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Design Quality Indicator as a tool for thinking

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The Design Quality Indicator (DQI) is based on a research project to provide a toolkit for improving the design of buildings. It seeks to complement methods for measuring performance in construction by providing feedback and capturing perceptions of design quality embodied in buildings. The research team worked closely with the sponsors and an industry steering group to develop the indicators that could be readily used by clients and practitioners to better understand and promote value through design. The development and piloting process was explored within a context of lessons from earlier attempts by others. The three main elements of the DQI toolkit (conceptual framework, data-gathering tool, weighting mechanism) mapped the value of buildings in relation to their design for different uses and their ability to meet a variety of physical, aspirational and emotional needs of occupants and users. The DQI pilot studies consisting of five design and construction projects are discussed along with their graphical representation of results generated by end-users, individual team members and project teams. The process raises questions about the difficulties in the description and application of indicators for design quality. It is argued that the benefit of the DQI is a 'tool for thinking', rather than an absolute measure, because it has the potential to capture lessons from current building design for strategic future use as well as initiate, represent and inform discussions involving designers', clients', producers' and end-users' perceptions on the tangible and intangible aspects of possibilities within live design projects. The limitations of the approach, the next phase of development and further research issues are raised.

Keywords: build quality, design, design quality, design research, functionality, impact value, indicators, performance measurement

Les indicateurs de qualité de la conception (DQI) sont le fruit d'un projet de recherche ayant pour objectif le développement d'une «boîte à outils» à utiliser pour améliorer la conception des bâtiments. Les DQI complètent les méthodes de mesure des performances dans la construction en assurant un retour d'information et en appréhendant la perception de la qualité de la conception dans les bâtiments. L'équipe de recherche a travaillé en étroite coopération avec les commanditaires et un groupe industriel pilote pour développer des indicateurs qui pourraient être facilement utilisés par les clients et les professionnels afin de mieux comprendre et de faire la promotion de la valeur à travers la conception. Le processus de développement et de pilotage a été exploré dans le contexte d'enseignements acquis dans le passé dans le cadre de tentatives antérieures menées par d'autres. Les trois principaux éléments de la «boîte à outils» DQI (cadre conceptuel, outil de collecte de données, mécanisme de pondération) ont permis de mettre en correspondance la valeur des bâtiments et leur conception pour différents usages et leur aptitude à répondre à une variété de besoins physiques, aspirationnels, et émotionnels des occupants et des utilisateurs. Les auteurs de cet article examinent les études pilote DQI comprenant cinq projets de conception et de construction ainsi que la représentation graphique des résultats générés par les utilisateurs, les membres des équipes et les équipes de projets. Ce processus suscite des questions sur la difficulté de description et d'application des indicateurs de qualité de la conception. La discussion porte sur le fait que les DQI sont plutôt un outil de réflexion qu'une mesure absolue car ils sont aptes à tirer des leçons de la conception de bâtiments actuels au profit d'une stratégie d'avenir ; ils permettent également, temps réel, d'engager des discussions, de représenter et de renseigner la perception qu'ont les concepteurs, les clients, les constructeurs et les utilisateurs des aspects tangibles et intangibles des possibilités de projets de conception. Les auteurs examinent les limitations de cette approche, la prochaine phase de développement et les futures recherches.

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Mots clés: qualité de la construction, conception, qualité de la conception, recherche dans le domaine de la conception, fonctionnalité, valeur d'impact, indicateurs, mesure de la performance

Introduction

A new culture of performance measurement has begun to take hold across the UK construction sector. Following publication of *Rethinking Construction* (Egan, 1998), this has been stimulated by collaborative industry/government initiatives that have led to the generation and implementation of policy instruments for improving practices. These recent approaches to performance measurement have their origins in experiences observed in the manufacturing sector and subsequently translated and adapted for use in construction. In particular, lessons have been drawn from the literature on *lean production* and Japanese approaches to quality management (Schonberger, 1982; Monden, 1983; Womack and Jones, 1996). Interest in performance measurement has led to the introduction of a suite of benchmarking techniques and the development of key performance indicators for use in the construction sector.[1] The focus of these measurement efforts has primarily been on production processes: headline indicators have included metrics relating to time and cost of production. Metrics associated with the quality of production have also been developed and implemented, with the focus on waste and defects. Yet, this overall approach to measurement says little about the design quality embodied in the products or outputs of the construction process – the buildings themselves.

The comparative lack of emphasis on design quality in the early stages of performance measurement following *Rethinking Construction* led to disquiet among leading members of the UK building design community. They were concerned that the value of building design might be relegated to a secondary issue because the performance-improving agenda focused heavily on the measurement of physical processes. At worst, a new generation of buildings might be produced where emphasis on measuring and reducing time, cost and waste in the process would lead to a loss of functionality and boring, unattractive building design. In short, the value of product design might be lost in the drive for process improvement. The problem of how to define and measure value lay at the heart of this debate. In this discussion, by 'value' it is meant the benefits that accrue to users through ideas developed in the design process and then acted on through production. It was recognized that 'value for money' – the construction sector mantra – was difficult to describe in terms of what constituted 'good design' (Loe, 2000). These issues were not confined to the UK building and construction sector. Other countries – including the US, Australia, Hong Kong and Singapore – were also embarking on performance improvement initiatives and were grappling with the problems of articulating the quality of design as an important dimension of value (Construction 21 Steering Committee, 1999; Department of Industry, 1999; Tang, 2001; Gibson and Gebken, 2003).

At the same time, interest in the quality of building design has been heightened – especially in the public sector – with the need for a better understanding of the use of buildings, growing concerns over environmental impact and a new enthusiasm for delivering 'best value'. In the UK, the Prime Minister Tony Blair has argued:

> . . . we know that good design provides a host of benefits. The best designed schools encourage children to learn. The best designed hospitals help patients recover their spirits and health. Well-designed parks and town centres help to bring communities together.
>
> (DCMS, 2000)

In response to pressures from designers and with a growing interest from government to add value by design (CABE, 2000; DCMS, 2000; Worpole, 2000), the Construction Industry Council (CIC) – the umbrella organization representing UK construction professional institutions – proposed developing a new tool for assessing design quality and successfully bid for a grant.[2] The authors were appointed as the research team, working in collaboration with the CIC and a steering group representing different professional, industrial and government interests.

The Design Quality Indicator (DQI) was developed as an extension of the *Rethinking Construction* agenda for targeting, mapping, measuring and managing performance improvement in construction. It was developed explicitly to measure quality of design embodied in the product – buildings themselves. It was not intended to assess the design process, although the tool has subsequently been used at various stages of design to help inform design decision-making during the process. The report *Accelerating Change* (Egan, 2002), which updates the *Rethinking Construction* agenda, makes explicit reference to the DQIs and calls for their adoption across the construction sector. It also highlights the role of clients in promoting value through design in new buildings and refurbishment projects.

Measuring the quality of design poses major conceptual and practical problems. Some attributes of buildings have physical parameters – such as the level of light in a room, measured in lux; others are more perceptual and subjective – such as the feeling of warmth emanating from a particular heat source. Designers of buildings have long been interested in the overall value added through their efforts and the legacy of design decisions on future generations of users. Their ability to 'prove the value of design' has been elusive and is a problem not unique to the building and construction sector. It is a familiar issue throughout manufacturing and the world of product design.

