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Improvement tools in the UK construction industry

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The use of improvement tools in manufacturing industry has proven to be an important aspect of continuous improvement activities. To determine whether the same is true in the UK construction industry, a survey was conducted to assess the current level of use and perceived importance of such tools. In addition, the impact of the ISO 9001 quality system on the level of use and perceived importance of these tools was also investigated. Following a comprehensive literature review, more than thirty improvement tools were identified and categorized using affinity diagrams. Factor analysis was used to demonstrate that the proposed classification was valid. The results of the survey showed that, in terms of use, *quality control*, *performance measures* and *technology* tools are common practice in the industry. A similar set of tools/techniques was perceived as highly important except that *technology* and *performance measures* were interchanged. When comparing the mean use and mean perceived importance for each group of techniques, significant differences were found in tools that help to *gather customer needs*, those aimed at *programming* and those used for *measuring performance*. In terms of the ISO 9001 standard, it was found that certified companies make more use of and place higher levels of importance on most of the groups of tools studied than those not certified. The conclusions from the survey will help to develop a framework for suggesting which tools to use at each stage of a construction project.

Keywords: Improvement tools, total quality management (TQM), survey, construction projects

Introduction

The construction industry is responsible for 5.4% of the UK's GDP and so, represents a major economic sector (Department of Trade and Industry, 2003a). According to the *Construction Statistics Annual* of 2003 (Department of Trade and Industry, 2003b), clients of construction projects were not entirely happy when asked about their level of satisfaction with the finished product/facility. On a scale of 1 to 10 (in which 10 meant totally satisfied, 5/6 neither satisfied nor dissatisfied and 1 totally dissatisfied), 22% of the respondents scored less than 8. Hence, in such an important industry, there is room for improvement in terms of customer satisfaction. An empirical study conducted by Torbica and Stroh (1999) confirmed that the implementation of total quality management (TQM) in the sector was positively related to customer satisfaction.

TQM is the shared collaboration in a company aimed at producing value-for-money products and services in order to meet and surpass customer needs and expectations (Dale, 2003). It has been successfully applied in the manufacturing sector to control processes and avoid deficiencies, leading not only to savings in terms of money and time (Lahndt, 1999) but also to high levels of customer satisfaction (Oakland, 1994).

According to Oakland (1994), three important components should be considered in order to implement TQM: a documented quality system, teamwork and the use of improvement tools and techniques. Dale (2003) also suggested that the use of improvement tools, together with measurement and feedback were the two pillars that formed the structure of a framework for the introduction of TQM. Chua (2003) stated that the appropriate application of such techniques could lead companies to better satisfy their customer requirements.

Many companies, including those in construction, have considered adopting TQM but the opinions in this particular industry are divided. According to Love *et al.* (2004), it is evident that various construction

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organizations are still reluctant to implement TQM in order to reduce quality problems in their projects because it is not uncommon for them to consider TQM to be synonymous with quality assurance (QA). Shammas-Toma *et al.* (1998) carried out a study within the UK construction industry and concluded that the way in which QA had been interpreted and implemented in the sector could challenge the implementation of a TQM programme. QA is a management process aimed at increasing confidence in a product or service by achieving quality objectives set out in writing (Pheng, 1993), but it is normally associated with paperwork and bureaucracy. TQM, on the other hand, is a philosophy aimed at improving all facets of an organization in order to meet and surpass customer expectations (McIntyre and Kirschenman, 2000).

Manufacturing industry started to develop good quality systems while the construction sector lagged behind, due to its different nature (Pheng and Ke-Wei 1996), although the situation has been changing over recent years (Pheng and Fong, 2002). In fact, the ISO 9001 standard has been adopted in the UK construction sector with very positive results (Moatazed-Keivani *et al.*, 1999). Few manufacturing processes are aimed at the production of single items whereas in construction, the work is generally not repetitive (e.g. one building or one dam) because the specifications normally change with each project.

In spite of this, the construction industry is beginning to recognize the importance of TQM and quality has now become a primary construction goal (Lahndt, 1999). Therefore, improvement tools that are currently being applied in the manufacturing sector should be adapted and used in the construction industry. This paper will discuss some techniques that having been applied in the manufacturing environment are now being utilized in the construction business and will highlight other tools that also have good potential for exploitation.

Construction projects

Before discussing the tools/techniques, it is necessary to define construction projects and processes in order to better understand how the tools might be applied. According to the *Construction Statistics Annual* (Department of Trade and Industry, 2003b), there are two main types of construction project: building and civil engineering. Austen and Neale (1984) highlighted the difference between the two types of projects by stating that buildings were structures in which people would work or live while civil engineering works were related to manipulating the natural environment to offer an 'infrastructure', e.g. roads, airports and bridges. Traditionally, a construction project has comprised several steps called the construction process, a schematic of which is shown in Figure 1 and is based on internationally accepted practice (Austen and Neale, 1984).

