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# Design Performance Measurement in the Construction Sector: A Pilot Study

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**Abstract**

This paper examines the role and deployment of design performance measurements (DPMs) in the construction industry, focusing on the consulting engineering sector, the design 'heart' of construction. Compared with manufacturing, there has been very little research on the use of DPMs in construction, and firms often struggle to find appropriate performance indicators. Using results from structured questionnaires, the paper shows that the few DPMs which do exist focus mainly on cost. Other measures are needed to address quality, innovative performance and client satisfaction. In contrast to manufacturing, DPMs in construction also need to address the project-based, multi-firm and non-routine nature of construction design, as well as the separation of design from manufacturing, build and operation. Interviews and workshops with industrialists were used to identify recent DPM practices in construction and combine these with lessons from other sectors. The resulting DPM tools provide guidance on how to: (a) integrate design into wider business processes in construction; (b) identify key design indicators, at both project and firm level; and (c) use DPMs to provide a balanced scorecard for design performance.

## INTRODUCTION

There is a now consensus in manufacturing that design has become central to competitiveness and delivering value-added. Design, in its broadest sense, is where the intellectual content for value-added in production processes is created. Good design is critical for competitiveness because it enables a firm to couple technical possibilities with market demands and new business opportunities. There has been significant progress in understanding and measuring design in manufacturing [2], [21], [31]. Yet there are few studies of design performance measures (DPMs) outside manufacturing and few, if any, in the construction industry.

The construction industry is a large sector of the economy and engineering design is critical to its performance, as in other industries. However, unlike manufacturing, engineering design is often carried out separately from production (or build) and consulting engineering firms usually have little control over most of the projects in which they engage. We used a structured questionnaire and workshops with leading designers to explore DPM practices in construction engineering design. The aims were to identify the key issues and problems confronting DPM in construction, and to develop a framework for understanding and applying DPMs appropriate for this sector.

The paper identifies modern DPM practices in manufacturing and combines these with elements of good practice from 12 leading firms in the consulting engineering sector. Based on the evidence from interviews and workshops with industrialists, a set of simple prototype tools are developed to enable firms to integrate design into wider business processes and to identify key design performance indicators at both the project and firm levels. The paper presents a balanced scorecard of DPMs which can be used comprehensively, or selectively to address the particular design needs of firms.

Given the primitive state of DPM research in construction, a limited exploratory study was a useful exercise to conduct. However, the construction sector is large and diverse: firms range from small local to large, international players. We recognise that further research is needed to assess the ability to generalise from the findings. The 12 companies studied manage a significant proportion of engineering design consultancy in the UK (around £3 billion per annum) and employ around 30,000 design engineers, a substantial proportion of the total. Further research is needed to examine DPM processes in other countries and firms and to examine the practices of small- and medium-sized specialist design companies. Research is also needed to develop and refine the DPM tools and to assess the impact of DPM use on firm performance.

Part 1 defines design and shows how consulting engineering firms are situated within the construction sector. It also identifies DPM lessons from manufacturing and looks specifically at the challenges facing design measurement in construction. Part 2 presents the results of the interviews and workshops, highlighting current DPM practices, as well as problems and needs within the sector. Part 3 presents tools for approaching DPM in consulting engineering firms, identifying the pre-conditions for their successful use. The tools show how DPMs can be developed to support and contribute to the strategic objectives of the company, at both the project and firm levels. They also provide guidance on how to select DPMs to target key areas for improvement and avoid ‘measurement for its own sake’. In the conclusions, we argue that the tools represent a balanced, if approximate, scorecard for design within construction. They may also be relevant to other complex product systems industries, characterised by one-off, high value, non-routine, multi-firm project environments.

## PART 1: ENGINEERING DESIGN IN THE CONSTRUCTION SECTOR

### 1.1 Design performance measurement

At its simplest level, design is "a set of plans and the process by which those plans are achieved" [74]. Industrial design is an integral part of the wider notion of engineering, that brings a set of skills, knowledge and understanding to the creation and production of useful artefacts. Engineering design knowledge is often embedded in individuals and organisational processes [55], [56], [57], [23], [6]. Vincenti argues that design can be classified into two types: *radical* and *incremental*. Radical design may be thought of as a totally new concept, designed from scratch, from the ground up [74]. By contrast, incremental, or normal design, which is far more common, takes up most of the design time of engineers and engineering departments. Normal design involves producing new or modified artefacts through the combination of 'off-the-shelf' technologies, as well as minor changes to existing technologies.

Design is a multi-level and hierarchical activity. While some elements of the design process may be performed concurrently, in other cases technical constraints mean that one thing cannot be done before another. In the design of complex products, such as major engineering constructs, there tend to be large numbers of intermediate engineering design tasks. One of the questions designers constantly face is whether modular, discrete components can be designed independently of each other or whether interface uncertainty and complexity mean that sub-systems need to be designed concurrently and in relation to each other [66], [67], [1]. Modularity implies that suppliers will be able to share common information and focus on their particular areas, as in the computer industry where system integrators, such as Dell Computers, need not design or manufacture any of the component parts. In this case, product architectures are divided into semi-independent modules which can later be ‘plugged in’ to create the computer system. In other cases (e.g. aeroengines) the scope for modularity is more constrained because of the complexity and iterative nature of the interfaces between components [61], [32], [27].

When effective, design is able to bring about a coupling between technical possibilities and market demands and opportunities [25], [63], [22], [64], [65], [76], [69]. Indeed, various innovation studies have shown that design is often a key component in determining competitiveness. In manufacturing, much of the value-added is now located in design rather than on the factory floor [11], [76]. Design is therefore important, yet there are few studies of performance measurement in engineering environments, and design activities are rarely and poorly measured [9], [53], [51].

The aim of performance measurement is to appraise the effectiveness of engineering design practices and design management within firms, or networks of firms (including suppliers and customers) with a view to improvement. Performance measurement is the “process of quantifying the efficiency and effectiveness of action” [46]. It usually involves the collection of individual measures of performance and their integration into a performance measurement system. A recent survey of performance measurement among UK firms showed that few firms have systematic approaches to performance measurement, but that formal systems were more valuable than the usual informal methods normally relied upon [47]. Performance assessment in manufacturing has traditionally focused on finance, manufacturing, and organisational measurements. Relatively few measures actually involve design and designers [53].

In new product development for manufacturing, where most DPMs are centred, the stock of measurements "is fragmented and only used in some parts of the product development process" [53]. However, new tools are being developed, such as the Design Structure Matrix, which focuses on the information flows necessary to manage design projects, rather than the work flows themselves [21].

**1.2 The construction sector**

The construction sector accounts for a significant proportion of economic output in OECD countries (e.g. ranging from around 6% of GDP in the UK, to about 12% in Japan). It also embraces many important design-intensive activities. Consulting engineering design firms based in the UK sold over $16 billion in 1996 and employed over 150,000 people [16]. In contrast with manufacturing, construction activities are organised in projects, often tailored for individual buyers. The organisation of work differs considerably between large and small projects and regionally, between Anglo-Saxon countries (N. America, UK, Australia), North European countries and Asian countries, (Japan, S. Korea). In N. America, the UK and Australia, consulting engineers are often engaged to carry out specialist design work by prime contractors/project managers. In contrast, large prime contractors in Japan often have integrated capabilities with in-house engineering design teams. A mix of approaches exists in Northern Europe [18], [26], [40].

