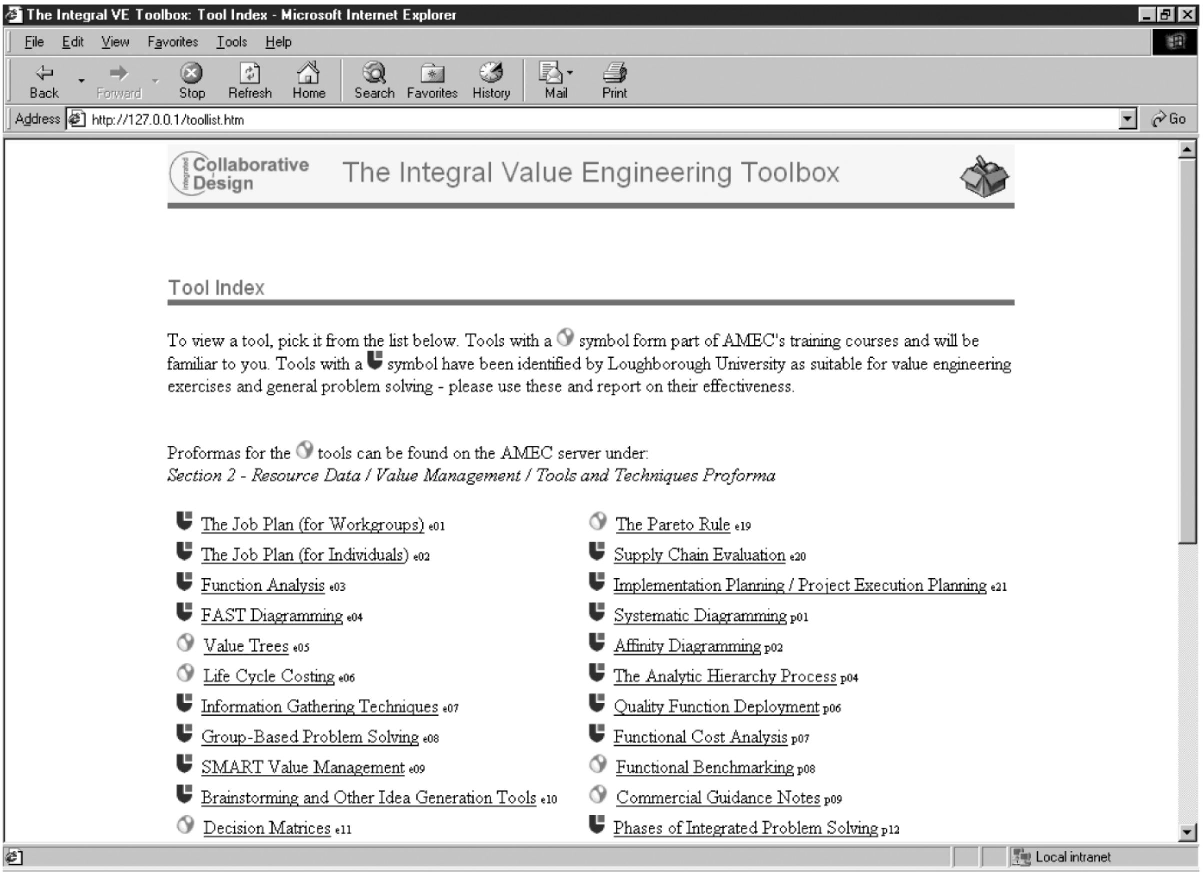

Figure 3 Toolbox recommendation of value adding tools

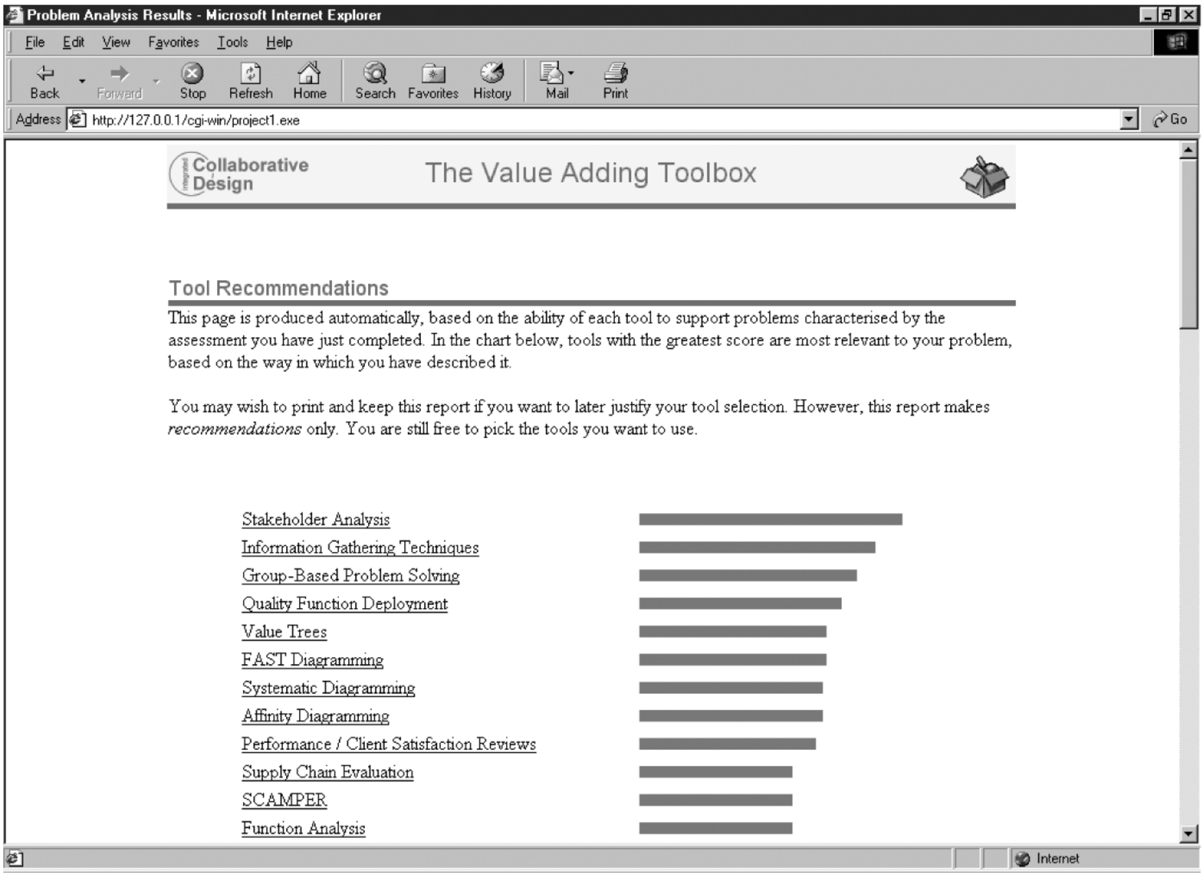

Figure 4 Extract from a typical value adding tool procedure illustration

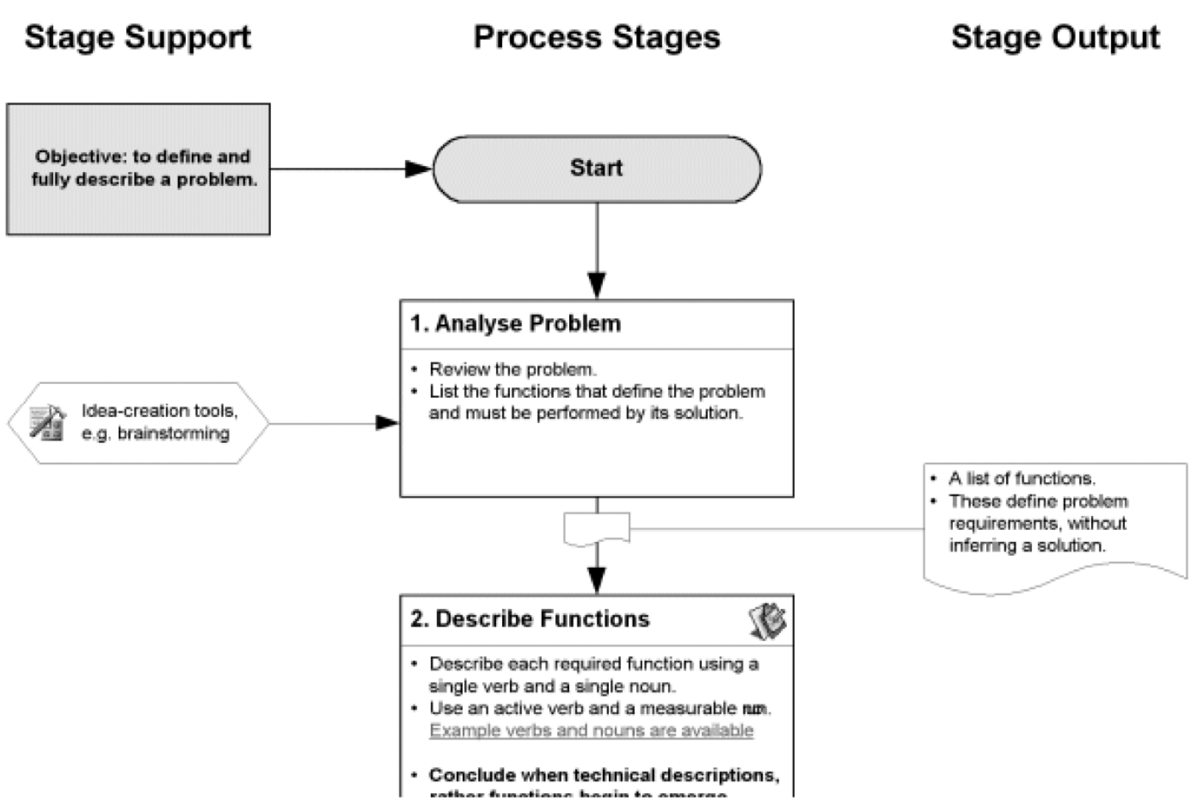

Figure 5 Case study problem solving process

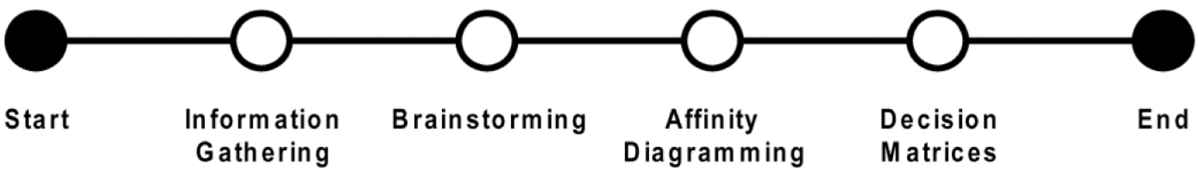

Figure 6 Case study design options

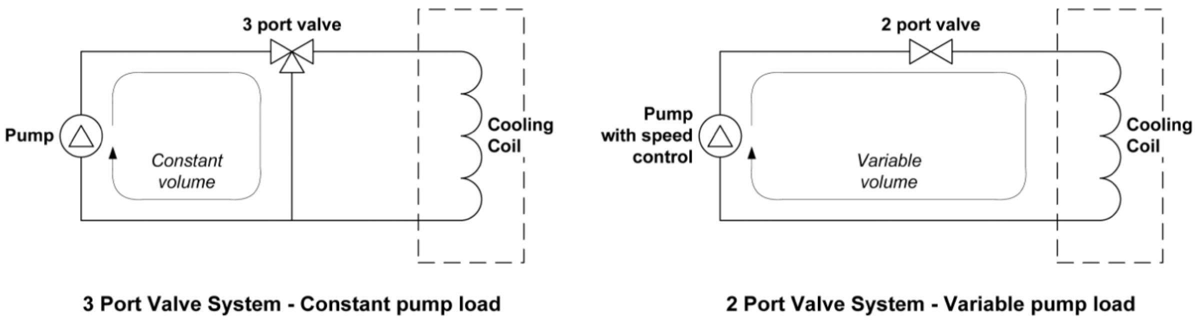

Figure 7 Case study design decision matrix

		Stakeholder expectations and requirements									
		a	b	c	d	e	f	g	l		
		Minimise pipework cost	Minimise pump cost	Minimise controls cost	Minimise cost of valves	Minimise running costs	Reliability	Low installation time	Good installation acces/space	Total Weighted Factor	Option Rankings
	Requirement weighting	25%	15%	25%	10%	11%	2%	10%	2%	100	
1	**3 Port Value System**	2 / 50	8 / 120	3 / 75	4 / 40	2 / 22	7 / 14	2 / 20	4 / 8	**349**	**2**
2	**2 Port Value System**	4 / 100	2 / 30	6 / 150	8 / 80	9 / 99	5 / 10	7 / 70	8 / 16	**555**	**1**
3		0	0	0	0	0	0	0	0	**0**	
4		0	0	0	0	0	0	0	0	**0**	

Table I Value delivery mechanisms required by large clients as prequalification requirements

Organisation	Value delivery requirement