The clearly defined stages vary from project to project depending on the contractual arrangements. Harris and McCaffer (1995) summarized various forms such as cost reimbursable contracts, two stage tendering, serial contracts and management design. More recently, the American Institute of Architects (AIA, 2004) defined three of the most common procurement approaches that are being used today within the industry: design-bid-build, design-build and construction management at risk. While the first is normally recognized as the 'traditional' delivery method in which two separate contracts are typical, owner-designer and owner-builder, the second, makes use of only one contract, designer-builder. In terms of the last method, a construction manager takes the risk of building a project and an architect is hired under a separate contract. Again, the stages depicted in Figure 1 may vary depending on the contractual arrangements adopted for the particular project; however, in this piece of research the traditional approach will be used. As can be seen there are five stages present in construction projects, briefing, designing, tendering, construction and commissioning.

In the briefing phase, the customer (who could be either the client or the end user) specifies the project purpose and the likely budget. Consequently, architects, engineers and the design team are able to interpret the customer's needs and requirements and supply their cost estimates. The project brief is finalized at the designing stage in which the layout, design, methods of construction and estimated costs are detailed. The customer and the appropriate authorities approve the project once they are convinced that it satisfies the requirements. All the necessary production information – such as working drawings, schedules,

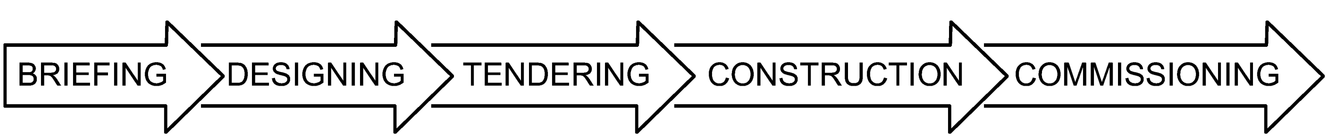

Figure 1 Stages of a construction project (source: Austen and Neale, 1984)

bills of quantities, time scales and specifications – are prepared ready for the tendering phase. The main purpose at this stage is to appoint a building contractor (it could be one or more), who will carry out the site construction work. It is not uncommon for the cheapest bid to win the contract. Since the final decision is based on price, quality and contingency costs are ignored leading to problems at the end of the construction process (Chen and Liew, 2003).

The construction phase is concerned with building the structure within the approved time, budget and quality limits. Suitable supervision of the work is organized to certify conformance to both quality standards and legal requirements. Finally, at the commissioning stage the building or the civil engineering work is inspected to ensure that it conforms to the contractual and legal requirements and that all the facilities work adequately. Certificates of compliance for the actual construction along with any necessary operating instructions are given to the customer. It is at this stage that any final amendments such as repairs of leaks (identified after the construction stage) are carried out.

Improvement tools

Problems and errors that arise during the stages previously outlined, offer opportunities for learning and improvement. As stated earlier, one of the main objectives of TQM (part of the philosophy of which is continual improvement) is to increase customer satisfaction (Chua, 2003). It requires a commitment to consider the customer viewpoint in every process. There are many concepts that have been successfully applied in the manufacturing sector to achieve continual improvement and ultimately product quality. One of these is known as the Juran Trilogy (Juran, 1992), which encompasses three aspects: quality planning, quality control and quality improvement. The first was used as a basis for conducting a literature review. According to Juran (1992), quality planning is the activity of satisfying customers by developing products and processes that meet their demands. To do so, a series of universal steps are followed: setting up quality goals, identifying customer needs, developing products that meet customer desires, establishing process controls and evaluating quality performance. With these phases in mind and as a consequence of a comprehensive literature review, a list was compiled of the more commonly used tools/techniques, which could support a continual improvement process in the construction industry.

At the outset, more than 50 tools/techniques were found, but almost half of them had seen very limited application and were only mentioned in specialized books (Mears, 1995; Tague, 1995). Hence, these were discounted as not being viable options for the authors' purpose. An affinity diagram was constructed using the remaining tools/techniques, which resulted in six different clusters. Five of the clusters were based on Juran's quality planning process: (a) planning tools for setting up quality goals; (b) customer needs for identifying customer requirements; (c) formal methods for developing products that meet customer needs; (d) quality control for establishing process controls; and (e) performance measures for evaluating quality performance. The sixth cluster entitled 'technology' encompassed software tools and the one called 'customer needs' was subdivided into gathering and organizing customer needs, thereby resulting in the seven categories shown in Table 1. A reference is given for each tool/technique, which will provide a detailed explanation of the tool and its application.

As is evident from the earlier discussion, the list is by no means exhaustive, nor is it meant to be exclusive to improvement tools. It shows those more commonly used techniques that the authors feel would be useful in the construction sector to encourage continuous improvement. For instance, within the *technology* group there are software tools such as computer networks that can lead to standardization and improved communication among members within the project team.

During the literature review, it became apparent that no agreement exists about the purpose of all the tools and methods presented in Table 1, for example while some authors consider matrix diagrams as a data collection method (Kanji and Asher, 1996), others consider it as a planning tool (Tague, 1995). Furthermore, some techniques such as QFD make use of different tools such as customer surveys or affinity diagrams. Factor analysis was used to validate the content and construct of Table 1, details of which will be presented later.