Building projects involve architectural and engineering design and there are a number of recognised stages within the design process. These begin with outline schematic designs and progress through detailed design and component specification. Prime contractors act as both project manager and systems integrator. This role is sometimes performed by large international consulting engineering design organisations. Large prime contractors are increasingly taking on risks of financing and operating facilities, such as hospitals, ports, rail networks and airports. Customers include government departments, infrastructure operators and many private manufacturing and service companies. Most major contractors and consulting design firms compete for international projects (e.g. for the Hong Kong international airport) but domestic markets are dominated by locally-owned firms. However, this is changing with a recent wave of acquisitions and mergers especially in Europe (e.g. Skanksa of Sweden purchased the UK-based Kaverner Constuction creating a major European competitor to Bechtel). In addition, in every country there are many hundreds of relatively small general builders: skills and financial barriers to entry are low.

Within construction, consulting engineering firms including Ove Arup, W.S. Atkins, Mott MacDonald and Halcrow carry out much of the detailed design content of projects. They are sometimes hired by developer/contractors or architects (e.g. Norman Foster, Richard Rogers, or Frank Gehry), to translate project visions and ideas into physical artefacts. This involves a great deal of conceptual and detailed (or operational) design work. In some projects, contractors manage the entire project, hiring in an architect. In other cases, the client hires an architect who then selects the contractor. Although there are many different types of bid structure, typically, major projects are broken down into a set of functional packages and the work is parcelled out. Packages usually include: (a) architectural services; (b) mechanical and electrical services (including acoustics, lighting, heating, and information technology systems); (c) structural engineering (involving design for structural integrity and the feasibility of construction); and (d) cost consulting services. The consulting engineering ‘design heart’ of the construction sector includes (b) and (c). Architects rarely carry out detailed engineering design work. Similarly, developer/contractors, project managers or general builders conduct little design, except for minor changes for ‘buildability’, usually approved by consulting engineers. A major project can include dozens or hundreds of companies organised hierarchically. For example the Channel Tunnel had a least four sets of collaborators: (1) the buyer (the UK and French Governments); (2) a consortia of four or five leading contractors; (3) consulting engineering sub-contractors; and (4) a consortium of building companies.

In contrast with manufacturing, construction design is separated organisationally from production (or build) and the division of tasks is highly specialised. Architectural designers, contractors, consulting engineers and builders are also divided in terms of organisation, tradition and culture. There is usually a wide spectrum of design functions, which have to be integrated together to realise a project. Each consulting firm contributes a proportion of the intellectual content of the overall project, unlike manufacturing where design teams tend to carry out most new product design within a single firm which is also responsible for production. In addition, in construction new designs tend to be one-off and therefore the potential for design ‘repeatability’ and standardised modules is restricted.

### 1.3 Insights from manufacturing

Despite major sectoral differences, results from manufacturing studies have some points of relevance for engineering design firms in construction. Regarding design in general, research shows that designers can act as ‘gatekeepers’ within and among firms, accessing specialist knowledge and providing a channel of technical communication [15], [19]. Despite its increasing importance, design in manufacturing is often poorly managed and few firms have explicit strategies to improve design performance [39], [76]. Much design management is 'silent', carried out through informal relations among interested parties across departments [22]. Sometimes designers occupy a relatively low position in the hierarchy of the firm, lacking management visibility [51].

In manufacturing, cost-based DPMs are the most frequently used. Although they can provide important measures of efficiency and profitability, other measures are needed to indicate design quality, user satisfaction, and contribution to future product generations. The emphasis on cost-based DPMs is worrying for some practitioners, who argue that a more 'balanced' approach is needed to embrace issues of quality, design learning and innovation. To this end, Eppinger and Hauser have separately developed new metrics for indicating performance in design activities, including measurement of information flows, time-to-market, defects and rework [21], [31].

Manufacturing studies show that DPMs require considerable effort to implement and maintain and that there can be no single set of performance measures suitable for every firm [13], [46], [48], [75]. However, while all DPMs are imperfect, they can help bring about improvements in the design process, as shown in the automotive sector. Here, indicators such as (a) the number of new product designs produced annually; (b) the contribution of new product designs to current sales; and (c) the number of times a design gets passed back and forth between the design team and the manufacturing team, can all provide useful information on different aspects of performance. Studies show that DPMs need to be viewed in the broader context of firm performance and strategy and that a range of performance indicators should be used [58], [53], [9], [47] if the whole design process is to be improved [70], [72]. For example, in both software and construction sectors, timeliness of delivery to clients is an important indicator. However, software producers also use indicators of the degree of errors in programming code and whether customer needs are satisfied [7]. It should be noted that the focus of most software measurement has been on the measurement of processes, rather than quality, innovation or customer satisfaction [4], [5], [12], [78].

Performance measures should be chosen carefully, as they can be expensive and time consuming to administer [47]. Organisations need to balance the costs of DPMs with the benefits likely to be derived, avoiding the collection of data which is not relatively easy to collect, readily understandable and easy to use. Once a set of measures is decided upon, one way of providing incentives for using DPMs is to embed them into the firm's appraisal systems or group performance targets [53].

One general weakness in DPMs is that they are not usually effective in addressing radical design performance or major improvements in the design process. DPMs tend to focus on efficiency rather than innovative performance. Sometimes, DPMs can negatively influence patterns of behaviour in the organisations they monitor, leading to conservative, non-risk taking behaviour and manipulation of the statistics. Overly bureaucratic DPMs can become an 'end in themselves', more important then meeting customer needs. Therefore, it is important that indicators are frequently reviewed and sparingly and intelligently used [79].

A major outstanding question for DPM is whether improvements in design alone can lead to step-changes in performance. Womack and Jones argue that changes in processes can only be effective if they are tied to an optimisation of the whole production process [79]. This implies that improvement in design needs to be part of wider performance improvement programmes to be most effective. Research also shows the importance of informal processes in intangibles in design performance.  Knowledge, ideas and customer satisfaction, although difficult to measure, are often central to design performance.  At the process level, informal discussions in the coffee lounge or at lunch can sometimes be more important than formal meetings.

Typically, if there is a mismatch between performance measures and the real practices and needs of designers, individuals object to what they see as time wasting ‘number crunching exercises’ [8].  DPMs appear to work best when design (and related) staff are involved in data collection and interpretation.  As shown in the automotive sector, if design workers are part of the team that analyses the DPMs they are more likely to understand the use of the data and buy into the DPM process [9], [79].

**1.4 Design measurement in construction**

To date very little research has studied the use of DPMs in construction [64], [49], [42], [73], [51].  While some insights from manufacturing may apply, for at least four reasons construction presents a different set of issues and problems.

First, engineering design in construction is often separated from production, and information flows (feedforward, feedback) between design teams, prime contractors, clients or end-users are often sparse. Clients are rarely the actual users of the design, and gaining direct user feedback on design performance is particularly difficult. The development of Design Quality Indicators is the subject of a separate research project involving two of the authors – Gann and Salter.

Second, constructed artefacts tend to be bespoke, costly items, tailored to individual client needs. There is a common belief that little of the design know-how can be recycled for future projects. Lack of repetition, and the perception of a 'non-routine' environment for engineering design, hinders the development of design metrics and makes the problem of measurement more acute than in single firm manufacturing environments.