The challenge was to develop a method for understanding the value of buildings in relation to their design for different uses and in meeting a wide variety of physical, aspirational and emotional needs of occupiers and users. Central to the approach was the recognition that designers (architects, consultant engineers and other specialists involved in design of buildings) have an important role to play in developing better quality buildings, and that they design buildings within particular social, political and cultural contexts. A steering group was established involving 15 professionals from different disciplines, representatives from government and the authors as the research team. This group met regularly under the chairmanship of Michael Dickson – Chairman of Buro Happold, a leading engineering design organization. This steering group had a key interest in addressing user requirements, but it did not include 'user' representatives.[3] Sincere effort was, however, made to engage clients and end-users in the process and to provide scope for 'lay' input into, and influence over, the agenda. A larger Reference Group was formed with 35 people including professionals, building owners, clients and constructors.

Two workshops were held with the reference group in order to develop terms and elicit current knowledge about different attributes of design quality. A large number of descriptions of good-quality buildings were collected from the first workshop. These were translated into questions and refined at the second reference group workshop. Detailed research and development work was undertaken by the research team in collaboration with a small subcommittee from the steering group. Detailed descriptions of this work are provided below.

The DQI sought to complement existing mechanisms for examining performance, providing feedback and capturing different perceptions of the value of design. Development of the tool was also motivated by a longer-term aim of capturing lessons from the outcome of current building design and feeding these into next-generation designs. The goal was therefore to create a tool for learning about design quality and thus continually improving upon it.

In the next section, the literature on user involvement is considered and past efforts at quality measurement are reviewed. It is followed by a description of the development of the DQI tool itself. Three elements of the development work are considered: conceptual framework, data-gathering tool and weighting mechanism. Then lessons obtained from the initial pilot studies and the graphical representation of the results generated by individual team members and project teams are analysed. The use of the DQI as a 'tool for thinking' is then explored and implications are drawn for developing new tools for integrating users and producers in design. Finally, the paper provides a review of the second phase of development and concludes with issues for further research and development.

Measuring design

Design quality is hard to quantify as it consists of both objective and subjective components. Whilst some indicators of design can be measured objectively, others result in intangible assets, depending in part on the subjective views, experiences and preferences of the people asked. In approaching issues of design quality, a number of general features of design were embraced: that good design often resulted from complex and uncertain starting points (Simon, 1962); that the process was often evolutionary and non-linear, involving interdisciplinary approaches (Vincenti, 1990); and that it resulted from iterative cycles of cumulative development, where 'satisficing' decisions are acceptable, rather than optimal results (Simon, 1962). The research team drew on the literature on user involvement and the lessons learnt in the development of existing indicators and design awards.

Understanding the views of users

The most important measure in any evaluation of a building's design quality is whether it satisfies user requirements and what users think and feel about it. However, understanding the views of users is not easy: there might be many different and conflicting views held by individuals and groups. Facilities managers, clients, occupants, visitors, cleaners, repair staff, etc. might all have different perspectives on the same facility.

Professionals and researchers working in the production of the built environment have developed sophisticated approaches for capturing and understanding user requirements, with new approaches to briefing and through post-occupancy evaluation (Leaman and Bordass, 2001; Lawson *et al.*, 2002). Unfortunately, the use of these methods is far from widespread in the UK and much more work is needed to close the loop between users and producer interpretation and practice in building design. Improving on this situation requires a change in culture and working practices on the part of designers, as much as the development of new design management and support toolkits.

The problem of understanding requirements and transforming them into high-quality designs is a universal one that many industries have struggled with. It raises questions about the nature of good quality design. Evidence from a diverse range of sectors—from scientific instruments to automotive manufacturing—shows that users often have considerable information and ideas about what a product must achieve and do (von Hippel, 2001). Yet, this information is difficult to transfer: it is often hard for users to express their preferences as they do not speak the technical languages used by professionals. They respond to products in immediate and direct ways, which have little structure in terms of how their reactions are captured and translated into next generation products.

Some manufacturing companies use a wide range of techniques for trying to capture these reactions and integrate them into their new product development processes. This often occurs after the fact and through a set of mediated relations, such as external consultancies. In some areas of manufacturing there tends to be a better understanding of the value of design embodied in products and better connectivity with customer preferences. For example, techniques such as Quality Function Deployment are used in the motor vehicle industry (Clausing, 1994; Ward et al., 1995; Smith and Reinertsen, 1998). A methodology to rank consumer responses to product attributes and alternative designs has been developed by Kodak in order to understand the link between camera design and purchase behaviour (Paul, 2000).

The aim of these tools is to assist participants in reaching a consensus about priorities and relationships. Consumer choice implies differentiation not convergence. However, in designing for large multi-user buildings, it is important to understand the different views of user groups and individual users and then to reach consensus about shared priorities and relationships. This consensus building has proven valuable in eliciting information during product design, and it can increase the value added by design.

In all these approaches, the role of users is of central importance in successful new product development. Users themselves can be innovators and can therefore greatly contribute to improvements in the design of products (von Hippel, 1986). Gardiner and Rothwell (1985) argue that the tougher and more demanding customers are in their requirements, the better and more robust the designs will be. They demonstrate this by examining a number of innovations based on commercially successful designs in aerospace and agricultural machinery. Aerospace and agricultural machinery share certain characteristics with construction, and many of their examples come from the capital goods sector, where products are designed for a long life and often require careful design for maintenance and flexibility to accommodate upgrades and improvements in subsystems. They demonstrate that good producers listen to their customers and can use information from one generation to 'stretch' design concepts further, producing 'families' of next-generation products that are better than the last.

Current practice in the design of buildings usually results in information from users not being transferred to design teams in a shape and form that can be used for reconfiguring and improving upon design—either in a single building project or for subsequent projects. If it is available at all, information generally arrives either too late or in a format that cannot be used by front-line designers and engineers. This is because of common problems in the construction sector, caused by the separation of design from production, ownership and use – a condition that gives rise to interdependent problems that are often left to independent individuals and teams to solve (Tavistock Institute, 1966). These problems are exacerbated by an overly specialized approach to education and training of built environment professionals (Gann and Salter, 1999). One common example of the tensions that exist within project teams is between architects and contractors. In part, this tension is a result of differences in styles of problem solving, types of training and language.

It was against this backdrop that the development of DQIs also sought to encourage widespread debates on the value of design in the built environment, addressing all parts of industry from clients and developers, designers, engineers, constructors and specialists, to customers and end-users. Part of the rationale was to engender cultural change and bridge divides between fragmented disciplines by focusing on users.

Existing indicators

A number of different tools were being used to understand building quality and design. In the process of developing the DQI tool, the research team drew on the experiences of initiatives to develop post-occupancy evaluation tools, quality indicators and sustainability assessment tools. For a detailed review of indicators, see Amin et al. (2000). Notable examples amongst these are:

- PROBE (The Post-Occupancy Review of Buildings and their Engineering): post-occupancy evaluation tool that provides commissioning clients, design and build teams, and the building's occupiers with useful snapshots of users' views and an assessment of technical and energy performance of a building (Leaman and Bordass, 2001).

- Housing Quality Indicator: developed by central government (DTLR, 2000), it is a tool for assessing the quality of housing projects, focusing on the links of the project to the local environment.

• BREEAM (Building Research Establishment Environmental Assessment Method), UK Ecopoints and SPeAR: both BREEAM and UK Ecopoints systems provide measures of energy use in construction. An alternative tool is the SPeAR (Sustainable Project Appraisal Routine) developed by ARUP which provides a range of sustainability indicators to explore the total environment contribution of a project.

The less tangible the aspect to be measured, the harder it is to describe numerically. Measurement of intangible assets such as knowledge has been described as an invitation to dialogue (Sveiby, 1997). Rather than avoiding intangible attributes, the research team sought to find a way of capturing viewpoints on them in order to extend the dialogue about design quality in buildings. The viewpoints captured may reveal different and conflicting understandings of design, which can then be discussed. This has the potential to uncover information that is hitherto lost in future design iterations and this attribute provides one of the dimensions to our concept of a 'tool for thinking'.