The first group of tools have been designed to collect customer requirements. Surveys allow the compilation of important amounts of data by means of large samples; the purpose of either one-to-one or telephone interviews is to discover customers' motivations, feelings and attitudes. Brainstorming permits the generation of new ideas by means of creative thinking and focus groups are very useful for producing new ideas from a selected group of users in order to determine the potential improvements that could be added to a product (note that roads, dams, buildings, etc. will, from now throughout the paper, be referred to as products).

The second group of tools is aimed at classifying the wishes of the customers. Affinity diagrams provide a methodology for generating ideas and organizing them

Table 1 The more common improvement tools/techniques

Tools/techniques	Sources
Gathering customer needs	
Customer surveys	Burns and Bush (2001)
Customer one-to-one interview	Berent (1966)
Customer telephone interview	Berent (1966)
Brainstorming	Dale (2003)
Focus groups	Nayar (2003)
Organizing customer needs	
Affinity diagram	Bossert (1991)
Tree diagram	Cohen (1995)
Matrix diagram	Chua (2003)
Formal methods	
Quality function deployment (QFD)	Cohen (1995), Martins and Aspinwall (2001)
Theory of inventive problem solving (TRIZ)	Shulyak (1997), Mann and Cathain (2001)
Concurrent engineering (CE)	Poolton and Barclay (1998), Kamara *et al.* (2000)
Planning tools	
Mission statement	Alexander (2004)
Gantt chart	Merrit *et al.* (1996)
Critical path method (CPM)	Harris and McCaffer (1995)
Program evaluation and review technique (PERT)	Harris and McCaffer (1995)
Teams & teamwork	Dale (2003)
Departmental purpose analysis (DPA)	Dale (2003)
Quality control	
Laws and regulations	Merrit *et al.* (1996)
Checklists	Tague (1995)
Housekeeping (5Cs; also known as 5Ss)	Dale (2003)
Inspection	Merrit *et al.* (1996)
Sampling	McCabe *et al.* (2002)
Quality audits	Landin (2000)
Contractor partnerships	Department of Trade and Industry (2003b)
Performance measure	
Customer satisfaction survey	Department of Trade and Industry (2003b)
Customer complaints	Cohen (1995)
Litigation	Reid (2003)
Technology	
Planning software (e.g. primavera, ms project)	Software vendor
Design software (e.g. autoCAD)	Software vendor
Finite element analysis software (e.g. SAP 2000)	Software vendor
Computer network (e.g. e-mail)	Software vendor

into a logical structure. Tree diagrams are another way of structuring ideas into a hierarchy while matrix diagrams are used to analyse the usefulness of the internal processes to satisfy customer needs. The tools categorized as formal methods are structured approaches that help to build quality into products (again these could be roads, dams, buildings, etc., in the case of the construction industry). Quality function deployment (QFD) is a technique that helps to translate the voice of the customers into products that truly satisfy their needs. The theory of inventive problem solving (TRIZ) is centred on several tools that help to solve situations that have either no known solution or have a predictable solution that generates other problems. Concurrent engineering is an approach that gives companies the opportunity to decrease the time it takes to generate products from conception to launch by overlapping the stages involved in the product development process.

The planning techniques as the name suggests, are useful for planning the required resources (e.g. money, people, plant, material) and the time allocated to each stage in the process. The mission statement is a phrase in which the purpose of the project is presented; Gantt charts or bar charts show starting and completion dates for each activity in the process and indicate how they overlap. The critical path method (CPM) and the program evaluation and review technique (PERT) enable planners to order the activities based on precedence and relationships. They also allow the calculation of the minimum duration of the project and highlight the importance of critical activities to avoid delays. Teams and teamwork promote the improvement of activities by means of the use of people skills and knowledge, and departmental purpose analysis (DPA) establishes the effectiveness of departments and the level of contribution that they must give to meet project goals.

The tools presented in the quality control cluster have the main purpose of verifying conformance to quality standards and legal requirements. Legal requirements and regulations should be adhered to at all stages of the construction process; Checklists are lists of key features important to the process and are a very useful guide to help during revisions; Housekeeping promotes a working environment that is comfortable for all employees (the 5Cs being clean out, configure, clean and check, conformity, custom and practice). Inspection and first line supervision were grouped as inspection and are used to highlight problems and then corrective action can be put in place to prevent their recurrence, they are a powerful force that have helped to control the quality of the end product in the construction industry; Sampling is a testing methodology that can be applied to control and assure the quality of construction material. Quality audits evaluate the quality system within a company or project and contractor partnerships promote long-term relationships with those contractors/suppliers that satisfy required quality standards.