Third, consulting engineering design organisations often operate in multi-firm projects [26], [27], [34], [38], [45], [68], [77]. Measurement of design therefore must involve a degree of co-operation between designers from different firms. Because cross-firm, team building skills are essential to all stages of engineering design, measuring this aspect of performance is a key challenge.

Fourth, 'tensions' between design and construction practices make the process of DPM more difficult than in the manufacturing sector. This is particularly evident in the roles and responsibilities carried out by architects and contractors who, in Anglo-Saxon processes often vie for supremacy. Pressures to reduce costs and to introduce new technologies and more efficient methods of production have raised the profile of contractors in relation to architects. For example, in the UK, architects were often responsible for liasing with clients. However, clients have increasingly turned to design-build contractors to manage projects and to intervene to resolve problems as they arise. Few clients have the capability to deal with the various factional interests in the construction system.

In some cases, detailed design work has moved 'up the value-chain' into component supply-firms which use modern manufacturing techniques to engineer and test standardised, factory-produced component parts. In addition, some architects and consulting engineering companies have been able to exploit new opportunities to re-organise the overall design and construction processes. For example, in the case of the Bilbao Guggenheim, Frank Gehry used information technology to engage designers in the total process, increasing the designers' overall responsibilities. In other cases, the leading role of architects has tended to decline as the industry becomes more technology intensive [26].

The increasing sophistication of design has placed new pressures on consulting engineers to develop and integrate different bodies of knowledge. New specialist disciplines include acoustics engineering, façade design, fire engineering, building physics, building instrumentation and control systems, geotechnical engineering, knowledge of changing work/use patterns, new materials, as well as wind, seismic and vibration engineering. The depth of design knowledge reflected in educational qualifications has sharply increased in the last two decades [28], [26].

The construction process has traditionally been managed through legal contracts which define official obligations among the partners. This can work well for relatively simple, clear cut projects, but where design uncertainty is involved or where new technologies or a new type of building is required, it becomes very difficult to define legal boundaries and responsibilities through the various stages of the project cycle. As Barlow shows [3], as a result of unsatisfactory performance, many leading firms have turned to modern partnering arrangements to define new business processes to enhance collaboration. Partnering arrangements focus heavily on the early phases of project definition and overall design. They aim to minimise misunderstandings, improve partner flexibility, accelerate project start up, and allow for better design and innovation, and increase learning from project-to-project. They reduce the amount of legal contractual detail and replace this with broadly agreed work targets and milestones, regular means of communication and systems for design change and conflict resolution between buyers, contractors and suppliers. One of the key aims is to remove the adversarial culture which often exists in construction projects.

Some of the difficulties in construction are confronted in other complex capital goods sectors where production is one-off or small batch [27], [32]. Unlike consumer products, they are characterised by high cost, high levels of user involvement in design, uncertainty over appropriate design paths, elaborate product architectures, and an unusually high degree of tacit knowledge in design [32]. Because of the complexity of design, suppliers often use simulations to express design ideas and gain feedback from users and other collaborating firms [50], [60]. In construction products, as in other complex product systems, good design relies on intensive feedback between the different firms involved, including users and sub-contractors. When design errors occur, they tend to be amplified throughout the supply-chain, leading to high levels of risk of project failure. Experienced engineers tend to rely on tacit knowledge and 'gut feelings' about design choices and decisions [50], [17], [32], making design measurement especially difficult.

Part 2 presents the results of our empirical research, highlighting current DPM practices, as well as problems and needs within the sector.

## PART 2: RESEARCH APPROACH AND FINDINGS

### 2.1 Method and limitations

Research for this paper was carried out in collaboration with a group of twelve leading consulting engineering design firms based in the UK, together with CIRIA, the Construction Industry Research and Information Association. The research method had two phases. Part

A involved a pilot survey designed to examine current DPM practices in the twelve companies, focusing on the nature of DPM systems, the extent of their use and major difficulties confronted. The audit used is presented in Annex 1. Part B involved a series of workshops designed to: (a) verify and explore the survey findings (e.g. to consider how widespread particular problems were); (b) provide guidance on how best to deploy DPMs in construction; (c) create a framework for understanding and using DPMs; and (d) develop a set of prototype DPM tools for construction, consisting of a composite of good DPM practices currently in use, new DPMs planned, and those not yet planned but needed.

Although the study sample was not representative of all firms in the sector (e.g. small firms were not included, nor were other industry leaders), the companies involved were all listed among the 500 largest consulting engineering and design firms world-wide [20]. In total, the 12 collaborators managed just under $3 billion in design work annually and employed roughly 30,000 engineers in their design activities. The median firm in the group had $300 million in design work with a design staff of 3,500.

Interviewees and workshop participants were normally those responsible for technical development within their organisations, including managing directors or heads of design, engineering and research and development. Although the respondents tended to be experienced observers, the results were naturally biased towards a ‘top down’ view of the management processes and practices in place, rather than a ‘bottom up’ view of actual project processes, a distinction shown to be important for measurement of software processes [33]. Therefore, while the pilot study proved useful for identifying key issues and problems, further research is required to verify the findings and explore the propositions generated.

### 2.2 Results: DPMs in construction engineering design organisations

All firms reported experiences which concurred with results from attempts to measure design in manufacturing. Financial indicators were the most widely used but could not, on their own, provide sufficient information about design quality and the ‘flair’ of a design organisation. Firms reported that the use of DPMs should be seen as a process and not a ‘once and for all’ event and they believed that there was no one ‘silver bullet’ solution for every firm. DPMs needed to be part of a firm’s wider business strategy and, while potentially useful, could not be a substitute for a lack of good management. Similarly, DPMs needed to be viewed in the broader context of firm performance, and a range of performance indicators were needed to guide future investment and strategy.

While all DPMs were viewed as imperfect, they were seen as key to continuous improvements in design, as in the automotive sector. Those using DPMs were aware of pitfalls such as the use of indicators as an ‘end in themselves’, as well as the dangers of overly complex measures (and the manipulation of data for individual goals). Most were aware that DPMs could be expensive and time consuming to administer and that benefits needed to be weighed against costs. The development of useful, simple metrics was a key goal for most firms, as in other sectors. While only some recognised the importance of informal and intangible ‘human’ processes, all were of the opinion that DPMs should gather data on whatever was important, rather than what was ‘easy to collect’, be it tangible or intangible. There was a belief that DPMs worked most effectively when design practitioners were involved in the development of metrics and the collection, interpretation and use of data, rather than DPM as a top down management-only exercise.

### Mechanisms for collecting performance data

In describing DPMs, firms revealed a wide variety of mechanisms and sources of data. Some firms collected data at the project level, with project representatives passing this information to senior managers for review. Other firms had top down, centralised systems for collecting data. In most firms, a committee, typically involving senior financial managers, reviewed the data. As in the case of manufacturing, data were frequently collected but not shared with other projects and departments and, sometimes, not fed back to the designers themselves to reflect on their own performance. When asked to indicate when DPMs were collected, those using DPMs tended to collect data at all main stages of the design process, again mostly financial information.