Furthermore, initial research showed that methods by which results are depicted has a direct bearing on how indicators are used and understood—and by whom (Tufte, 1983). Jesinghaus (2000), the developer of controversial indicators of environmental sustainability, argues that graphical indicators should represent, not determine, the perception of importance of a given policy issue. The usefulness of indicators for decision-making is seen in part by their transparency. In contrast to many evaluation methods that are accessible only to the expert community, indicators can be represented graphically in a disaggregated manner so that everyone can understand the outcomes. The form of visual representation therefore became another variable to be considered in the development of the DQI.

Design awards

Design award schemes are generally accepted by building designers as a standard for assessing quality in architecture. As such, they provide a mechanism for the profession to reward excellence (Giddings and Holness, 1996; Andrews, 2000). Design awards might therefore provide a source of information to the process of developing the DQI because of their focus on 'design quality'. For example, Holness and Giddings (1997) showed it was possible to compare award-winning designs, quality of design proposal and quality of design processes.

In the UK, two examples of design awards are the Royal Institute of British Architects (RIBA) awards and the British Construction Industry awards:

• RIBA awards focus on the traditional Vitruvian values of commodity, firmness and delight. They address a series of questions, such as: Does the building work? Does it feel right? Does it stimulate and engage the occupants and visitors?

• British Construction Industry awards recognize excellence in the overall design, and in the construction and delivery of buildings and civil engineering projects. The judges take particular note of their understanding of the quality of architectural and engineering design and of construction, value for money, application of quality management, performance against prediction and client satisfaction.

Yet, only a few projects ever achieve the high levels of performance associated with the awards, making it difficult simply to apply the rules and criteria of the awards onto other projects. Award systems are based on peer review within the professions that design and construct buildings. They rarely provide an opportunity to engage users and create a dialogue between actors on a specific project about the goals and design of that project. The priorities of the judges of such award schemes might differ dramatically to the priorities and requirements of the occupants, users, passers-by, neighbours and other end-users of a building. Such award schemes are concerned with the architectural qualities of the building and might not evaluate the function and build quality; they do not involve stakeholders and are usually done after a building project has finished rather than in real-time in the process.

The research team found that judgements were often made 'behind closed doors' and it was often difficult to obtain accurate information and feedback about the results. The fact that decisions were taken by professional peers (who have their own particular interests) together with a lack of transparency in criteria in some cases introduced a layer of 'professional control' into the process that the research team wished to avoid in the DQI. Moreover, design awards often focussed on novelty in architecture or prestige and 'headline' buildings. The authors had no complaints about this in itself, but their aim was to develop a method that could be used to equal benefit in understanding the value of design for all types of buildings.

Developing the DQI

An applied method of research and development was adopted involving a series of iterative steps in close collaboration with industrial users. This allowed knowledge from practitioners to be integrated and tested in subsequent versions of the tool. The research team drew from the background literature and made presentations to the steering group over several months. The steering group set the agenda for the research, guiding the research questions and development process according to its over-arching perception of what was needed. The specification for the DQI thus evolved through time during the first year of the project and was formalized after several iterations.

The specification stated that the resultant DQI should:

- assist in informing choice in design decisions
- be useable by anyone – including professional designers and lay users
- raise public awareness of the importance of design
- be capable of measuring an individual's view of design quality against their own chosen intent for the building
- allow participants to compare and contrast different options
- be of a flexible, multipurpose and generic nature, and useable on many different types of buildings
- be useable at different phases in a buildings' life-cycle: conception, design, construction and in-use
- be swift to use, with a simple and clear interface

Existing tools have been used as a starting point for the development of the DQI. There is considerable overlap between the present approach and several previous attempts to understand the quality of buildings. Unlike previous tools, however, the DQI focused on design quality and could be used across all stages of a building's life, including conception, design, construction and in-use. Key terms used in the DQI are defined in Table 1.

Table 1 Terms used in the DQI development process

Conditioners	Constraints or enablers that bound a building project: human resources, natural resources, time and finances
Resource envelope	Set of conditioners or constraints and enablers that bound a building project
Build quality	Encompasses aspects of its performance, engineering systems and construction
Function	Encompasses aspects of its use, access and space
Impact	Encompasses aspects of its contribution to form and materials, the internal environment, urban and social integration, identity and character
'Doughnut' representation	Visualization used in the first phase of the DQI project, which is 'doughout' shaped

A number of views of the DQI emerged during the early period of validation. It aimed to be useable by professionals and users across a wide range of building types. The original aim was to develop a tool for benchmarking design quality. However, over time the focus changed. At the first meeting of the Steering Group, it was agreed that there could be no single, universal result from the analysis of design quality of a building. Rather, design quality reflects multiple viewpoints from communities of design professionals and from user groups including lay people. Individuals needed to be provided with an opportunity to express their intentions and viewpoints in order to create a dialogue between all the different actors involved in the design and building process. The authors sought to create an interactive, user-focused approach to design quality.

It was recognized from the outset that design quality was conditioned by what was described as the 'resource envelope' within which design takes place. Clearly some designs might be 'better' because more resources are deployed to achieve the design objectives. Any measure of design quality should take into account the level of resources in relation to the appropriateness of the particular outcome. For example, one might expect prestige building to involve more design resource and therefore to achieve higher levels of design quality than everyday buildings. Nevertheless, everyday building should embody an appropriate level of design quality. The definition of 'resource envelope' in this context includes human resources, natural resources, time and finance (Figure 1). It was anticipated that proxies for these could be captured along with 'design intent' and that this would provide a means for evaluating the quality of design in relation to a particular type of building. Work to develop a

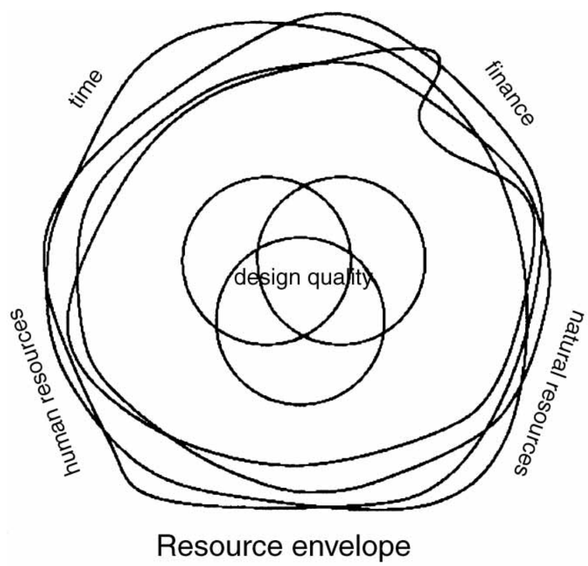


Figure 1 Design conditioners – the resource envelope

means of assessing these design 'conditioners' is ongoing and is discussed below.

As the DQI was developed, it was increasingly seen as a mediator between customers, end-users, designers and producers. It structured questions about the process, providing information that is easily accessible to architects, engineers and constructors. It enabled design teams to explore differences in expectations across professional and user groups. A key element in the research approach to developing the DQI was to focus on the intent for the building. This made the DQI indicator different from others that had been developed previously. The Steering and Reference Groups suggested that the tool should draw out from respondents their intent for the building and that design quality should be assessed against this intent. This was a turning point in the process and reflected the widespread view that imposing one model of design on the tool would be unrealistic. Each score would be a reflection of the score of the building assessed against individual respondents' personal and/or professional views.

The DQI consists of three elements: a conceptual framework, a data-gathering tool and a weighting mechanism. The relationship between these different parts is shown in Figure 2.

