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# WHY SMALL AND MEDIUM CONSTRUCTION ENTERPRISES DO NOT EMPLOY SIX SIGMA

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Six sigma (6σ) is a powerful business strategy which is aimed at increasing customer satisfaction and profitability by improving the quality of products and services. Many organisations have implemented 6σ and achieved significant levels of success. Successful implementation of 6σ leads to outcomes that would be welcome in the construction industry, given its reputation of suboptimal performance. The construction industry relies heavily on small and medium enterprises (SMEs). Any improvement in construction SMEs would lead to improvements in the construction industry as a whole. Against this background, a survey was undertaken to establish whether construction SMEs used 6σ and to identify factors affecting the adoption of this business strategy. It was found that none of the SMEs in the sample used 6σ. The reasons given for not employing 6σ, in descending order of importance, were: lack of knowledge about 6σ programme; lack of resources (human, time, money); 6σ programme not required by customers; other sufficient quality system in use; 6σ provides no perceived benefits; and end users not prepared to pay for 6σ programme. These reasons can be challenged when a critical analysis of innovation in the external environment within which construction SMEs operate, trends in the mode of delivery of construction industry products, trends in performance measurement in the construction industry and the flexibility of 6σ as a quantitative approach to managing quality. Construction industry stakeholders need to think about 6σ critically and make informed decisions about its role in the construction industry quality management agenda.

Keywords: construction industry, performance, quality management, six sigma, small and medium enterprises.

## INTRODUCTION

### Defining six sigma (6σ)

6σ can be defined in various ways. From a management perspective, 6σ can be defined as "a powerful management tool that assists companies to achieve breakthrough improvements in quality, eliminate defects, streamline operations, and thus dramatically improve profits" (Ferng and Price 2005). Primavera (2004) defined 6σ thus: "Six Sigma is a process improvement strategy that drives operational and financial improvements to positively impact revenue, cost reduction, customer satisfaction, productivity improvement and innovation." According to Pheng and Hui (2004), 6σ is ''a way of measuring processes, a goal of near perfection represented by 3.4 defects per million opportunities and more accurately, a comprehensive and

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flexible system for achieving, sustaining, and maximizing business success." The statistical perspective is important in the quest to understand 6σ. Sigma (σ) is a classical Greek letter which represents the standard deviation - the spread of the data about the mean value (Basu and Wright 2003). In a normal distribution, one standard deviation (σ) from both sides of the mean will include 68.27% of the total, two standard deviations (2σ) from both sides of the mean will include 95.45% of the total, 3σ will cover 99.73% and 6σ will cover 99.99966% (Pande and Holpp 2002). Within a 6σ regime 99.99966% of products and/or services are expected to meet customer requirements and only 3.4 defects per million opportunities are expected.

## Historical context of 6σ

In the 1920s, Walter Shewhart at Bell Telephone Laboratories applied 3σ as a measurement standard for processes which required improvement (Ferng and Price 2005). In the early 1980s many industries such as manufacturing, pharmaceutical, and chemical started to require substantially better degrees of product reliability (Antony, Bañuelas and Kumar 2006). The old defects measurement in terms of 3σ became unacceptable. Engineers at Motorola realized that the defect-free products were not only superior and imminently more reliable but they actually cost the company less (Persse 2006). The lesson was clear: improving the quality reduces costs - it reduces costs by reducing activities and materials. According to Pande and Holpp (2002), Motorola started to measure defects per million as represented by 6σ. As a result, over a period of 20 years (from around 1985 to 2005), Motorola reported $16 billion in savings from its 6σ efforts (Persse 2006). In 1995, Jack Welch, Chief Executive Officer of General Electric, made 6σ part of General Electric's culture. Persse (2006) indicates that application of the 6σ concept in General Electric led to savings of hundreds of millions of dollars over a period of 10 years. Other organizations such as Sony, Allied Signal, American Express, Texas Instruments and Bechtel Corporation have reported similar results. In the last few years, the construction industry has reported successful implementation of the 6σ approach. In 2002 Bechtel Corporation, one of the world's largest construction and project management companies, reported savings of $200 million with an investment of $30 million in its 6σ programme (Kwak and Anbari 2006). The Housing and Development Board under Ministry of National Development in Singapore applied 6σ approach to improve the quality of internal finishes for public housing projects - in this case improvement measures taken by a contractor helped to raise the sigma level from 2.66σ (77.39%) to 3.95σ (99%) (Pheng and Hui 2004). 6σ has also been implemented on the St Pancras Station (London) project as part of the extension of Channel Tunnel Rail Link – the 6σ programme was initiated to improve the construction of raised platform beams with the explicit aim of identifying particular activities that were causing defects and delays (Stewart and Spencer 2006). From these examples, it can be argued that 6σ can be successfully implemented in large organisations. However, there is still much debate about whether the 6σ approach can be effectively implemented and utilized in SMEs.