Performance measures are aimed at measuring the effectiveness of quality actions. Customer satisfaction surveys can provide evidence of the level of satisfaction that clients have with the finished product/facility. Customer complaints refer to the level of dissatisfaction that customers experience with the finished product/ facility, and can provide useful information for improving aspects of future projects. Litigation is related to legal problems that result from the final product/facility not complying with the agreed contract. Although technology is not directly related to quality and cannot be regarded as a quality tool, its use within the construction industry is an important aspect to consider because its common use can lead to standardization and improvement in communication. Software is available to help both the planning task in the construction process and at the design stage, the latter includes finite element analysis (no references are given here but information is readily available from software vendors). The use of a computer network can help to improve communications within teams (Poolton and Barclay, 1998).

Survey in the construction industry

In order to determine the breadth of use and the perceived importance of the improvement tools presented in Table 1, together with the impact of the ISO 9001 quality system on the use of these tools within the UK construction sector, it was decided to carry out a survey. The first task was to choose the type of survey to conduct (one-to-one interviews, telephone interviews or postal questionnaires). It is a known fact that personal and telephone interviews give a better response rate, but they are more expensive and time consuming than postal questionnaires. The latter can provide an acceptable coverage even with a limited budget (Burns and Bush, 2001). Moreover, similar studies that have been reported in the UK manufacturing sector (Tidd and Bodley, 2002), in the Netherlands manufacturing sector (Nijssen and Frambach, 2000) and in the construction industry in the USA (Lahndt, 1999; McIntyre and Kirschenman, 2000), have all employed postal surveys.

It was decided to use this medium as a means of data collection, because potential respondents were distributed throughout the UK and a postal survey provided a relatively cheap and effective way to reach them. Nevertheless, it should be noted that there are certain disadvantages associated with using postal questionnaires. These are low response rate, lack of opportunity to clarify respondent doubts and no control over the speed with which participants return the completed questionnaires (Burns and Bush, 2001). To overcome these obstacles the questionnaire was carefully designed and reviewed several times by the authors to avoid misunderstandings related to the wording of the questions. The actual content of the questionnaire and its layout were finalized after a pilot run was conducted in four companies. In addition, a deadline was set for the return of the completed questionnaires, after which a reminder letter was sent to companies in order to increase the response rate.

The questionnaire was divided into four sections. The first was designed to classify the companies according to size and project type. In terms of size, small and medium (less than 250 employees according to the Commission of the European Communities (2003)) and large companies (250 employees or more) were considered. It is worth noting that the classification of size was based only on the number of employees, although there are other factors such as turnover that affect this categorization. With regard to project type, both building and civil engineering were considered. No attempt was made to organize the tools and techniques into the five stages of the construction process. This was one aspect that the authors hoped would be possible from the empirical evidence. The second section of the questionnaire was devoted to the quality activities currently being undertaken within the respondent companies. Features like whether the company had a certified quality assurance system were included, and if so, the year in which it had been obtained, and whether certain quality initiatives were being carried out together with the year in which they were first started.

The third part of the survey was the most important. Here, respondents were asked to indicate both the current level of use and the perceived importance of the tools presented in Table 1. A 5 point Likert scale (1=very low, 2=low, 3=moderate, 4=high, 5=very high) was used for both aspects, with the addition of a zero score if the tool was unknown or not used, if it did not appear to be relevant to the kind of work carried out within the organization or if the respondent was unsure of how to respond. Participants were given the opportunity to indicate any additional tools that they employed. The final section of the questionnaire was designed to investigate issues related to Project Managers' commitment to quality, to training programmes and to the recognition of individuals and teams in the company. The survey was addressed to the Managing Director, who has a complete view of the company, and would, it was felt, pass the questionnaire to an appropriate member of staff if necessary.

A total of 300 construction companies within the UK were chosen from the FAME database (FAME, 2004). The criteria for selection were as follows: (1) approximately half were small or medium size and the remainder large; (2) companies were homogeneously distributed throughout the country in order to ensure a complete view of the sector; and (3) approximately half of the companies were involved in design activities and the rest in construction work. Following the selection process, the questionnaires were distributed along with a covering letter explaining the purpose of the survey.

Survey results

Of the 300 questionnaires distributed, 86 were returned, of which only 72 could be used in the analysis; the other 14 respondents either stated that it was company policy not to participate in surveys or had moved/ceased to trade. This response rate of 24% was within the expected range of 20–40% (Furtrell, 1994), and in fact, might be regarded as especially good since the survey was conducted during the Easter period and the authors believe that UK companies currently receive so many questionnaires that a large proportion do not respond. After testing the questionnaire for possible bias (Amstrong and Overton, 1977), it was concluded that there was little or no non-response bias in the survey. Therefore, it would provide useful information not only about the current use of improvement tools within the construction industry but also about their perceived importance.

Respondents' profile

The profile of the respondents reflected the selection criteria used for the participant companies. In terms of their size, 46% of the respondent companies had less than 250 employees and so could be considered as SMEs while the remainder were large companies. In addition, respondents were homogeneously distributed throughout the UK. With regard to the stages within the construction process in which the respondent companies were involved, most worked in at least two of them. The results are shown in Table 2. It was no surprise to find that most of the companies involved in the tendering stage were also concerned with the construction phase. The percentages of companies involved in the briefing and the commissioning stages were lower than those of the others.