Regarding the co-ordination and use of DPMs, in most cases, financial and non-financial data were used separately by different groups within the firm. In only one case, where data was collected at the project level by a project manager, was the collection, analysis and use of both types of data co-ordinated. The integration of data collection and use was seen as a major problem in construction, intensified by the dislocation of design groups from construction and use, and the number of different companies participating in building projects.

### Financial and cost-based indicators

Each firm listed and commented on their three most important DPMs. A large number of different DPMs were used. However, many were viewed as unreliable and most did not focus on design specifically, but examined the performance of projects, or the firm as a whole, similar to the manufacturing sector [53], [9]. Among group members, financial data (especially cost) were the most frequently used. Cost measures included the rate of return on the project, as well as cost of design time as a percentage of total project costs. There was a strong incentive for firms to collect cost data and most firms had project finance systems which enabled reviews of the cost of design. Cost-based indicators permitted income forecasting and assessments of the financial viability of individual projects. Cost information was also useful for bidding for future projects. Financial DPMs usually originated from, and were subsequently used by, the financial division. Sometimes employee incentives were linked to financial performance, giving incentives to build financial data into performance measurement.

However, firms which relied solely on cost-based indicators also pointed to disadvantages. Cost-based indicators did not allow firms to analyse the performance or completion of the design activities, or identify technical failures in design. Cost data alone could not (a) generate useful lessons for future projects; (b) provide insights into the quality or reliability of the final product; or (c) help firms develop alternative design strategies. Their main value was to provide a measure of efficiency of existing systems and performance in meeting cost targets set at the beginning of projects.

**Design reviews and quality indicators**

The second most commonly used DPMs were collected during design reviews or quality assurance procedures. Design reviews varied in form among firms, with some deploying experts within the firm to assess project teams' design quality and others using external experts to provide impartial measures of quality performance. Some quality procedures focused on the process of design to ensure that methods used by teams were standardised across the firm. Most allowed design teams to take corrective or preventative action to deal with problems as they occurred in the course of projects. Quality systems tended to force designers to log their design activities and justify their design decisions - processes useful for correcting errors and for learning lessons at the end of projects. When conducted in a positive atmosphere, reviews helped to support teams and tie together groups from within the firm and from other companies working on large projects. Reviews sometimes became a valuable forum for designers to share ideas, learn from each other, and deal with the "big issues" raised by key projects (e.g. radical new designs). Most respondents felt that design reviews required more effort to implement than financial measures.

On the negative side, quality assurance and design reviews were sometimes treated as a bureaucratic procedure, and some lacked quantitative measures of performance. Also, while reviews forced some designers to identify and address root causes of design problems, in other cases they became a "paper chase" and failed to identify inefficiencies and real problems in current processes. One firm noted that quality procedures could limit innovation by forcing designers to follow traditional methods, leading to conservatism in design. Also, if conducted in a threatening or hostile atmosphere, reviews could be non-productive and damaging to project progress. The skill of the chief designers and project managers in conducting reviews was seen as critical to their success. Similar results have been found in manufacturing, where design reviews sometimes failed to identify errors, occurred too late, or were viewed suspiciously by those being reviewed. In the case of construction, the participation of designers from different firms meant that design reviews needed to be conducted with even more skill and diplomacy to avoid pitfalls.

**Time-based indicators**

The third most commonly used set of DPMs were time-based indicators, often tied to cost measures. Tracking time spent against forecast gave designers early warning if a project was not going according to schedule. On-time delivery was seen as critical for project success, the firm's wider reputation and future business success. While time-based measures alone could not help with rescheduling, they could contribute as part of the broader design review.

**Client feedback**

Although infrequently used, client feedback mechanisms played an important role in measuring design performance. Over half of the sample listed client feedback as a key indicator, giving information on various aspects of success and failure in projects and pointing to key areas for improvement. While most respondents recognised the need to gather client feedback in a systematic manner, most failed to do this, sometimes because of the organisational separation of the user and/or buyer from the design firm, compared with typical manufacturing projects conducted under one roof with one 'internal customer'. Client feedback was viewed as a major potential source of objective information on design quality, innovativeness, and future design strategy.

Several firms were in the process of developing formal systems for measuring client satisfaction and at least one firm had integrated client feedback into post-project appraisals. This firm found clients could provide very useful information on design, particularly if feedback was based on simple measurements. Overall, however, client feedback was rare, *ad hoc*, and often completed too late in projects to be useful. If not organised professionally they could become defensive, adversarial and ultimately embarrassing to the firm. Firms agreed that client co-operation in DPMs at the start of projects could help establish performance criteria, key milestones, and information on technical feasibility.

### Benchmarks with competitors

In terms of benchmarks against other firms, most respondents did not have DPMs for comparing their design performance. Usually, this was done through informal discussions with other organisations at conferences, sector meetings and by word of mouth. In some cases, client feedback enabled firms to assess their performance against others and to gather impressions of the overall state of firm practices. Industry recognition and awards, such as 'consultant of the year', were used to signal excellence across and within firms. Working in joint ventures and with leading sub-contractors provided informal opportunities for assessing the performance of others.

Collaborating firms were usually selected on the basis of reputation and experience from past projects. The choice of new collaborator was sometimes based on the number of awards a firm had received. Information was also gained from participating in national institutions and working parties. Few *ex post* appraisals of collaborators were carried out and these were largely through customer satisfaction surveys conducted only when a project was either very successful or very unsuccessful.

### Measuring out-sourced design

Within consulting engineering firms, part of the design work was sometimes out-sourced, complicating the DPM activity. However, all firms reported that design out-sourcing accounted for less than 10% of total design, and this was unlikely to change substantially in the next five years. Firms tended to minimise design out-sourcing due to difficulties of communication among staff, problems in defining out-sourceable work packages, additional risks, extra management resources required, and financial incentives for retaining business in house.

However, it was common among firms to resource design activities *across* divisional boundaries within the firm. This averaged between 25% and 30% of the total design activity, as groups sought to acquire the input of various specialists and build up larger project teams by hiring in colleagues from other departments.  The extra management required for external and ‘internal’ out-sourcing varied substantially (between 10% and 50%).

**Usefulness of current DPMs**

Most respondents reported that current DPM use was unreliable and patchy, and lacking in factual information.  Most consulting engineering firms believed that by working with clients it might be possible to develop a set of indicators and to use these profitably throughout the life of the project.  Most firms also felt that major clients were willing to engage in two-way communications of this kind, but that mechanisms and good practice were scarce.

Turning to the usefulness of DPMs, the highest scoring use was as a financial indicator on project performance.  DPMs were also commonly used to check over work, measure group performance and assure quality.  Only a few respondents indicated that DPM data were used as a management tool or as part of the design strategy of the firm.  Most DPMs were not well integrated into management strategy, but focused mainly on project performance.

Regarding DPM gaps and priority needs, a key area cited was quantitative measures of design quality, seen by most as a very difficult measure to develop.  Most respondents wished for more systematic data on the performance of other departments within the company, believing that inter-departmental learning could be improved.  Others pointed to the need for more cross-firm benchmarks to feed into strategy.  Several respondents were developing new and more flexible financial systems to enable better communication of data within the firm. Some respondents were adapting existing financial systems to allow them to better identify good practices in design and to benchmark other areas of the firm against best practice. Other firms were working to integrate financial DPMs with other measures of design performance, but none had yet arrived at a balanced set of measures to guide and improve the design function.