BBC Framework Pre-Qualification	"Explain how you will demonstrate the delivery of business value for the BBC"
SmithKline Beecham – Worldwide Alliance	"How would you add value to our company (both monetary and systems/processes)?"
British Telecom Pre-Qualification	"Explain, with examples of process and results, your company's approach to value engineering"
Havering Hospital – £150m PFI Pre-Qualification	"Please detail experience of how the applicant has provided value management at each stage of a contract in the past"
West of Scotland Water Authority (WSWA) – Waste Water Treatment Tender	"How would you approach value management on this project to ensure that West of Scotland Water Authority would benefit from significant cost savings?"

Table I.
Value delivery mechanisms required by large clients as prequalification requirements

Table II Value adding toolbox development method

Development stage	Stage content
1. Develop theory	Established principles of toolbox use, including the problem-solving view of design tasks
2. Gather information	Identified problem-solving tools capable of helping designers consider value in design problem solving. Interviews with representatives of future users validated initial tool selection and identified links to existing design practices
3. Assemble prototype toolbox	Prototype toolbox assembled from value adding tools and selection mechanisms (developed in response to interview findings)
4. Launch prototype toolbox	Prototype toolbox introduced to design chain members for evaluation via regional workshops held throughout the UK
5. Validate toolbox in use	Designers use of the toolbox observed to identify improvements. Case studies of tool use compiled to inform subsequent toolbox users
6. Revise as necessary	Toolbox content (value adding tools and case studies) improved in usefulness through an interactive development process, informed by validation exercises
7. Package for final dissemination and use	Where requested, toolbox customised to reflect corporate identity to increase the buy-in of designers who are members of that organisation. Generic version prepared for general industry dissemination

Table II. Value adding toolbox development method

Table III Rationalisation of toolbox content

	Number of tools in initial content	Number of tools after validation
Value management tools	21	18
Tools drawn from other sources	17	11
Totals	38	29

Table III. Rationalisation of toolbox content

References