Conceptual framework

The multifaceted nature of design has been recognized since late Antiquity, when Vitruvius (1999) described design in terms of *firmitas*, *utilitas* and *venustas*, terms often translated as commodity, firmness and delight. Modern architectural theorists continue to identify and explore aspects of design and their interrelationships. For example, Frampton (1980) describes design in terms of space and tectonics. Whilst our focus is on a range of project stakeholders' understandings of design rather than on a theoretical discussion, an important element in the development of the DQI was an easily understood conceptual framework for design assessment that acknowledges the multifaceted heritage of design theory. The conceptual framework focuses on three aspects: Function, Build Quality and Impact. These aspects can be seen as a modern-day interpretation of the Vitruvian framework; and there was an extended discussion and many iterations before these terms were agreed upon. In the framework to explore the design quality of a building, Function encompasses aspects of its use, access and space; Build Quality encompasses aspects of its performance, engineering systems and construction; and Impact encompasses aspects of its contribution to form and materials, internal environment, urban and social integration, identity and character.

The Steering Group considered a number of different models in the development process. The first was a three-layered cylindrical model in which lifecycle became an enhancement to functionality, with 'delight' at the highest level (Figure 3). This model was rejected because it did not account for the interaction between Function, Build Quality and Impact. Another model was to consider the DQI as a pyramid with sides representing function, build quality and impact (Figure 4). Representing the framework developed as a pyramid stresses the multifaceted nature of design quality. For example, lighting in a building can have a functional quality, such as providing a bright and accessible work area, but it can also impact on the pleasure and wellbeing in use of the building. The DQI was designed to reflect these overlapping qualities.

Developing the conceptual framework helped to create a shared language among participants in the project. It also helped to direct users' attention to the range of features characteristic of high design quality. For example, owners and operators of a building might be more concerned with its functional performance

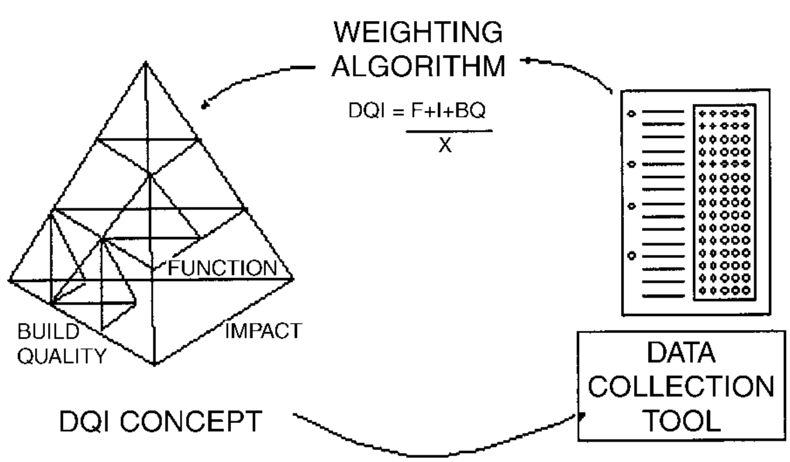


Figure 2 Relationship between the DQI conceptual framework, weighting algorithm and data collection tool

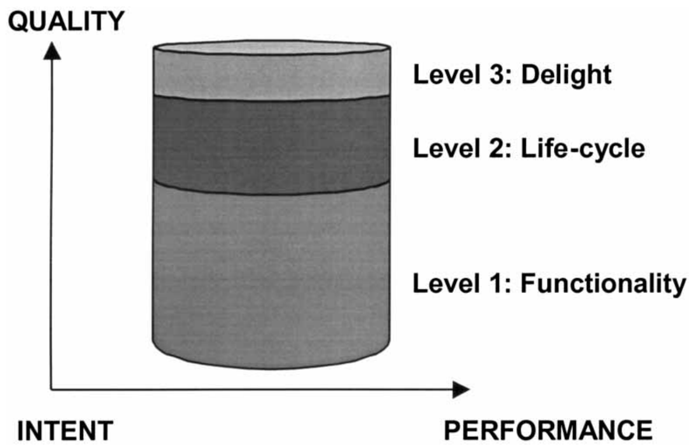


Figure 3 Early version showing the cylindrical model

and may not give consideration to form. On the other hand, architects may focus on form without giving high levels of consideration to the function of the building. The tool attempted to bring together these concerns into a common framework that recognized the links between different facets of design quality and overcame the traditional divide between form and function in the design process.

Data-gathering tool

At the core of the DQI tool was a questionnaire that was designed to be used by anybody involved in design or use of buildings, and to be short, simple and clear. A rough guideline of 20 minutes was established for respondents to complete the questionnaire. The aim was to ensure that the questions were consistent and respondents able to move quickly through the questions without being overwhelmed by technical terms or jargon. Within the Steering Group, there was concern that questions should not be simplistic or facile. It was a difficult balancing act between creating questions that were useful, clear and direct, but at the same time did not leave themselves open to the accusation that the tool was 'dumbing down' design quality.

The first task in building the questionnaire was to develop a list of questions. The project used the Reference Group workshop to do this. The workshop was intended to draw as many potential questions as possible. Industry participants were allocated working groups and each was set the task of developing questions for one category of the tool. Through this exercise, the professionals produced a large number of potential questions for inclusion in the tool. These questions were added to a list developed by the research team and the Steering group. Many hundreds of questions for exploring design quality were generated. The research team and Steering Group edited and shaped this list of questions and produced the first version of the DQI questionnaire. An iterative development process ensued and the questionnaire is currently on version 6.4.

The questionnaire begins with a general introduction to the tool. This introduction is designed to be accessible to a wide audience of potential participants. It describes the goals of the tool and asks individuals to fill out the questionnaire from their perspective:

- Section 1: collects information about the respondent and the type of building. Individuals are asked to list their aims for the building and the stage of development of the building. This information can be used to sort the data for later analysis.
- Section 2: focuses on function and has three subsections: use, access and space.
- Section 3: focuses on impact and contains four subsections: form and materials, internal environment, urban and social integration, and character and innovation.
- Section 4: explores build quality and contains three subsections: performance, engineering systems and construction.

Within each subsection, there was a set of questions and respondents indicated their response on a one-to-six scale (Figure 5).

At the end of Sections 2–4, respondents are asked to assign a weighting to the importance of each of these features to their building. This was implemented to enable the authors to set the users' design intent for the building. The number was used in the weighting mechanism of the