Quality initiatives

In terms of the quality initiatives undertaken, approximately 72% of the respondent companies were certified to ISO 9001 of which 47% obtained the certificate based on the 1994 version and 53% on the 2000 version. Only 31% of the respondents (most of which were in the civil engineering sector) were certified to ISO 14001. (This is probably because civil engineering projects are more likely to affect the environment than building projects e.g. the environmental impact of building a house is lower than that of say building a motorway.) On average companies received certification to either ISO 9001:1994 or ISO 9001:2000 almost four years ago whilst the average for ISO 14001 was about nine months. Only 18% of the respondents used other management systems e.g. OHSAS 18001, SpecC (which is a certification requirement for specialist concrete contractors) and ISO 9002:1994.

Table 2 Distribution of companies according to the stages within the construction process

Stage	Percentage of companies
Briefing	55.55%
Designing	81.94%
Tendering	90.27%
Construction	93.05%
Commissioning	58.33%
Total (Companies)	72

In terms of other quality programmes, most of the companies that have a quality system in place, have implemented some kind of initiative such as: setting up a quality department (55.56%), a cultural change programme (37.50%), strategies for total quality (37.50%), employee involvement to improve quality (68.06%) and customer satisfaction initiatives (73.61%). This indicates that TQM is receiving some recognition within the UK construction industry. On average, at least one of the five initiatives has been employed for the last 6.5 years. Other initiatives that have been implemented include the balanced score-card, continual process improvement, benchmarking through key performance indicators, integrated departments and key stage system checking on site.

Table 3 Internal consistency results (n=72)

Group	Tools/techniques	No. of elements	Alpha value
1	Gathering customer needs	5	0.8385
2	Organizing customer needs	3	0.8491
3	Formal methods	3	0.8090
4	Planning tools	6	0.6588
5	Quality control	7	0.8066
6	Performance measures	3	0.6026
7	Technology	4	0.6035
		Total: 31	

Validation of the survey instrument: reliability and validity test

Before discussing the survey results in terms of the specific tools/techniques studied, this section will present the questionnaire validation process. As stated earlier, during the literature review it was found that no agreement existed among authors with regard to the categorization of some of the tools that appear in Table 1. Therefore, reliability and validity tests were performed to determine the appropriateness of the proposed classification, making use of the approach adopted by Saraph *et al.* (1989). Cronbach's alpha (α) model, which is aimed at measuring internal consistency, was utilized in the reliability analysis. The values of alpha reflect the degree to which elements in a group are homogeneous (Nunnally, 1978) and the extent to which these elements are related to each other. The final purpose is to help in the recognition of problem elements that should be removed from the group in order to increase its reliability.

The questionnaire was also subjected to construct validity testing, which encompasses: content, face, convergent and divergent validity (Brewer and Hunter, 1989). The first two are determined qualitatively (i.e. based on judgment), while the last two can be established by means of the quantitative method known as factor analysis in which each group (or factor) is checked to verify unifactoriality.

Internal consistency analysis

The SPSS Statistical Package for Windows, Version 11.0 (SPSS, 2001), was employed to carry out the reliability analysis employing 31 elements in seven groups. The results of the study are shown in Table 3.

An internal consistency analysis was conducted independently for the elements of each group of tools/techniques. Alpha values greater than 0.6 are sufficient for testing the reliability of factors in exploratory research (Black and Porter, 1996) and since all the values exceeded this, the conclusion is that, the instrument has internal consistency and is therefore reliable.

Construct validity

The instrument was subjected to four different tests in order to assess its construct validity. As stated earlier, content and face validity are qualitatively determined. It is the researcher who subjectively evaluates these aspects of the instrument (Nunnally, 1978). In terms of content, since in the case of this study, a comprehensive literature review was made regarding improvement tools/techniques, the questionnaire was carefully designed, reviewed and improved on several occasions by the authors, sensible methods of test construction were employed, and it was piloted before distribution, it is strongly believed that the instrument developed has content validity. With regard to face validity, all the items seem to pertain to the groups in which they were put. Again, this is a subjective judgement and perhaps the weakest to demonstrate construct validity, however its assessors also deemed the instrument appropriate during the pilot study.

In order to test whether the questionnaire had convergent validity or not, factor analysis was employed. Each group of tools/techniques was assessed by considering its constituent elements. The main purpose of the analysis was to test whether specific tools/techniques belonged to the group allocated (convergent validity), belonged to another group (divergent validity), or should be eliminated. Again, SPSS 11.0 (SPSS, 2001) was used in the analysis, which was carried out using the steps followed by Yusof and Aspinwall (2000).

The Kaiser-Meyer-Olkin (KMO) indicator was firstly considered to assess sample size adequacy. Since all the groups exceeded its minimum acceptable level of 0.5 (Brah *et al.*, 2002), no elements were initially removed and the factor analysis could progress. The first run showed that *Gantt chart* and *CPM*, the second and third techniques of the *planning tools* group, should be removed and relocated to a new one. As a result, they were eliminated from the group leading to its unifactoriality, and were regrouped and located in a new one named *programming tools*. Another tool/technique removed during the first run was *sampling* i.e. the fifth tool of the fifth group. After two runs, all the groups were considered unifactorial. Table 4 summarizes the results obtained, and includes those for the new group (*programming tools*).