## PART 3: DEVELOPING A BALANCED SCORECARD FOR DPMS IN CONSTRUCTION

### 3.1 Pre-requisites for effectiveness in DPM

Given the limits of current practice, a series of workshops were held to develop an understanding of how DPMs might fit into firms' wider business strategies and to develop a framework which incorporated: (a) good DPM practices currently in place; (b) new measures under development in specific firms; and (c) additional DPMs identified as essential, but not yet in place within the partner firms. All firms agreed certain pre-requisites for a useful DPM approach. DPMs needed to go beyond cost-based indicators to deal with issues such as quality and innovation and to show how design is situated within the wider business goals of the firm, to ensure the relevance of design strategy. There was a need to help managers reach agreement about the role and future of design and to guide the selection and use of DPMs.

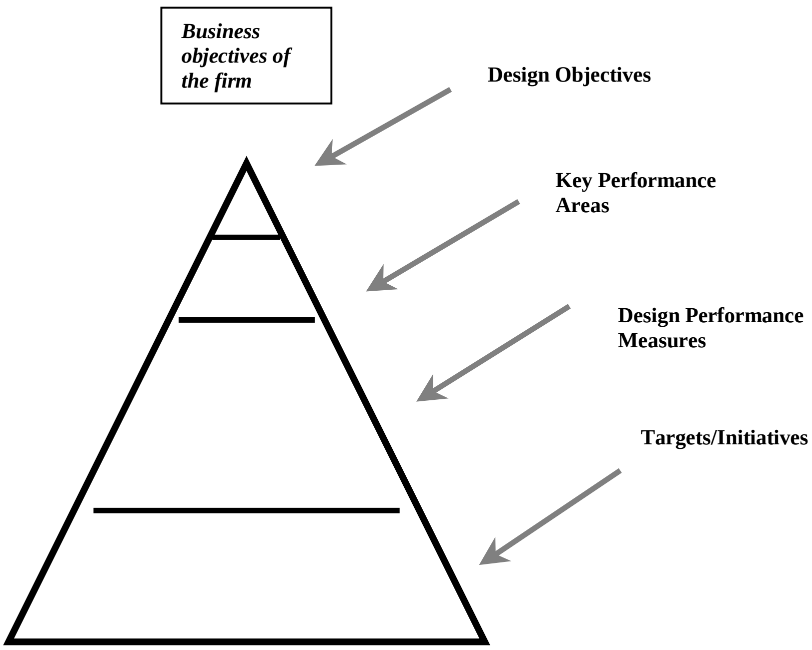
Given the adversarial environment traditional in construction, firms believed that a DPM approach could only work as part of the modern partnership initiatives discussed in Part 1.4. Indeed, DPMs could become a key part of these initiatives enabling partners to use measurements across the supply chain and client networks in order to drive design strategy and harness design to maximum effect.

Firms agreed that simple, clear metrics were needed which were understood, accepted and used at both the firm and project levels, and accepted by collaborators outside the firm. If integrated into partnership agreements, DPMs could help express and translate broader goals into a series of measurable objectives to be agreed upon, quantified and tracked. Within collaborations, DPMs could then be used to measure and improve performance. Identifying measurements could help force the clarification of design objectives within companies and projects, help existing objectives and set new goals for the future.

### 3.2 Integrating DPMs into business goals

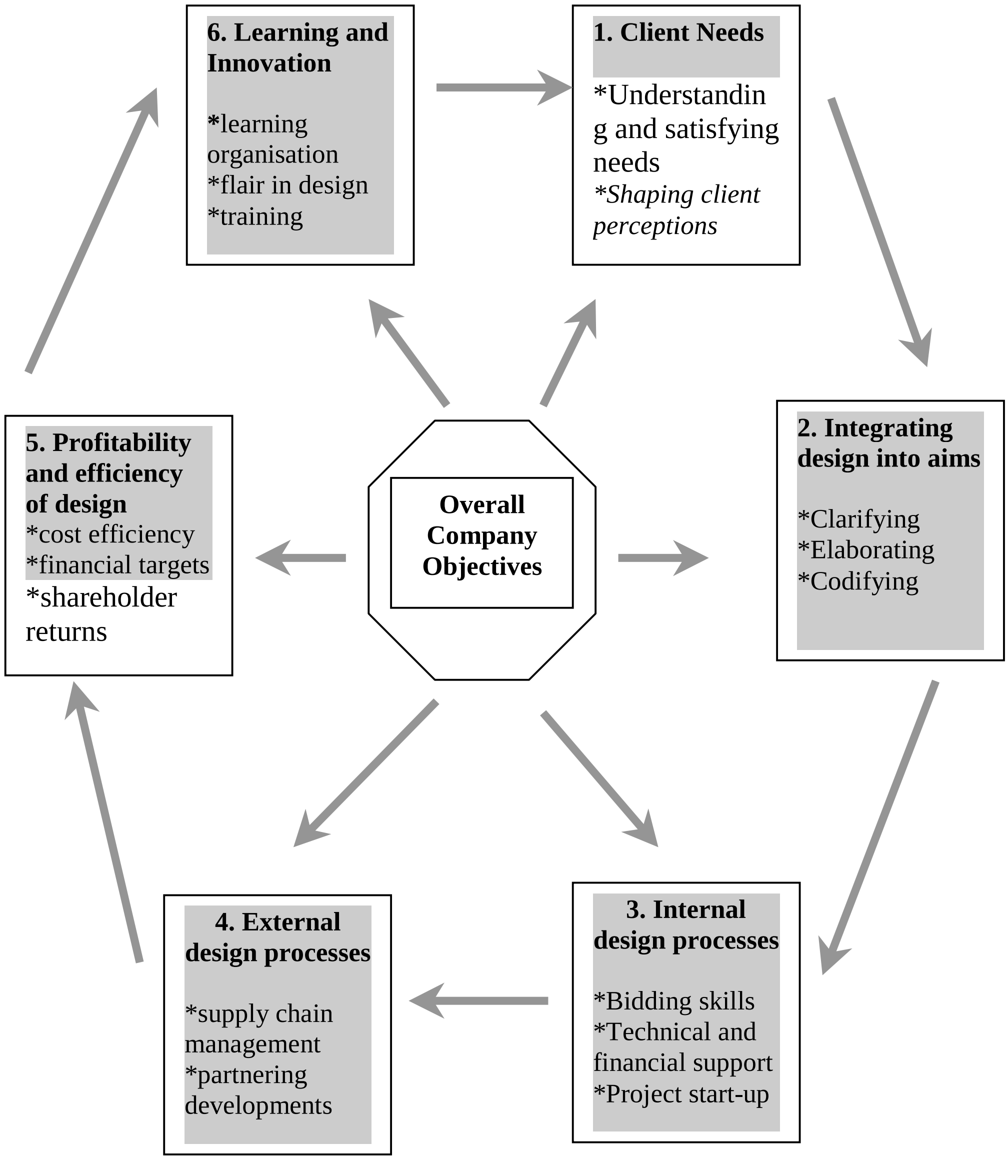
During the workshops, firms agreed that no single set of measures were appropriate, and that the nature of DPMs depended on the design objectives of each individual company. Figure 1 shows how DPMs fit in with the aims of the firm, through key performance areas (KPAs), discussed below, which lend themselves to specific DPMs, as well as performance targets and initiatives. DPMs cannot be defined in isolation, but must be selected according to the design goals of the firm.