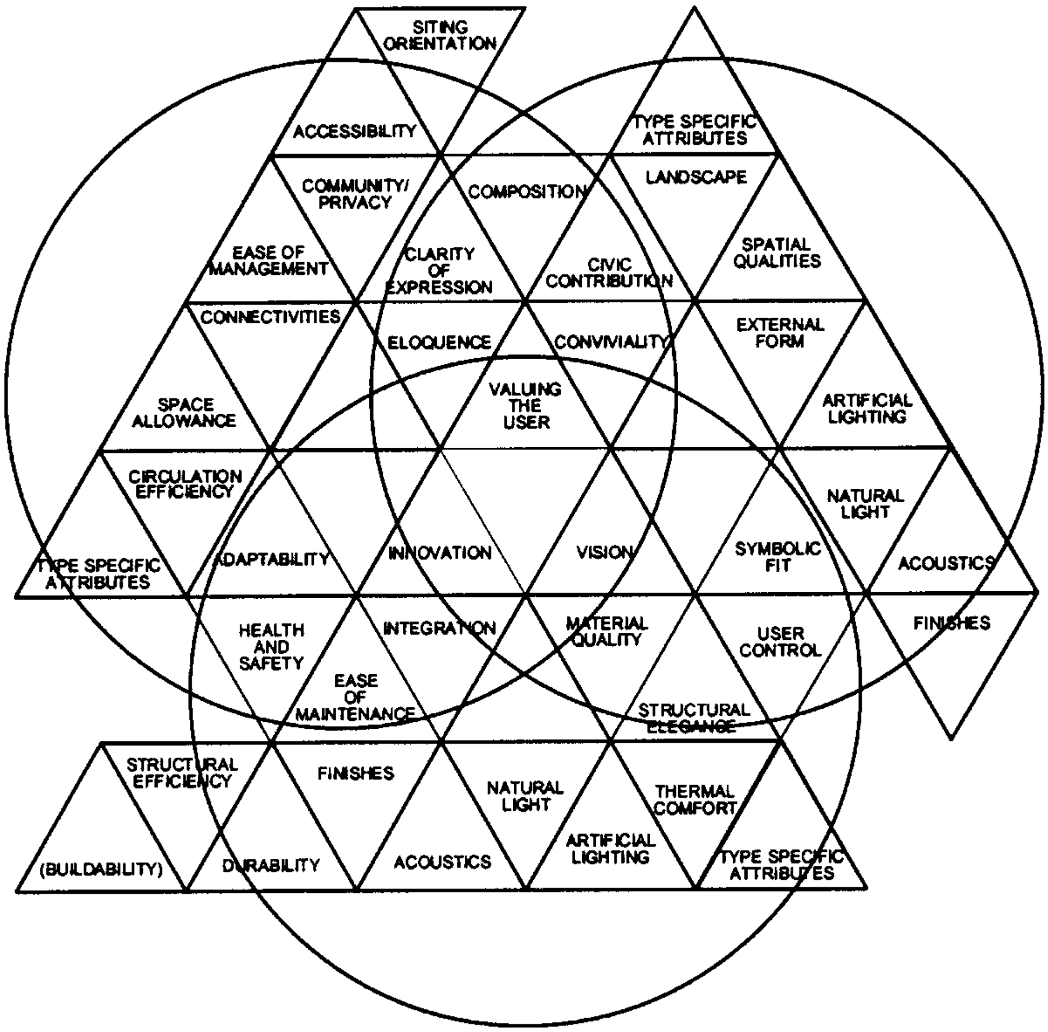


Figure 4 Conceptual framework developed by the Steering Group to show the overlapping nature of design and to agree a common language for describing aspects of design quality

tool. For each question, respondents had the option of answering 'don't know' and this meant that their responses would not be counted in the weighting mechanism. To create a data source that would allow for comparison, few opportunities were made for open-ended responses that would be difficult to categorize and compare. At the end of each section, there was a blank box allowing respondents to write in their views.

The last section of the tool focuses on the 'constraints' and 'enablers' of the project, or what have been called the 'conditioners' of the project. These include issues such as the financial resources available to the project and its commitment to sustainability. These questions are used to help weight the responses. They help to magnify the scores of buildings, which score well on the rest of the questionnaire, yet also operate within a limited financial budget.

Weighting mechanism

The third element of the DQI was the weighting mechanism. This was developed through the use of a simple multicriteria assessment algorithm. The weighting mechanism used the priorities that the user had set for the building and weighted users' perceptions of design quality against these intentions. The responses to the questionnaire were weighted using a simple formula reflecting the weighting that individual respondents gave to particular attributes in each section of design quality. The first aspect of the weighting system was weighting by subsection of each design quality field. For example, in Section 2, individuals weighted across Use, Access and Space. Their scores on individual questions were compared with their weights in those subsections. The weighting mechanism operated in each section and this ensured that individuals were accorded their own importance to particular features

Build Quality

For sections **N** to **P** please additionally circle the 3 statements within each section that you feel are the most important for your building

N PERFORMANCE	Strongly Disagree	Disagree	Tend to Disagree	Tend to Agree	Agree	Strongly Agree	Not Applicable
01 The building is easy to clean	O	O	O	O	O	O	O
02 The building withstands wear and tear in use	O	O	O	O	O	O	O
03 The building is easily maintained	O	O	O	O	O	O	O
04 The building design has responded to the site microclimate	O	O	O	O	O	O	O
05 The building will weather well	O	O	O	O	O	O	O
06 The building's structure is efficient	O	O	O	O	O	O	O
07 The building's finishes are durable	O	O	O	O	O	O	O
08 There is sufficient daylight in the building	O	O	O	O	O	O	O
09 The artificial lighting levels in the building are sufficient	O	O	O	O	O	O	O
10 The thermal climate in the building is appropriate to its use	O	O	O	O	O	O	O
11 The acoustics quality is appropriate to its use	O	O	O	O	O	O	O
12 The air quality is appropriate to its use	O	O	O	O	O	O	O
13 The building is easy to operate	O	O	O	O	O	O	O
14 The building produces a low number of complaints/faults reported by users	O	O	O	O	O	O	O

Figure 5 Detail of a draft of the questionnaire

of the design and their views were reflected in the scores they received for that section.

There was another mechanism to ensure that intent was expressed in the weightings. At the end of the questionnaire, individuals were asked to weight across the three main features of design quality: function, impact and building quality. This weighting was then compared with their scores for that section and highlighted the importance of their answers to particular questions on the questionnaire. For example, if a respondent indicated that function was the most important feature of the building, their responses to the function portion of the questionnaire would be magnified.

The initial weighting system remained relatively simplistic. In the future, it might be necessary to develop a more sophisticated system for weighting the questions. This would involve amplifying scores based on responses in the last section of the tool, which includes questions on constraints and conditioners relating to the resource envelope, and linking this to responses across different categories. However, increasing the complexity of the weighting mechanism has the disadvantage of making the tool more opaque and the results more sensitive to the algorithm. This is a tension inherent in many multicriteria assessment tools. Research has shown that increasing the complexity of the assessment can lead to a subsequent increase in the degree to which individuals respond 'strategically' to the assessment. As one expert of multicriteria tools ruefully commented, 'figures don't lie, but liars can figure'. In terms of the DQI, it was attempted to balance this tension by making available the raw data of the assessment and also to ensure that the use of the tool was embedded in a social dialogue that supported interaction and consensus building among all members of the project.

Piloting the DQI

As part of the development process, pilot studies were used to test and refine the instrument. Choice of buildings and designs for piloting were made by the Steering Group and the sample attempted to reflect a broad range of building types and a cross-section of different levels of completion – from the outline design stage to a completed building. The design team was gathered for each pilot study and, where possible, users or potential users were also brought into the DQI assessment. A short presentation was made to explain the purpose of the DQI at each pilot study. Participants were then asked to fill in the questionnaire. After participants had completed this, their views on the process were obtained either through individual interviews or through group discussion using a semistructured format. A out-turn questionnaire was used to capture feedback on how the pilot tool performed. The resultant information was used for subsequent revisions.

Buildings used for the pilots

The five buildings on which initial pilots were conducted were as follows:

- The Freeman Centre, University of Sussex, designed to accommodate the Science Policy Research Unit (SPRU), University of Sussex, and the University of Brighton's Centre for Technology and Innovation Management (CENTRIM). This £9.4 million project was at the detailed design stage when the DQI was piloted. Both the design/project management group and the user group were participants in the pilot.

- The National Ice Centre, Nottingham, provides a major stadium for training ice-skaters and for holding national and international ice-skating and entertainment events. The DQI was piloted on the completed first phase of the two-phase development. The project team reconvened to take part in this pilot and users were also involved.

- The Peabody Trust's Dalston Lane housing project, London, provides social housing accommodation in the inner city, and includes shops and office space. The DQI was piloted on this completed residential and commercial development. The project team reconvened to take part in this pilot, and residents of the housing also took part.