With regard to divergent validity, the results of the analysis suggested that various tools could be relocated in different groups. For instance, it was no surprise to see that, within the correlation matrix generated during the factor analysis, *CPM* and *Gantt chart* were highly correlated to *planning software*. This is because the first two methods are an essential part of any planning software. Likewise, *brainstorming* and *teams & teamwork* showed a high correlation; this is to be expected since brainstorming is a common feature of teamworking. These statistical results confirmed that not all the tools belong necessarily to one specific group and explained why, although different authors have classified the tools in different ways, their categorizations are still correct. Statistically speaking, all tools/techniques that have a high correlation to others could be grouped together. Analysing the results within the correlation matrix, it became apparent that various combinations of tools/techniques were feasible, however it was decided to keep the groups as originally defined because it was evident that the classification proposed was valid due to the generally high correlation observed among elements in the original groups. Therefore, the analysis concluded that the survey instrument was reliable and valid with respect to its construct and content, hence valid conclusions about the level of use and the perceived importance of the tools/techniques could be drawn.

Having performed the factor analysis, the data was substantially reduced from 31 items (tools and techniques) to a more manageable eight groups. After relocation all the items belonged to their groups, hence it was more useful to compare factors based on these groups and not on individual elements. Consequently, the following discussion will consider groups rather than elements.

Tools/techniques use

As stated earlier, the main objective of the survey was to determine the breadth of use of different improvement tools in the construction industry. The respondents were also asked to rate their perceived importance of each. Once the various means for use and perceived importance were calculated, the rank for each group of tools/techniques was determined. The results are presented in Table 5. In all cases, the opinion of both users and non-users was taken into consideration to calculate the average ratings i.e. participants who rated a particular tool as 0, were included in the analysis. Although this inclusion reduced the scores, the authors felt it appropriate to analyse not only the 'voice of users' but also the 'voice of non-users' in order to gain a general view within the sector.

As can be seen, the mean scores for 'use' range from 0.49 to 3.43. When they were ordered, *quality control*, *technology* and *performance measures* were the three groups most used by the respondent companies while *gathering customer needs*, *organizing customer needs* and *formal methods* were the three least used. It was no surprise to see *quality control* first since the industry has traditionally relied on this type of tool to ensure the

Table 4 Final results of Factor Analysis (n=72)

Group	Tools/techniques	Kaiser-Meyer-Olkin	Element loading range for group	Eigenvalue	Variance explained by group (%)	Obtained by deleting
1	Gathering customer needs	0.756	0.705–0.870	3.051	61.01	–
2	Organizing customer needs	0.731	0.883–0.886	2.314	77.14	–
3	Formal methods	0.706	0.837–0.885	2.201	73.35	–
4	Planning tools	0.608	0.510–0.828	1.777	44.43	4.2, 4.3
5	Programming tools	0.500	0.876–0.876	1.536	76.79	–
6	Quality control	0.789	0.566–0.857	2.979	49.65	5.5
7	Performance measures	0.625	0.713–0.799	1.684	56.15	–
8	Technology	0.542	0.440–0.772	1.860	46.49	–

Table 5 Tools/techniques mean use and perceived importance (n=72)

Group of tools/techniques	Companies [users]	Mean use	Rank	Mean importance	Rank
Gathering customer needs	66	2.30	6	2.78	4
Organizing customer needs	24	0.74	7	0.74	7
Formal methods	16	0.49	8	0.51	8
Planning tools	67	2.40	5	2.58	6
Programming tools	58	2.57	4	2.71	5
Quality control	69	3.43	1	3.54	1
Performance measure	69	2.94	3	3.38	2
Technology	68	2.94	2	2.96	3

Notes: 1=very low; 2=low; 3=moderate; 4=high; 5=very high.

quality of its products. For instance, the use of inspection and first line supervision have been widely exploited to ensure the quality of the end product. Likewise, it was expected to see *technology* at the top of the list since this is the age of technology. With regard to *performance measures*, a high usage was also expected because they are being used in all sectors now. In contrast, the low level of use of tools for *gathering customer needs* and *organizing customer needs*, and more particularly *formal methods* possibly means that more attention needs to be paid to the tools that help to collect the voice of the customer and thereby ensure that quality is built into projects. This finding supports long held anecdotes regarding the lack of readiness and ability of designers to consider the needs and requirements of users and commissioners of buildings. One important aspect to highlight is that the proportion of users within both the *organizing customer needs* and the *formal methods* groups was lower than for the others, which could indicate a lack of knowledge of these tools.