Akin, O. (1979), "An explanation of the design process", *Design Methods and Theories*, Vol. 13 No.3/4, pp.115-19.

Alexander, C. (1971), "The state of the art in design methods", *DMG Newsletter*, Vol. 5 No.3, pp.1-7.

Austin, S., Thomson, D.S. (1999), "Integral value engineering in design", Proceedings of Cobra 1999, RICS Construction and Building Research Conference, School of Construction and Property Management, University of Salford, Salford, .

Austin, S.A., Thomson, D.S. (2001), "Solving design problems to add value", *Proceedings of W096 – Architectural Management, Value Through Design Conference, University of Reading, CIB*, .

Austin, S., Baldwin, A., Hammond, J., Waskett, P. (1999), "Application of the analytical design planning technique in the project process", *Proceedings of the Conference on Concurrent Engineering in Construction*, VTT, Finland, .

Austin, S., Baldwin, A., Hammond, J., Murray, M., Root, D., Thomson, D., Thorpe, A. (2001), *Design Chains: A Handbook for Integrated Collaborative Design*, Thomas Telford, London, .

Bamford, G. (2002), "From analysis/synthesis to conjecture/analysis: a review of Karl Popper's influence on design methodology in architecture", *Design Studies*, Vol. 23 No.3, pp.245-61.