*Fig. 1. Integration of DPMs into Business Objectives.*



Within the engineering design consulting context, there are two sets of related DPMs crucial to design in construction: (1) firm-level DPMs and (2) project-level DPMs, both of which need to address company objectives across the KPAs. At both project and firm level, six KPAs were identified which lead on to specific DPMs. Figure 2, which deals with the firm level, situates business goals at the centre of design strategy and performance.

*Fig. 2. Firm-Level Design Performance Areas.*



Taking each of the six key firm level performance areas in turn:

**KPA 1. Client needs**

This includes the firm's performance in understanding and satisfying existing demands for normal and radical designs, as well as anticipating future needs and ultimately shaping clients' perceptions about the design ability of the company.

**KPA 2. Integrating design into objectives**

This involves translating the main business objectives into design goals, and elaborating on these for the purpose of measuring and improving. This is essential to ensure that design is properly integrated into the firm.

**KPA 3. Internal design processes**

These include project management systems and business support (e.g. technical, bidding, and project team start up) given by companies to projects throughout their life cycle. It also includes developing the leadership and communications skills essential for project effectiveness across the firm.

**KPA 4. External design processes**

These include the management of suppliers and clients during the design process, as well as developing company-wide capabilities in modern partnering arrangements in order to improve cross-firm team performance.

**KPA 5. Profitability and efficiency**

These goals include financial targets and profitability of design. In the long run, none of the other goals can be achieved without a good performance in this area.

**KPA 6. Learning and innovation**

To be effective in consulting engineering, firms need to become as close to 'learning organisations' [29] as possible. They need to learn new design skills from experiences in major projects, from outside suppliers and clients. These learning abilities can assist firms to become more agile and responsive to changing client needs. Similarly, innovativeness in design is also essential for meeting the long-run goals of most firms. Innovativeness can be seen in radical design concepts and skills, flair in expressing design ideas, and new ways of executing design projects. Without the ability to innovate, firms are likely to lose business and fall behind their competitors.

Each of the six areas relate to each other in various ways as suggested in Figure 2. For example, meeting a client's radical design needs (KPA 1) will depend on integrating these aims into business objectives (KPA 2) and learning more about radical designs to ensure innovation in product and process proceed rapidly enough (KPA 6).

### 3.3 Developing measurable firm level indicators

One way to derive DPMs is to identify particular business goals and translate these into measurable design targets. Hypothetical examples of overall company goals include the following:

a) 'to become one of top three industry leaders in new projects'

b) 'to raise profitability from 5% to 10%'

c) 'to grow market share from 10% to 15% in three years'

d) 'to become the leading firm in low cost, high quality design for the mass market'

e) 'to become the industry leader in niche X'

With clarification and discussion, these broad company aims can be translated to design objectives by asking: "what must be done in the design area to reach these business goals?" Taking each of the above goals in turn, these translate into various design aims:

a) 'increase share of radical designs in the project portfolio from 30% to 60% in three years'

b) ‘reduce the share of low return projects in portfolio and improve the organisational efficiency of design’
c) ‘increase the number of large projects by 20% in all design areas’
d) ‘reduce design costs through improved processes and develop new processes for meeting customer needs at reasonable cost’
e) ‘increase the share of projects in design area X’

These design aims enable the firm to establish appropriate DPMs, as well as targets and initiatives. For example, measurable targets could be:

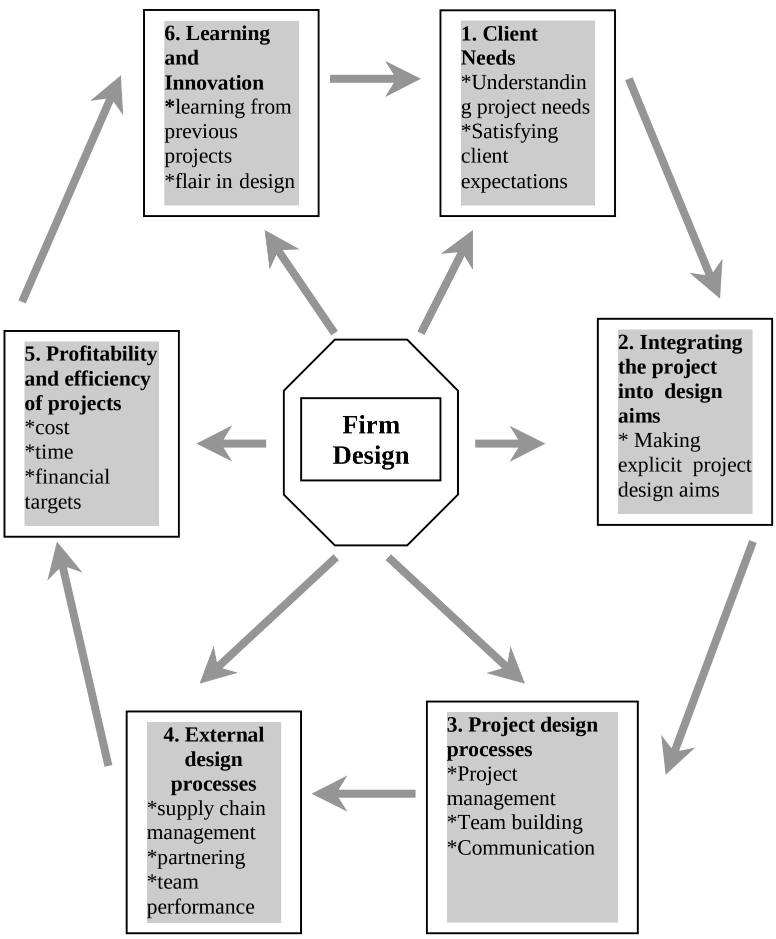
a) ‘increase the number of design awards per annum from from 1 to 3’; ‘increase the ratio of radical to normal designs from 30% to 60% in three years’. Initiative: ‘hire in 3 new senior designers, and set up business teams to gain $5m in new business’
b) ‘raise share of high return projects to 30% of total’; initiatives could be to ‘complete 3 experimental process change projects within year one, and to roll out new design process across all projects within 2 years’
c) ‘reduce share of small design projects from 80% to 30% of portfolio’
d) ‘improve customer satisfaction with respect to design cost and quality by 30% over the next two years in 90% of all projects’. Measurement could be client feedback on cost and quality (compared with industry average), ranked from ‘1’ (very low) through to ‘5’ (very high/industry leader)
e) ‘increase the number of design area X projects to 50% of total business’; initiative: ‘hire in 2 new project leaders to lead task force and gain $60m in new business in two years’.

Within the firm and within partnering agreements, mechanisms for data collection and sharing need to be established. Depending on the focus of the goals, data will be collected from different sources. For example, the customer is the best judge of design quality and customer perception, supply chain partners are the best judge of a firm's ability to manage supply chain relations, whereas financial indicators can be gathered from in-house project managers and/or the finance department.