## Research problem

SMEs have a crucial role in the UK construction industry. SMEs often act as suppliers of products and services to larger enterprises and lack of product or service quality would significantly affect the competitive ability of larger companies (Antony 2004a). Due to globalization and growing importance of supply chain management issues, large firms are heavily dependent on SMEs for the provision of high quality products and services at low costs (Antony and Kumar 2005). Therefore, it is in the interest of all SME stakeholders, whether employees, customers or suppliers, to adopt the best practices in order to compete in today's global marketplace (Stewart and Spencer 2006). Many organizations have recently reported successful implementation of 6σ. Although 6σ has been successfully implemented in many industries, there is still little documented evidence of its implementation in construction SMEs. The authors set out to establish the extent to which 6σ is used in construction SMEs and the reasons underlying the state of affairs.

## METHODS EMPLOYED

A random sample of 700 SMEs was drawn from the Financial Analysis Made Easy (FAME) database. Company details were extracted and through company web pages and/or telephone contact, appropriate respondents from the organization were identified and their e-mail details collected.

A literature review was undertaken to identify possible reasons why SMEs might not implement 6σ. Nonthaleerak and Hendry (2006) indicated that 6σ is a high investment and resource intensive programme that only big companies can afford. This was supported by Sinthavalai (2006) who identified barriers to 6σ implementation in SMEs as follows: high investment costs; lack of resources; full-time effort required; and inefficient teamwork. Moreover, Antony and Kumar (2005) studied 6σ application in manufacturing SMEs and found out that the two most common reasons for not implementing 6σ were lack of knowledge about the programme and lack of sufficient resources. Furthermore, Antony and Kumar (2005) indicated that "linking Six Sigma to customers and linking Six Sigma to business strategy" are the most critical factors for successful deployment of this approach. Thomas and Barton (2006) presents similar factors and goes on to identify a number of issues which affect the ability of SMEs to implement 6σ:

- Management in small companies does not have the sufficient theoretical knowledge to see the potential of using statistical tools;
- Lack of resources in terms of time and personnel; and
- Lack of Six Sigma methodology suitable for SMEs.

Taking into consideration all the above, the following were identified as some of possible reasons why construction SMEs might not implement 6σ:

- Lack of knowledge about 6σ programme;
- Lack of resources (human, time, money);
- 6σ programme not required by customers;
- Other sufficient quality system in use; and
- 6σ provides no perceived benefits.

The above reasons were included in an online questionnaire. Respondents were asked to identify the importance of each of the possible reasons as an explanation for not implementing 6σ on a Likert scale (3 - great importance, 2 - some importance, 1 - no importance; and 0 - can not say). In addition, opportunity was provided to respondents to identify any other reasons not included in the list and to identify the respective importance score. This approach made it possible for the authors to discover the importance of all possible reasons within the sample.

A web page was developed to facilitate the administering of the online questionnaire. In order to enable storage and processing of data, the web page was linked to a database. A cover letter which explained the research objectives and invited respondents to participate was designed and sent to the target sample by e-mail. The cover letter contained a link to the web page that contained the online questionnaire.