Tools/techniques perceived importance

With regard to perceived importance, as shown in Table 5, it is evident that the companies placed a higher degree of importance on practically all the groups of tools/techniques than was displayed by their level of use. The values range from 0.51 to 3.54, which correspond to a 'very low' and between a 'moderate' and a 'high' level of perceived importance (1 to 4 on the Likert scale). Again *quality control, performance measures* and *technology* in that order, received the three highest scores, while *planning tools, organizing customer needs* and *formal methods* were placed at the bottom of the list. This could indicate that although respondent companies think that quality control and performance measures are very important (e.g. *customer satisfaction surveys* and *customer complaints*), they also think that formal methods and tools to organize the voice of the customer have low importance (e.g. *QFD*, *matrix diagrams* and *affinity diagrams*). While the rank position for tools that help to gather customer needs improved from 6 (with regard to use), to 4 (with regard to perceived importance), that for tools that help to organize the voice of the customer remained the same (7). Regardless of the tools employed to gather and organize the voice of the customer, it is obvious that to increase customer satisfaction, consideration should be given to their desires preferably from the very beginning of a project's development. Unless this is done, any other initiative will almost certainly be unsuccessful.

Significance tests on difference of means

As has already been stated, the respondent companies rated the perceived importance of the tools/techniques higher than the extent to which they were used. Statistical tests were performed in order to ascertain whether there was any significant difference between current use and the level of perceived importance for each group of tools, making use of the approach followed by Yusof and Aspinwall (2000). Levene's (1960) test was computed to verify the assumption of equality of variances between both samples when performing ordinary comparison t-tests and has been considered in the results presented in this paper. Three comparisons were made; the first was based on the whole sample, the other two looked at ISO 9001 certified companies and those not certified to this standard. The following hypotheses were formulated and a 5% level of significance used throughout.

(a) To test for a significant difference between the use and the perceived importance means:

H_o: $\mu_1-\mu_2=0$, i.e. there is no significant difference between the two means;
H_1: $\mu_1-\mu_2\neq 0$, i.e. there is a significant difference between the two means.

(b) To test for a significant difference in the extent of use between companies certified to ISO 9001 and those not:

H_o: $\mu_1 - \mu_2 = 0$, i.e. there is no significant difference between the practices of ISO 9001 certified companies and those not certified.;
H_1: $\mu_1 - \mu_2 \neq 0$, i.e. there is a significant difference between the practices of ISO 9001 certified companies and those not certified.

(c) To test for a significant difference in the perceived level of importance reported by ISO 9001 certified companies and those not certified:

H_o: $\mu_1 - \mu_2 = 0$, i.e. there is no significant difference between the perceived level of importance for each of the groups of tools/techniques of ISO 9001 companies and those not certified;
H_1: $\mu_1 - \mu_2 \neq 0$, i.e. there is a significant difference between the perceived level of importance of ISO 9001 certified companies and those not certified.

The first hypothesis was tested using a paired comparison t-test, whilst the others were analysed using an ordinary comparison t-test. Again, SPSS 11.0 (SPSS, 2001) was employed in all cases (Blouin and Riopelle, 2004). When comparing the mean use and mean perceived importance for the whole sample, significant differences were found in three of the seven groups: *gathering customer needs, programming tools* and *performance measures*. This means that the importance perceived by respondent companies for these tools has not been transformed into action i.e. companies are aware of the importance of these groups of methods but are not applying them. Possibly, this shows that more effort needs to be focused on promoting tools that help to capture the voice of the customer and those that help to measure how well the initiatives undertaken are working. All the results are summarized in Table 6.

The second comparison was between the companies certified to ISO 9001 and those not with regard to current use. In this case, an ordinary comparison t-test was performed. Since the ISO 9001 standards require evidence of the use of continuous improvement tools/techniques (Yusof and Aspinwall, 2000), it was expected to find a great deal of difference between the two groups under study. Indeed, the results showed significant differences between six groups: *gathering customer needs, organizing customer needs, planning tools, programming tools, quality control* and *technology*. It was no surprise to find that, after *technology*, the biggest difference in means was for *quality control*. The results are shown in Table 7.

The final test on perceived importance was carried out between companies certified to ISO 9001 and those not certified to the standard. The results summarized in Table 8 were very similar to those for the previous comparison. Apart from *planning tools, gathering customer needs, organizing customer needs, programming tools,*

Table 6 Paired sample statistics for mean use and perceived importance (5% level of significance, $n=72$)

Group of tools/techniques	Mean use	Mean importance	P-value	t_{calc}	Results
Gathering customer needs	2.30	2.78	0.000	5.258	Sig
Organizing customer needs	0.74	0.74	0.894	0.134	Not Sig
Formal methods	0.49	0.51	0.509	0.664	Not Sig
Planning tools	2.40	2.58	0.011	2.627	Not Sig
Programming tools	2.57	2.71	0.008	2.742	Sig
Quality control	3.43	3.54	0.117	1.585	Not Sig
Performance measure	2.94	3.38	0.000	5.104	Sig
Technology	2.94	2.96	0.813	0.237	Not Sig

Table 7 Ordinary comparison statistics for ISO 9001 vs. non-ISO 9001 certified companies for mean use (5% level of significance, $n=72$)