- Brighton Library, Brighton, will house the city's public lending library. It was at the initial design stage. The project team participated in the pilot.

- Brindley Place, Birmingham, a major new office development, has won many regional and national awards and has Arthur Andersen management consultants as one of its tenants. The facilities manager for Arthur Andersen joined the project team for this pilot.

Results from the pilots

The pilots indicated that it was difficult to determine *ex ante* what the implications of using the tool would be for different projects. In each project, there were tensions and debates about the quality of design within the project team. In the initial phase, it was found that the tool allowed for direct comparison between different actors involved in the building design. These direct comparisons can reveal differences in expectations and views about the project. The results were fed back to participants using simple visual 'doughnut' representations (Figures 6 and 7) at the highest level of analysis, i.e. without interpretation at the level of individual questions. For example, in the Freeman Centre pilot, the two client representatives were much more critical of the overall building design than the architect and engineers. This reflected the clients' concerns about the lack of specificity in the current state of

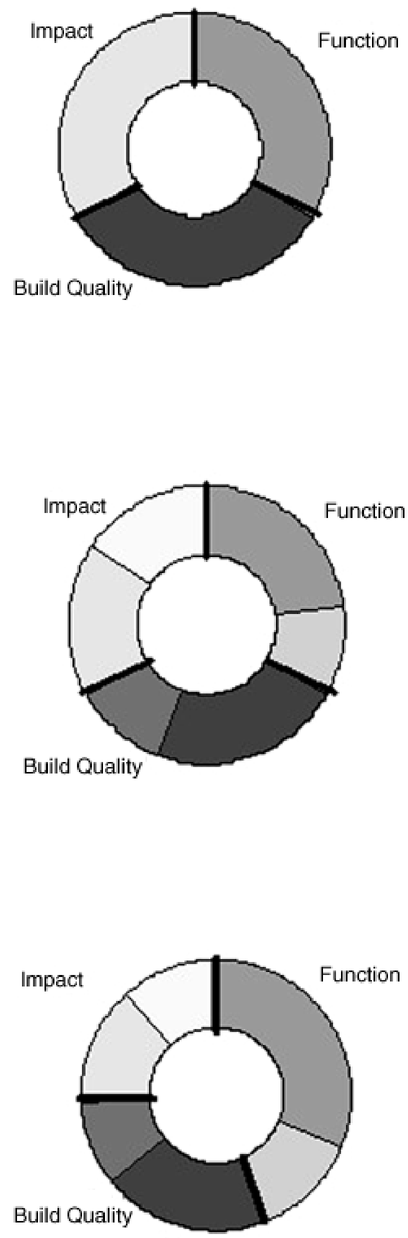


Figure 6 Example of the early visualization used to show results with (top) the maximum score for all sections with the sections weighted equally, (middle) different scores for each section with the sections weighted equally and (bottom) different scores for each section with the sections weighted differently

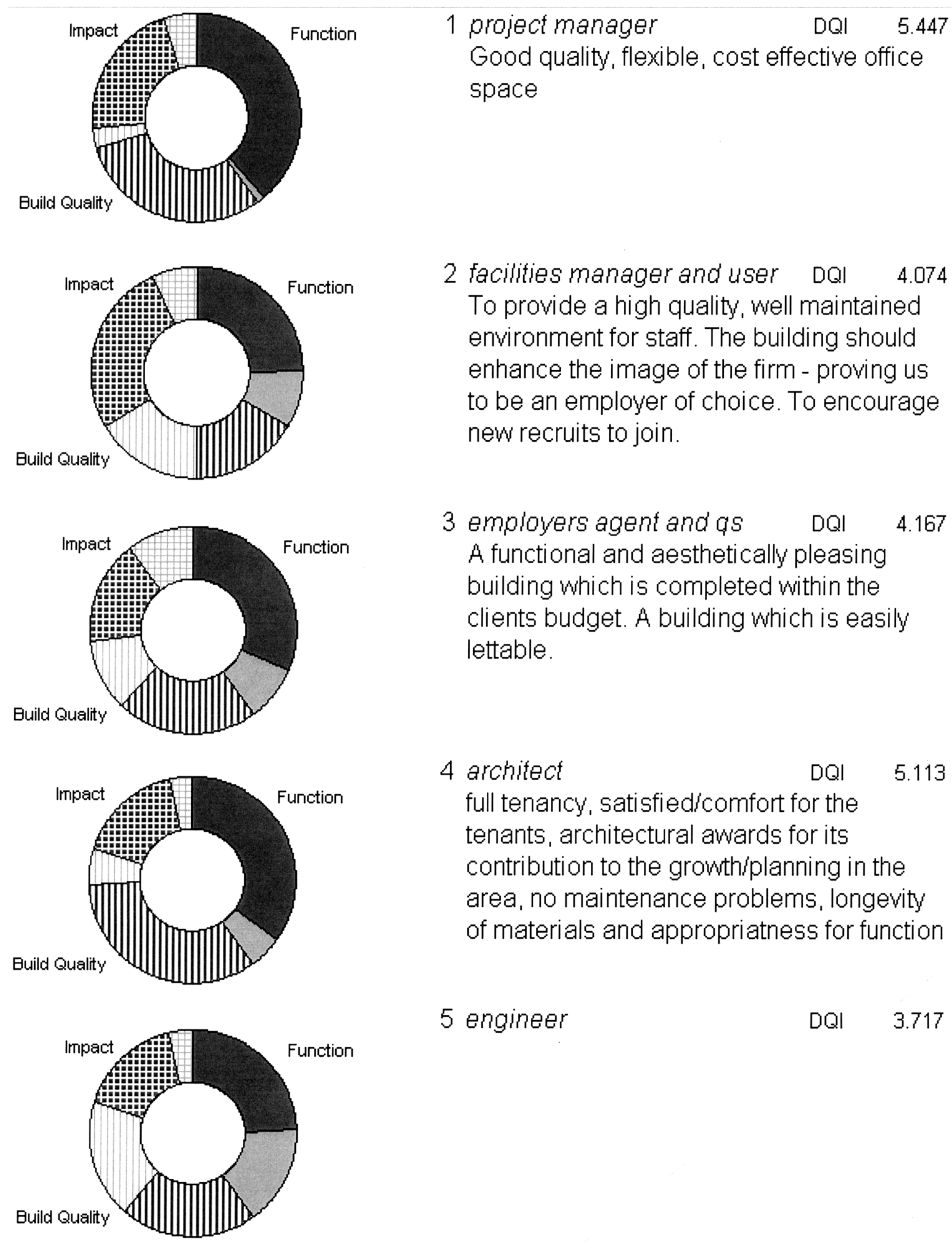


Figure 7 Comparison of different stakeholder perspectives on design quality on one of the pilot projects

the design. Presenting the results of the pilots to the project team helped to facilitate a debate among them about the state of the design.

Some members of the steering group were keen to use the tool for comparisons of different types of buildings. A wider sample of projects would be needed to achieve this. This became the objective of the second phase of the project (discussed below).

The initial pilot studies elicited participants' views about the questions, sections, subsections, weighting mechanism and overall DQI concept that led to the refinement of the questionnaire. Several questions were removed or revised based on suggestions from respondents. Respondents also questioned several aspects of the tool. For example, the Nottingham Ice Centre was designed to provide an exciting atmosphere for spectators, but most of the questions on the questionnaire focused on minimizing the impact of the environment on users of the building. Overall, however, responses to the DQI were positive. They included:

- 'It touched on things we clearly hadn't thought of' (client)
- 'It's a very useful tool to use for a public sector client to get a balanced brief' (financier)
- 'I was pleasantly surprised to be asked if the flat was ''delightful'' and ''convivial'' ' (tenant)
- 'I'd like to use this throughout the project life-cycle' (project manager)

Visualizing the Results from the DQI

The framework was used to develop the visualization of the outputs of the tool. Once it had been decided that the DQI would not generate objective measures, an alternative approach was needed and attention focused on graphical representation of the results.