Barrett, P., Stanley, C. (1999), *Better Construction Briefing*, Blackwell Science, Oxford, .

Borkowski, A., Branki, C., Grabska, E., Palacz, W. (2001), "Towards collaborative creative design", *Automation in Construction*, Vol. 10 pp.607-16.

Bresnen, M., Marshall, M. (2001), "Understanding the diffusion and application of new management ideas in construction", *Engineering, Construction and Architectural Management*, Vol. 8 No.5/6, pp.335-45.

British Standards Institution (2000), *BS EN 12973: Value Management*, British Standards Institution, London, .

Broadbent, G. (1966), "Design method in architecture", *The Architects' Journal*, Vol. 144 No.11, pp.679-85.

Broadbent, G. (1973), *Design in Architecture: Architecture and the Human Sciences*, Wiley, London, .

Buckley, J.W., Buckley, M.H., Chiang, H.F. (1976), *Research Methodology and Business Decisions*, National Association of Accountants, New York, NY, .

Choueiri, L.S. (2003), "Diagrams of the design process", *Proceedings of 5th European Academy of Design Conference*, Barcelona, 28-30 April, .

Commission for Architecture and the Built Environment (2002), *Client Guide: Achieving Well Designed Schools through PFI*, Commission for Architecture and the Built Environment, London, .

Commission for Architecture and the Built Environment (2003), *The Value of Housing Design and Layout*, Thomas Telford, London, .

Craig, D.L., Zimring, C. (2000), "Supporting collaborative design groups as design communities", *Design Studies*, Vol. 21 pp.187-204.

Dalton, J.P., Manning, H., Mines, C., Dorsey, M. (2002), *Packaged Apps Fail the Usability Test*, Forrester Research, Cambridge, MA, .

Davies, A., Tang, P., Brady, T., Hobday, M., Rush, H., Gann, D. (2001), *Integrated Solutions: The New Economy between Manufacturing and Services*, Science and Technology Policy Research Unit, University of Sussex, Brighton, .

Davies, S.P. (1995), "Effects of concurrent verbalization on design problem solving", *Design Studies*, Vol. 16 No.1, pp.102-16.

Dell'Isola, A. (1997), *Value Engineering: Practical Applications for Design,* *Construction, Maintenance and Operations*, RS Means, Kingston, MA, .

Department for Culture, Media and Sport (2000), *Better Public Buildings: A Proud Legacy for the Future*, The Better Public Buildings Group, Department for Culture, Media and Sport, London, .

Drucker, P.F., Garvin, D.A., Leonard, D., Straus, S., Brown, J.S. (1998), *Harvard Business Review on Knowledge Management*, Harvard Business Review Press, Boston, MA, .

Fowler, T.C. (1990), *Value Analysis in Design*, Van Nostrand Reinhold, New York, NY, .

Galle, P. (1996), "Design rationalization and the logic of design: a case study", *Design Studies*, Vol. 17 No.3, pp.253-75.

Gedenryd, H. (1998), *How Designers Work*, Department of Cognitive Studies, Lund University, Lund, .

Gil, N., Tommelein, I.D., Kirkendall, R.L., Ballard, G. (2001), "Leveraging speciality-contractor knowledge in design-build organizations", *Engineering, Construction and Architectural Management*, Vol. 8 No.5/6, pp.355-67.

Gill, J., Johnson, P. (1991), *Research Methods for Managers*, Paul Chapman Publishing, London, .

Griseri, P. (1998), *Managing Values: Ethical Change in Organisations*, Macmillan Business, Basingstoke, .

Horváth, I. (2004), "A treatise on order in engineering design research", *Research in Engineering Design*, Vol. 15 pp.155-81.

Houkes, W., Vermas, P.E., Dorst, K., de Vries, M.J. (2002), "Design and use as plans: an action-theoretical account", *Design Studies*, Vol. 23 No.3, pp.303-20.

Huang, G.Q., Mak, K.L. (1999), "Web-based collaborative conceptual design", *Journal of Engineering Design*, Vol. 10 No.2, pp.183-94.

Jeffries, R., Turner, A.A., Polson, P.G., Atwood, M.E. (1981), "The processes involved in designing software", in Anderson, J.R. (Eds),*Cognitive Skills and their Acquisition*, Lawrence Erlbaum, Hillsdale, NJ, pp.255-83.