### 3.4 Project level measures

While firm-level indicators are concerned with the overall design performance of the organisation, project level measures seek to assess the contribution of projects to the design goals of the firm and to monitor and improve the performance of projects. As Figure 3 shows, project-level KPAs correspond closely to firm-level areas. Indeed, much of the overall business data can be aggregated from project-level data, enabling project DPMs to help manage and assess the wider business goals (e.g. KPA 1, meeting client needs).

*Fig. 3. Project-Level Design Performance Areas.*



In contrast to business-level measures, project DPMs are less concerned with the portfolio of projects and more with the performance of individual projects and their contribution to the wider design objectives of the firm.  Taking the hypothetical example '(a)' above, the overall company objective: 'to become one of three world leaders in radical new projects', translates into business-level design objective: 'to increase the share of radical designs in the project portfolio from 30% to 60%' which, in turn, translates into project-level goals, DPMs and targets in each of the six KPAs, in each company project, through the use of leading questions.  For example, for project X:

**KPA 1 –** Question:  'how well did project X meet the innovation needs of the client';  'to what extent did project X change the clients view of the firm's innovative ability'?  These types of question translate directly into a likert scale ranging say from 1 ('very poorly indeed') to 5 ('extremely well'), to be completed by the customer at various stages of the project.

**KPA 2 –** Question: 'how well did project X contribute to the radical design aims of the firm'?  This could translate into a likert scale of 1 ('very little new knowledge and skill required') to 5 ('very high levels of new knowledge and skill required'), data which can be gathered from project designers.

**KPA 3 –** Question: 'to what extent did project X's organisation and management encourage risk-taking and adventurousness in design'? which translates directly to a scale of 1-5. Similarly, 'how well did company technical support perform in supporting the radical needs of the project'?

**KPA 4 –** Question: 'to what extent did external partners contribute to the radical design needs of project X'?  translates directly into a likert scale, while the question 'in which specific design areas did project X need to rely on external partners', provides information on internal weaknesses which may need to be addressed.

**KPA 5** - Question: 'to what extent were costs within budget in project X'? What was the profitability of project X'?

**KPA 6 –** Question: 'to what extent did project X draw from the experience of previous projects within the firm'? and 'to what extend did the project create new avenues for future radical design projects for the client and other clients'?

### 3.5 A balanced scorecard for design performance

The above DPMs can help focus useful questions on design goals and performance at both company and project levels. Applying Kaplan and Norton's [35] balanced scorecard approach to design, the DPMs can also be used to construct a balanced scorecard for each project or the firm as a whole, as shown in Figure 4.

*Fig. 4. Balanced Performance Scorecard for Construction Firms and/or Projects.*

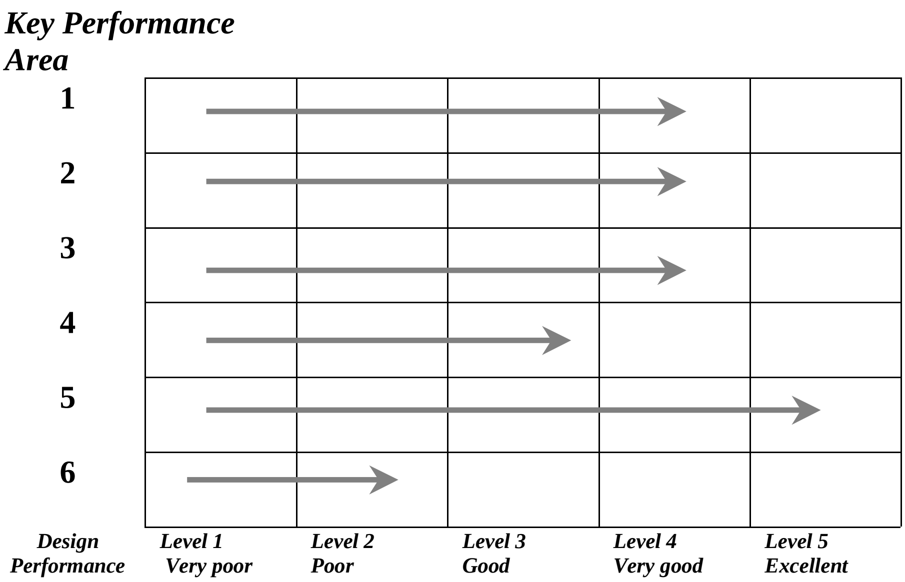



Figure 4 provides a picture of a firm (or a project) which excels in profitability and cost management (KPA 5), and performs well in project management (KPA 3) and supply chain relations (KPA 4). However, the firm is weak in terms of innovation and learning from other companies (KPA 6). While this may not be a problem for a firm which is content on a low cost/reasonable quality strategy, it may be very risky in areas where innovation is required for long-term performance and new business development. In fact, in most consulting engineering fields, a fairly high degree of innovation and flair is required to win major projects, so even in this case the firm may wish to begin innovation initiatives in order to reduce the risk of losing future business.

In this case, the firm might wish to focus its DPMs and initiatives solely on innovation (KPA 6), given its strong track record in other areas. In other firms, innovation performance and learning from others might be very strong, but profitability and cost poor due for instance to weak project management skills, leading to a focus of DPMs and initiatives on project management and cost control techniques. These examples indicate not only that DPMs are contingent on the wider objectives of the firm, but also that they can also be used selectively and sparingly to address weaknesses or to build new strengths. Following a rapid initial audit of the firm to produce a rough balanced design scorecard, management can then focus its design strategy and DPMs on what matters, avoiding the pitfall of measurement 'for its own sake'.

Similarly, each major project can utilise a balanced scorecard, identifying design strengths and weaknesses in relation to company objectives. For example, if the company aim is to excel in innovative designs, then a low score in KPA 6 on a major project would need to be addressed, perhaps through a new project-level initiative. By contrast, if the company goal is to excel in low cost/reasonable quality areas, then it may accept a reasonable level on KPA 6, and focus attention on weaknesses in areas such as KPA 3 and KPA 4.

### 3.6 Implementing the DPM scorecard

Further research is needed to address the problems of implementation. However, during the workshops the firms pointed to relevant experiences in implementing DPMs of various kinds. For example, while quantitative data is important, understanding and resolving problems also requires qualitative information. Firms reported that short qualitative inputs were valuable as an adjunct to DPMs. For example, the radical design goals may have been met by project X, but design costs were too high leading to a loss overall on the project. This was caused by poor project management and confused relations with suppliers. In general, explanation of the causes of problems and possible solutions to them, by practitioners, are valuable for ongoing improvement.

Firms felt that the explicit process of identifying key process areas and DPMs can improve design performance. For example, within KPA 6 (learning from project-to-project) if the project manager of a radical new design project is aware that learning from previous projects is a key measurement, then he or she is likely to have discussions with managers of earlier relevant projects which, in turn, is likely to improve performance through better awareness of risks and ideas already tried and tested.

Workshop participants believed that the above framework and tools could allow them to focus in on critical areas for early improvement and help set up appropriate initiatives to raise performance levels and to measure improvements against targets, even within complex multi-firm projects. The tools also ensure that actual DPMs directly support the business objectives of the firm. The approach could also be used to identify training needs. For example, if a firm is weak on learning from project-to-project then it can begin training on tools and methods for capturing lessons from projects and transferring these to new projects. The scorecard could also be used comprehensively or selectively. Some large firms felt that the method could provide the basis for long-term, overall development of design performance across the board, while others wished to use it selectively and quickly. Where speed is important, then a rough internal audit based on Figure 4 can quickly be arrived at from internal group discussions, which could then lead to fast track design initiatives, using DPMs to track changes over time in say one or two key areas.