Group of tools/techniques	Mean use		P-value	t_{calc}	Results
	ISO 9001	Non-ISO 9001			
Gathering customer needs	2.56	1.61	0.003	3.135	Sig
Organizing customer needs	0.89	0.31	0.020	2.379	Sig
Formal methods	0.55	0.31	0.384	0.876	Not Sig
Planning tools	2.60	1.86	0.032	2.191	Sig
Programming tools	2.95	1.57	0.001	3.464	Sig
Quality control	3.63	2.89	0.003	3.028	Sig
Performance measure	3.05	2.66	0.177	1.363	Not Sig
Technology	3.17	2.35	0.001	3.455	Sig

Table 8 Ordinary comparison statistics ISO 9001 vs. non-ISO 9001 certified companies for mean perceived importance (5% level of significance, n=72)

Group of tools/techniques	Mean importance		P-value	t_{calc}	Results
	ISO 9001	Non-ISO 9001			
Gathering customer needs	3.05	2.04	0.004	3.010	Sig
Organizing customer needs	0.91	0.30	0.015	2.506	Sig
Formal methods	0.56	0.36	0.475	0.718	Not Sig
Planning tools	2.75	2.12	0.054	1.956	Not Sig
Programming tools	3.11	1.65	0.001	3.554	Sig
Quality control	3.78	2.90	0.002	3.286	Sig
Performance measure	3.51	3.03	0.123	1.560	Not Sig
Technology	3.22	2.26	0.000	3.805	Sig

quality control and *technology* were again significantly different for the two groups. It was a surprise to see that the means for the group *formal methods* was higher, although not significantly so, for those companies that did not have ISO 9001 certification than for those with it, indicating that companies whether adopting the quality management system or not are aware of the level of importance that methods such as *QFD* have in increasing customer satisfaction. This is an encouraging finding since it is believed that formal methods are crucial to continual improvement.

From the results obtained, two conclusions are evident. One is that the implementation of the ISO 9001 standard has an impact on the level of use of the improvement tools analysed. The other is that certified companies placed higher importance on all of the groups of tools/techniques than non-certified companies, which possibly means that the implementation of the standard has made certified companies more aware of the existence of these methods.

Quality issues

The final section of the questionnaire requested information about general quality issues. A total of 96% of the respondent companies considered that the quality of their products/services could be improved. In 94% of the companies, their project managers were committed to quality, indicating the concern and importance of quality aspects in the industry. Dale (2003) highlighted the importance of training to support continual improvement. He stated that the appropriate type of training should be given to the right people, emphasizing the why and how of the tools as well as their advantages and drawbacks. In spite of this, only 72% of the respondents replied positively to the question 'Do your employees receive training in any of the tools listed in Table 1?'. Recognition within the TQM philosophy plays a key role (Juran, 1992). It consists generally of 'ceremonial' actions performed to acknowledge the work of both individuals and teams, with the main focus being the improvement of activities. From the responses obtained, it could be said that the industry is aware of this important aspect because 88% of the respondent companies recognized the efforts of teams, and 96% did so for individuals.

Conclusions

In this paper, various improvement tools perceived by the authors as being useful to the construction industry have been analysed based on an empirical study. After testing the survey instrument for possible bias, it was concluded that there was little or no non-response bias associated with it. In addition, a reliability and validity analysis concluded that the survey instrument was reliable and valid with respect to its construct and content. Factor analysis helped not only to either relocate or remove some tools from their original groups but also to demonstrate that the proposed tools/techniques' categorization was appropriate. Therefore, the survey instrument provided useful information not only about the current practice of improvement tools within the construction industry but also about their perceived importance. Additionally, it was possible to compare ISO 9001 certified companies against those not certified to assess the impact of the standard on the level of use of the tools/techniques studied.

For managers, the paper offers some benchmark for current use and perceived importance of various improvement tools within the sector. In relation to practice, *quality control, performance measures* and *technology* are commonly used in the UK construction industry. However the number of users of *formal methods* (e.g. *QFD*, *TRIZ* and *CE*) and tools to organize customer needs is still very limited. With regard to *formal methods*, for instance *TRIZ*, the results were similar to those found during the literature review, in which its level of use was reported as low (Campbell, 2002). In spite of the successful application of *QFD* in the manufacturing environment, construction organizations are not yet reaping their benefits. These results were not unexpected. A possible solution to this situation could be to encourage the application of improvement tools in the construction industry by tailoring them and developing frameworks for helping their implementation, as has been done in the manufacturing sector.

With regard to companies certified to ISO 9001 and those not certified to the standard, various significant differences in terms of both use and perceived importance of the group of tools studied were found. In general, *gathering customer needs, organizing customer needs, planning tools, programming tools, quality control* and *technology* were either more used or perceived as more important by certified companies than by those not certified. The use of improvement tools in the construction industry will attract continuing professional and academic discussion. The results presented here offer material to support it. The results from this work will help to develop a framework for selecting the best tools to use at each stage of a construction project.

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