Jones, J.C. (1984), "A method of systematic design", in Cross, N. (Eds),*Developments in Design Methodology*, John Wiley & Sons, Chichester, pp.265-76.

Jones, J.C. (1992), *Design Methods*, 2nd ed., John Wiley & Sons, New York, NY, .

Kaga, A., Nakahama, K., Hamada, S., Yamaguchi, S., Sasada, T. (2001), "Collaborative design system with hypermedium and networking", *Automation in*

Construction, Vol. 10 pp.309-18.

Kelly, J., Male, S. (1993), *Value Management in Design and Construction*, E&FN Spon, London, .

Kirk, S.J. (1989), "Integrating value engineering into the design process", *Ekistics*, Vol. 56 No.336/337, pp.166-70.

Lawson, B. (1980), *How Designers Think*, Butterworth Architecture, Oxford, .

Lawson, B., Bassanino, M., Phiri, M., Worthington, J. (2003), "Intentions, practices and aspirations: understanding learning in design", *Design Studies*, Vol. 24 pp.327-39.

Loe, E. (2000), *The Value of Architecture: Context and Current Thinking*, RIBA, London, RIBA Future Studies, .

McGeorge, W.D., Palmer, A., London, K. (2002), *Construction Management: New Directions*, 2nd ed., Blackwell Science, Oxford, .

MacKinder, M., Marvin, H. (1982), "Design decision making in architectural practice", Information Paper, No. 11/82, Building Research Establishment Watford, Report IAAS Research Paper 19, York, .

Male, S., Kelly, J., Fernie, S., Gronqvist, M., Bowles, G. (1998), *The Value Management Benchmark: A Good Practice Framework for Clients and Practitioners*, Thomas Telford, London, .

Newton, S. (2004), "Designing as disclosure", *Design Studies*, Vol. 25 pp.93-109.

Phillips, R. (2000), *The Architect's Plan of Work for the Procurement of Feasibility Studies: A Fully Designed Building Project, Employer's Requirements or Contractor's Proposals*, RIBA Publications, London, .

Rogers, E.M. (1995), *Diffusion of Innovations*, 4th ed., The Free Press, New York, NY, .

Rosenman, M., Wang, F. (2001), "A component agent based open CAD system for collaborative design", *Automation in Construction*, Vol. 10 pp.383-97.

SAVE International (1997), *Value Methodology Standard: Revised October 1998*, SAVE International, Dayton, OH, .

Saxon, R. (2002), "The industry ‘formerly known as construction’: an industry view of the Fairclough Review", *Building Research & Information*, Vol. 30 No.5, pp.334-7.

Sayer, A. (1992), *Method in Social Science: A Realist Approach*, Routledge, London, .

Schön, D.A. (1983), *The Reflective Practitioner: How Professionals Think in Action*, Basic Books, New York, NY, .

Shen, Q., Chung, J.K.H. (2002), "A group decision support system for value management studies in the construction industry", *International Journal of Project Management*, Vol. 20 pp.247-52.

Steele, J.L. (2000), “The interdisciplinary conceptual design of buildings”, PhD thesis, Loughborough University, Loughborough, .

Thiry, M. (2002), "Combining value and project management into an effective programme management model", *International Journal of Project Management*, Vol. 20 pp.221-7.

Thomas, J.C., Carroll, J.M. (1984), "The psychological study of design", in Cross, N. (Eds),*Developments in Design Methodology*, John Wiley & Sons, Chichester, pp.221-35.

Woo, S., Lee, E., Sasada, T. (2001), "The multiuser workspace as the medium for communication in collaborative design", *Automation in Construction*, Vol. 10 pp.303-8.

Woodhead, R., McCuish, J. (2002), *Achieving Results: How to Create Value*, Thomas Telford, London, .

Worpole, K. (2000), *The Value of Architecture: Design, Economy and the Architectural Imagination*, RIBA, London, RIBA Future Studies, .

Yin, R.K. (1994), *Case Study Research: Design and Methods*, 2nd ed., Sage, Thousand Oaks, CA, .

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