Results from the pilots were weighted and analysed in a spreadsheet, but it was necessary to develop a simple and clear representation of this analysis. The research team sought to make explicit the assumptions and priorities that went into its creation rather than to give a single numerical result. It was important to the team to show the effect of the weightings and of the scores on the overall result. This allows users to examine critically the different assumptions and priorities behind their own and others' understandings of design quality.

The representations used in the initial pilot phase were 'doughnut' shaped. Different colours distinguished the three main sections: Function, Impact and Build Quality. Within each section, a darker shade indicated the score as a total of the available score for this section. The darker the overall doughnut, the higher the rating of design quality is. In this way, the user could see the effects of their weighting and scoring of different sections.

In Figure 6 (top), the maximum score was obtained for each section, and the sections were weighted equally. In Figure 6 (middle), different scores were obtained for each section and the sections were weighted equally. In Figure 6 (bottom), Function is seen as the most important aspect and given 45% of the weighting for the building considered, Build Quality is given 29% of the weighting and Impact is given 26% of the weighting.

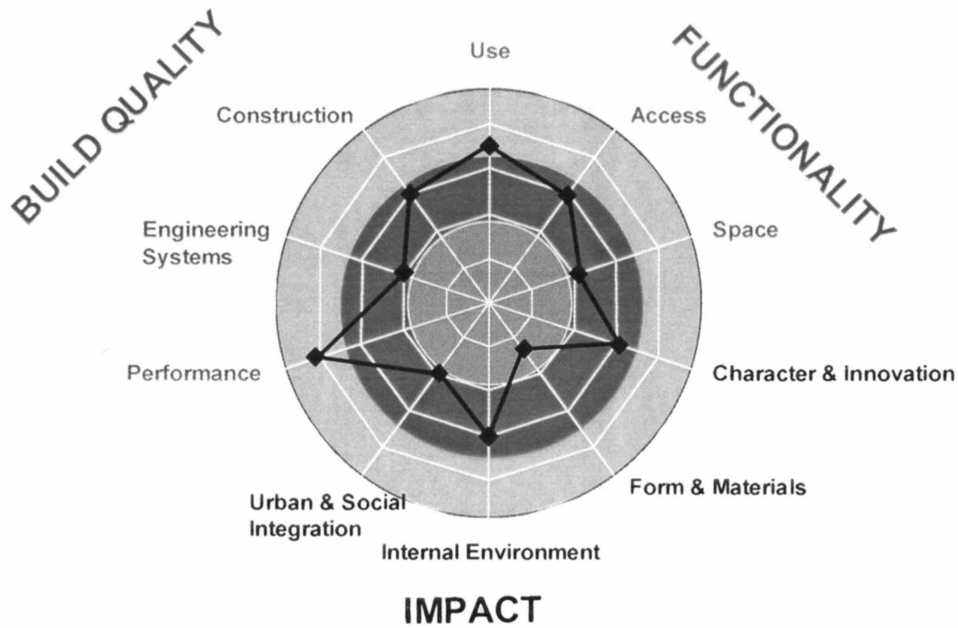
These representations have a number of advantages. They make explicit both the overall extent of design quality and the contribution of the weighting for design intent. Team member's representations can be compared to facilitate discussion about priorities in design (Figure 7). However, the representations also have disadvantages. For example, they show the weightings and scores only at the level of the section, not the subsection or individual question. Work was required to rethink the visualization of results from the DQI tool. Following the initial pilot phase, a spider-diagram approach was adopted to represent results. This brought the appearance of the DQI results in line with those used for UK construction Key Performance Indicators (Figure 8).

Discussion: is the DQI a tool for thinking?

In presenting this work on the development of DQIs, the research team recognizes that deeper and more detailed explanation and analysis are needed, both on the ideas underpinning the development of the instrument and on the results from initial use. Stage 2 in the development, evaluation and review of the DQI is ongoing and these discussions will be the subject of the work-in-progress paper in this issue. However, in this paper, the authors wish to reflect upon one attribute that emerged during the initial development and pilot study phase: the idea that the DQI might be used as a 'tool for thinking'. There are several aspects to this. For example, the DQI has been shown to be useful in capturing what are often deemed to be intangible attributes about the perceptions of design quality. Once captured and codified, they can be explored from different viewpoints. In this context, a tool for thinking can be helpful in closing the loop between different iterations in design in a particular project. It might also be useful in bridging the gap between projects so that lessons from one generation of design (of say a school building) can be carried forward and acted upon in the next project or generation of design.

The concept of 'tools for thinking' is not new. Academics in the US have successfully developed approaches to evaluation and development in product design processes, most notably in the form of Eppinger's Design Structure Matrix and Baldwin and Clarke's work on Design Rules (Eppinger et al., 1994; Anderson et al., 1998; Baldwin and Clark, 2000; Eppinger, 2001). The Design Structure Matrix has been 20 years in development. It recognizes that design is an information-intensive iterative process and that in many instances the outcome is difficult to specify before the process begins.

These tools measure a range of subjective and objective indicators of quality. They have been conceived of either as tools for thinking or as rational, objective measures. In this case, tools for thinking capture the subjective and objective information that can be used in subsequent iterations of design, whilst rational, objective measures attempt to capture an objective measurement of the quality of the output. The approaches taken in the development of these two



M IMPACT SUMMARY

Having addressed sections **I** to **L** above, please indicate the relative importance to you of these 4 aspects by allocating a total of **20** points to them. You can give any aspect **0** if it is not at all important, but the total must add to **20**. An example is given below:

CHARACTER & INNOVATION	eg. **5**	6
FORM & MATERIALS	eg. **5**	3
INTERNAL ENVIRONMENT	eg. **5**	8
URBAN & SOCIAL INTEGRATION	eg. **5**	3
	total points **20**	total points **20**

V COMPARATIVE ANALYSIS

Having addressed the 'Impact', 'Build Quality' and Functionality' sections above please indicate the relative importance to you of these 3 aspects by allocating a total of **15** points to them. You can give any aspect **0** if it is not at all important, but the total must add to **15**. An example is given in the grid below:

FUNCTIONALITY	eg. **5**	
IMPACT	eg. **5**	
BUILD QUALITY	eg. **5**	
	total points **15**	total points **15**

Figure 8 Spider diagram visualization of results

categories of indicators came from different theoretical starting points with the aim of providing a variety of practical end results.

One outcome of implementing Eppinger's Design Structure Matrix is the propensity for design assessment to be used as a heuristic. Similarly, Baldwin and Clark's Design Rules provide a conceptual framework around which different members of a design team can converge and discuss potential design outcomes (Baldwin and Clark, 2000). The potential to provide a means for practitioners to reflect upon their contributions to the overall design of a building was an unintended consequence of developing the DQI. However, in today's environment of construction design and procurement, it might be one of the most useful outcomes. Professional designers have few opportunities for what Schön (1991) describes as reflective development, using a common language across disciplines. This potential will be carried forward and tested in future phases of the DQI project.

Furthermore Lester et al., (1998) used the concept of 'interpretative management' to describe the processes by which managers and designers make decisions under conditions of uncertainty, for example when customers themselves are not completely clear about what they want. This level of unpredictability is commonplace in building design and it is suggested that the DQI could assist as an aid to interpreting the value of design. When the tool is used iteratively during the design of a project, it might also become part of the design management toolkit.