The design of any questionnaire should address the following issues: time, cost and data quality (Gillham 2000, Naoum 1998 and Oppenheim 1992). To address the issue of time required by respondents to complete the questionnaire, the questionnaire was kept as short as possible while at the same time maintaining the ability to cover all the required variables (Naoum 1998).

To address the issue of costs of handling the data, as the questionnaire was to be administered online, appropriate coding was incorporated during the design phase. An ASP file was included to pass the data from the online form directly to the database, which allowed easy transformation into a spreadsheet or word processor.

The issue of data quality was addressed by pre-testing (Gillham 2000). The questionnaire was initially sent to 100 respondents in order to identify any quality issues and test the efficacy of the approach to data collection - after one week, the website was visited 14 times and 5 respondents completed the questionnaire. The response rate at this stage was 5% which is relatively low in comparison to postal surveys. For instance, Antony and Kumar (2005) reported response rate of 16.5% (postal survey) in manufacturing SMEs, Antony (2004b) claimed to get 14% (postal survey) response rate in a study in UK of service organizations. The fact that the response rates for online surveys tend to be lower than those of postal surveys has been confirmed by Banuelas, Tennant, Tuersley and Tang (2006). Banuelas et al. reported response rate of 24.3% for a postal survey and 2.3% for an online survey. In order to increase the response rate it was decided to send a reminder. Therefore, a week after the initial e-mail was sent, respondents were reminded to complete the questionnaire. This time 11 people visited the web page and 3 completed questionnaires were submitted. The response rate after the reminder was 8%.

The pre-test responses did not indicate any quality issues with the questionnaire. The pre-test showed, however, that response rates can be improved by reminding participants. As a result, the questionnaire and the ‘reminding’ strategy were adopted for the remaining 600 organisations in the original sample.

## RESULTS AND DISCUSSION

The work started with a target sample of 700 SMEs randomly selected from a population of 7,967 construction SMEs in UK and ended with an ‘achieved’ sample size of 30. This was a low response rate (4.28%), but it is comparable to response rates from other online questionnaires (Antony and Kumar 2005; and Banuelas et al.). Furthermore, most statisticians accept a sample size of 30 in random samples as large enough for data analysis purposes (Owen and Jones 1994). A large sample does not completely eliminate sampling error, but it makes it possible for valid deductions and conclusions to be made. The authors, therefore, contend that the random sample of 30 cases used in this study provides a reasonable basis upon which the deductions and conclusions in the following sections can be made.

### Extent of implementation of 6σ

None of the SMEs in the sample indicated that they implemented 6σ in their organization. Not withstanding the possible sampling errors, this demonstrates the construction industry's relative reluctance to adopt 6σ compared to other industries such as manufacturing and automotive industries (Rodney and Clinton 2006).

There are some contextual factors that differentiate the construction industry from other industries such as those identified in Ferng and Price (2005) namely:

- High proportion of SMEs which often do not have the resources or skills required to launch a performance improvement programme;
- Project-based industry reliant on complex supply chains involving many different organizations with diverse approaches to performance and quality;
- Difficulties of generating long-term partnerships, since many of the industry workers are self-employed; and
- Products tend to be unique one-offs providing few opportunities to learn through repeatability, unlike manufacturing where many products are mass-produced.

The uniqueness argument continues, however, to be diminished by developments in the construction industry such as:

- Increased competitiveness - requiring innovation and efficiency;
- Framework agreements - providing medium to long term relationships in specific areas of work; and
- 'Enlightenment' - myth-bursting arguments such as Sir John Egan's: many construction industry processes are repeated from one project to another and provide many opportunities to learn (Egan 1998).

### Reasons for not implementing 6σ

In addition to the five reasons that were shown in the questionnaire, one respondent identified one 'extra' reason: end users not prepared to pay for 6σ programme. Table 1 below summarises the responses received - the reasons are shown in the first column in descending order of importance.