## CONCLUSIONS AND IMPLICATIONS

This paper provides an initial study of the use of DPMs in the consulting engineering sector, the design core of the construction industry. It focuses on the use of performance measurement tools for project-based firms, developing a set of tools for understanding, producing and using DPMs at both the firm and project level: business process and project process. The pilot survey showed that few DPMs are used in construction and most focus on cost issues, overlooking design quality, flair, project management and client satisfaction. In manufacturing, design projects are usually carried out within a single firm which provides an internal customer for the results. By contrast, most construction activities are one-off, multi-firm projects and there is a separation of design from building and use. Architectural firms, contractors, consulting engineers and builders are each separated in terms of organisation, tradition and culture. Nevertheless, a wide spectrum of high technology design functions have to be integrated together across firms to realise construction projects. Therefore, a key challenge confronting consulting engineering firms is how to use DPMs to measure their relatively small design contribution to large projects over which they may exert little control.

The pilot survey identified key issues and problems facing consulting engineers and highlighted new developments in DPM.  These findings were combined with DPM results from manufacturing and fed into a series of workshops with industrialists to evaluate the results and to produce a balanced scorecard for DPM use, including DPMs currently in place or planned by leading firms.  A set of simple tools were developed to show: (a) how design fits (or should fit) with, and contributes to, wider firm strategy;  (b) which key performance areas need to be addressed in consulting engineering design;  (c) how simple DPMs can be derived from company design objectives; and (d) how the problem of DPM use in multi-firm projects can be addressed, at both the project and firm level.

Given the adversarial environment often found in construction, DPMs work best as an integral part of modern partnership arrangements.  Within these arrangements, DPMs can potentially enable design firms to use measurements across the supply and client networks in order to shape design strategy and improve performance.  Performance targets on projects need to be determined at the earliest possible stage with a high level of collaboration with clients and other suppliers.  Design and wider business strategy need to be integrated using DPMs which find a balance between cost, quality, internal and external business processes, innovation and client satisfaction.  The balanced design performance scorecard potentially allows firms to use DPMs to promote design excellence and innovation, as well as efficiency and profitability.

Further research is needed to verify the survey findings and to evaluate the use of DPM within firms and projects.  Although there is a widespread belief in construction (and elsewhere) that measurement is essential to good management and performance improvement, these beliefs need to be tested by research on the impact of DPM use and the requirements for successful deployment. While the paper explored DPMs from a top down management perspective, there is a need to research the 'bottom up' real experiences of practitioners to throw light on the dynamics of DPMs in use. Research is also needed to test and refine the key performance areas for design, and further elaborate on simple metrics suitable for consulting engineering firms.

Regarding wider implications, it is possible to argue that the tools developed may also apply to other high cost, design-intensive, complex capital goods (sometimes referred to as 'complex product systems'), also produced as tailored one-offs for individual clients. In contrast to consumer goods produced by manufacturing firms, these complex products and systems are often characterised by high levels of user involvement in design, elaborate product architectures, uncertainty over design processes, and an unusually high degree of tacit knowledge in the design process. Further research could explore the use of DPMs in other complex capital goods including aircraft, power generators, flight simulators, weapons systems, ships, telecommunications exchanges, supercomputers and train engines, and compare the results with construction.

In conclusion, the paper provides a first step in developing a balanced scorecard for DPMs in construction, combining cost indicators with measures of quality, customer satisfaction, innovation and design 'fit' with business strategy. However, further research is required to investigate the propositions generated and to evaluate the use and impact of the tools developed.

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Annex 1: Survey of Performance Indicators for Design Activities

1. Please list in order of **importance** the three most important measures you currently use to assess/monitor performance in your design activities.

| |
|---|
| 1. |
| 2. |
| 3. |

2. For each of the measures listed above describe their **strengths** and **weaknesses**, i.e. what they tell you and what they don't.

| *Strengths* | *Weaknesses* |
|---|---|
| 1. | |
| 2. | |
| 3. | |

| |
|---|
| 3. What measures, if any, do you plan to implement in the future to improve design performance? |

4. How are these performance measures collected within the firm?

5. Please rate the importance of various uses of design performance data within your company.

| Uses of performance data | Importance (1=not at all important, 5=very important) | | | | |
|---|---|---|---|---|---|
| Measure group performance | ① | ② | ③ | ④ | ⑤ |
| Measure individual's performance | ① | ② | ③ | ④ | ⑤ |
| Check over work | ① | ② | ③ | ④ | ⑤ |
| Quality assurance | ① | ② | ③ | ④ | ⑤ |
| Staff assessments | ① | ② | ③ | ④ | ⑤ |
| Develop design strategy for the firm | ① | ② | ③ | ④ | ⑤ |
| Financial indicator on project | ① | ② | ③ | ④ | ⑤ |
| Management tool | ① | ② | ③ | ④ | ⑤ |
| Other (please specify): | ① | ② | ③ | ④ | ⑤ |

6. What mechanisms do you use to locate the position of your firm's design performance in relation to other firms in the sector?

7. What additional information would you like to collect but are unable to do so?

8. At what project stages are design performance data collected?

| Project brief | Preliminary sketch | Final sketch plan | Detailed design | Construction | Commissionin g | Handove r |
|---|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

9. Formal measures of design activities often fail to incorporate informal understanding. In order to supplement formal measures, what informal mechanisms do you use to better understand your design performance?

10. To what extent do you rate the design performance of collaborating firms on projects? If so, what measures do you use?

11. Please estimate what percentage of your firm's design activities is outsourced, i.e. done outside your firm?

| | |
|---|---|
| | % |

12. By what percentage do you expect your current percentage of outsourced design activities to change in the next five years?

| | | | | | | |
|---|---|---|---|---|---|---|
| <20% ☐ | <10% ☐ | <5% ☐ | 0% ☐ | >5% ☐ | >10% ☐ | >20% ☐ |

13. What percentage of your design activities are resourced across divisional boundaries within your organisation?

| | |
|---|---|
| | % |

| |
|---|
| 14. What additional management resources are required to resource design across divisional boundaries (% of time, skills, etc.)? |

15. Please rate the importance of the following factors in limiting the outsourcing of design?

| Factors limiting outsourcing | Importance (1=not at all important, 5=very important) | | | | |
|---|---|---|---|---|---|
| Requires extra management resources | ① | ② | ③ | ④ | ⑤ |
| Need for communication among internal design staff | ① | ② | ③ | ④ | ⑤ |
| Extra transaction costs, e.g. writing and agreeing contracts | ① | ② | ③ | ④ | ⑤ |
| Lack of skills and quality in suppliers of design services | ① | ② | ③ | ④ | ⑤ |
| Designs are too complex | ① | ② | ③ | ④ | ⑤ |
| Design cannot be divided into packages that can be easily outsourced | ① | ② | ③ | ④ | ⑤ |
| Lack of time | ① | ② | ③ | ④ | ⑤ |
| Too risky | ① | ② | ③ | ④ | ⑤ |
| Other (please specify): | ① | ② | ③ | ④ | ⑤ |

***Thank you for your time and co-operation***