As a tool for thinking about design, the authors contend that the DQI in its current form is most useful as a starting point for discussion. It cannot provide an absolute measure of the design quality of a building but can be used to articulate the subjective qualities felt by different stakeholders in the design process and thereafter in the use of a building. Tools for thinking aim to elicit and represent knowledge about design in order to initiate conversations about client and user priorities, design possibilities and consequences. This is possible because results from different members of the project team and user groups can be compared and contrasted during design and subsequent evaluation processes.

Conclusions and further developments

This paper describes Phase 1 in the development of the DQI – a two-year process of research and development that has culminated in the award of funding for Phase 2, which began in June 2002. Since completion of Phase 1, the DQI concept, framework and data-gathering tool have been adopted by the National Health Service Estates Division and by the Ministry of Defence. The aim is to use the system to assess design quality in all new buildings.

Whilst the first generation of the DQI has been completed, there is still further work to be done in refining its use for different applications across all building types. The authors have embarked upon a second phase of development, including an improved questionnaire with a Web-based interface to allow respondents to complete it online. This is known as the 'Trailblazer' phase. By October 2002, 44 organizations had signed up to carry out beta tests of the DQI. Each organization would use the tool on six projects and attempt to elicit responses from 20 individuals per project. The intention is to sign up 100 organizations, providing a sample population of 600 pilot studies using 12 000 respondents. Data from this phase will be analysed in much greater detail than hitherto, and the results from this analysis will be used to refine the tool.[4]

Moreover, new ways of visualizing the results are under development to enable richer levels of analysis. Also planned are the inclusions of new approaches to eliciting information about the conditioning features of the project and the resource envelope that underpins the parameters of design. In addition, a detailed weighting system is under development that will take into account three levels of design quality linking our existing fields of Function, Impact and Build Quality: Basic, Value-added and Excellent. It is hoped that this approach will lead to a more informed debate about the value of design in buildings and that this will complement approaches to measuring performance in design and construction processes.

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of the DQI. Without them, the development component of the project would not have been possible.

References

Amin, A.-L., Gann, D.M. and Salter, A. (2000) Key Performance Indicators in Design. First Phase Project Report, CIC/DETR, London.

Anderson, J., Pohl, J. and Eppinger, S.D. (1998) A design process modeling approach incorporating nonlinear elements, in Proceedings of the 1998 ASME Design Engineering Technical Conferences, Atlanta, GA.

Andrews, S. (2000) Design Sense Award, Design Museum, London.

Baldwin, C. and Clark, K. (2000) Design Rules: The Power of Modularity, MIT Press, Cambridge, MA.

Construction 21 Steering Committee (1999) Construction 21 – Re-inventing Construction, Ministry of Manpower and Ministry of National Development, Singapore.

CABE (2000) By Design, DETR, London.

Clausing, D. (1994) Total Quality Development: A Step-by-Step Guide to World-Class Concurrent Engineering, ASME Press, New York.

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

Department of Industry, S.A.R. (1999) Building for Growth—An Analysis of Australian Building and Construction Industries, Commonwealth of Australia, Canberra.

DTLR (2000) Housing Quality Indicators, DTLR, London.

Egan, J. (1998) Rethinking Construction: The Report of the Construction Task Force to the Deputy Prime Minister on the Scope for Improving the Quality and Efficiency of UK Construction, Department for the Environment, Transport and the Regions, London.

Egan, J. (2002) Accelerating Change, Rethinking Construction, London.

Eppinger, S.D. (2001) Innovation at the speed of information. Harvard Business Review, 79(1), 149–158.

Eppinger, S.D., Whitney, D.E., Smith, R.P. and Gebala, D. (1994) A model-based method for organizing tasks in product development. Research in Engineering Design, 6(1), 1–13.

Frampton, K. (1980) Modern Architecture: A Critical History, Thames & Hudson, London.

Gann, D.M. and Salter, A. (1999) Interdisciplinary Skills for Built Environment Professionals, Ove Arup Foundation, London.

Gardiner, P. and Rothwell, R. (1985) Tough customers: good design. Design Studies, 6(1), 7–17.

Gibson, R. and Gebken, R. (2003) Creating design quality through planning charettes – applications of the project definition rating index. Building Research & Information, 31(5), 346–356.

Giddings, B. and Holness, A. (1996) Quality assessment of architectural design and the use of design award schemes. Environments by Design, 1(1), 53–65.

Holness, A. and Giddings, B. (1997) Developing a methodology for investigating the design of award winning industrial architecture. Nordic Journal of Architectural Research, 4, 96.

Jesinghaus, J. (2000) On the Art of Aggregating Apples and Oranges. Working Paper, Fondazione Eni Enrico Mattei, Milan.

Lawson, B.R., Worthington, J., Phiri, M. and Bassino, M. (2002) Learning from Experience: Applying Systematic Feedback to Improve the Briefing Process in Construction, University of Sheffield, Sheffield.

Leaman, A. and Bordass, B. (2001) Assessing building performance in use 4: the Probe occupant surveys and their implications. Building Research & Information, 29(2), 129–143.

Lester, R.K., Piore, M.J. and Malek, K.M. (1998) Interpretive management: what general managers can learn from design. Harvard Business Review, March–April, 86–96.

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

Monden, Y. (1983) Toyota Production System, Industrial Engineering and Management Press, Norcross.

Paul, J.J. (2000) Performance metrics to measure the value of design. Design Management Journal, 11(4), 71–75.

Rowland, I.D. and Howe, T.N. (eds) Vitruvius: Ten Books on Architecture, Cambridge University Press, Cambridge.

Schön, D.A. (1991) The Reflective Practitioner, Ashgate, Aldershot.

Schonberger, R. (1982) Japanese Manufacturing Techniques, Free Press, New York.

Simon, H. (1962) The architecture of complexity. Proceedings of the American Philosophical Society, 106(6), 467–482.

Smith, P.G. and Reinertsen, D.G. (1998) Developing Products in Half the Time, Wiley, New York.

Sveiby, K.E. (1997) The New Organizational Wealth: Managing and Measuring Knowledge-based Assets, Berrett Koehler, San Francisco.

Tang, H. (2001) Construct for Excellence. Report of the Construction Industry Review Committee (CIRC), Hong Kong.

Tavistock Institute (1966) Interdependence and Uncertainty. Report to the Building Industry Communication Research Project, Tavistock Institute, London.

Tufte, E.R. (1983) The Visual Display of Quantitative Information, Graphic Press, Cheshire, CT.

Vincenti, W. (1990) What Engineers Know and How They Know It, John Hopkins University Press, Baltimore.

Von Hippel, E. (1986) Lead users a source of novel product concepts, in W.L. Moore and M.L. Tushman (eds): Readings in the Management of Innovation, Ballinger, pp. 352–366.

Von Hippel, E. (2001) User toolkits for innovation. Journal of Product Innovation Management, 18, 247–257.

Ward, A., Sobek D.K., II, Cristiano, J.J. and Liker, J.K. (1995) Toyota, concurrent engineering and set-based design, in J.K. Liker, J.E. Ettlie and J.C. Campbell (eds): Engineering in Japan, Oxford University Press, Oxford.

Womack, J.P. and Jones, D.T. (1996) Lean Thinking, Simon & Schuster, London.

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

Endnotes

[1]http://www.kpizone.com/

[2]The first phase was funded collaboratively through the former Department of the Environment, Transport and the Regions (DETR). The funding stream is now with the Department of Trade and Industry (DTI). Industry contributed time-in-kind.

[3]Users come from all sections of the population and reflect its diversity, varying in terms of age, cultural and ethnic background, wealth, etc. Hence, one or two ‘representatives’ are unlikely to represent such a diverse group.

[4]Details of this phase are described in the work-in-progress paper in this issue and can be found at: http://www.dqi.org.uk