*Table 1: Explanation for not implementing 6σ*

| | Number of respondents | | | |
|---|---|---|---|---|
| Reason | Great importance | Some importance | No importance | Cannot say |
| 1.Lack of knowledge about 6σ programme | 12 | 3 | 6 | 9 |
| 2. 6σ programme not required by customers | 10 | 10 | 1 | 9 |
| 3. Other sufficient quality system in use | 10 | 7 | 3 | 10 |
| 4. 6σ provides no perceived benefits | 7 | 7 | 4 | 12 |
| 5. Lack of resources (human, time, money) | 2 | 7 | 5 | 16 |
| 6. End users not prepared to pay for 6σ programme | 1 | - | - | - |

### Lack of knowledge about 6σ programme

Lack of knowledge was the most important explanation for not implementing 6σ programmes within the sample. This reason is an indication that the immediate external environments within which SMEs operate, especially in forward project supply chains, do not promote 6σ. This should not, however, be an excuse for the respective SMEs. Any organisation seeking competitive advantage should be looking at the environment beyond the immediate industry sector to identify ways and means with which it can differentiate its products and/or services (Johnson, Scholes and Whittington 2008). There is plenty of evidence in other industries from which SMEs can identify drivers for competitiveness. Although 6σ will not be the panacea for each and every SME, the very least that can be done is to explore its potential in the context of each organisation and make informed judgments accordingly. If SMEs or any other organisation limits its environmental analysis to immediate markets and/or sectors, the chances of strategic drift are increased which may mean that organisational and/or industry performance will be, at least, limited in the medium to the long term.

**6σ programme not required by customers**

The argument that 6σ was not required by customers of the SMEs was the second most important explanation for not implementing 6σ. This is a reflection of the culture of the construction industry as a whole. It is important to realise that the customer base of SMEs is quite wide – it includes client organisations for which SMEs work as main contractors as well as larger construction organisations for which the SMEs work as subcontractors. These customers are willing to accept lower quality standards than those that would be delivered within a 6σ regime. Antony and Kumar (2005) suggests that many SMEs operate their business processes at the 2σ to 3σ quality level and an improvement of even 1σ can bring huge improvements in customer satisfaction and cost reduction. The construction industry customers not only determine what is built but standards to be achieved. Their wishes and aspirations are normally expressed in project contract documents including specifications and forms of contract. As was argued in the preceding section above, reluctance to push the performance bar has a negative impact on the construction industry relative to other industries. The customers need to use their power to drive improvement in standards. 6σ should be part of the toolbox. It is clear that it has worked for many organisations including construction organisations, albeit, mainly large organisations. However, a well designed 6σ programme appropriate for the size of the organisation is likely to be equally beneficial for SMEs (Pfeifer, Reissiger and Canales 2004; Harry and Crawford 2004; and Wessel and Burcher 2004).

**Other sufficient quality system in use**

The presence/use of alternative quality systems was the third most important explanation for not implementing 6σ. The alternative quality systems used were:

- ISO9000 - the number of organisations that always, often, sometimes and never employed ISO9000 were 14, 2, 3 and 11 respectively;
- Quality function deployment (QFD) - the number of organisations that always, sometimes and never employed QFD were 4, 11 and 15 respectively;
- ISO14000 - the number of organisations that always, often, sometimes and never employed ISO14000 were 4, 2, 2 and 22 respectively; and
- Total quality management (TQM) – the number of organisations that always, often, sometimes and never employed TQM were 3, 2, 12 and 13 respectively.

While ISO9000 was the most widely used quality system (47% of the construction SMEs always employ the system), Antony and Kumar (2005) shows that 80% of manufacturing SMEs implement ISO9000. It can be argued that construction SMEs cannot defend their lack of implementation of 6σ on grounds that they are busy implementing other quality systems. The manufacturing industry (which has almost twice the rate of employment of ISO9000), for example, still performs much better than the construction industry in the implementation of 6σ. Again, the underlying factor for the reason 'other sufficient quality system in use' is the culture in the environment – the construction industry - within which construction SMEs operate. Construction SMEs are not justified in dismissing 6σ without consideration. 6σ may not be the answer to every SME's problems but it may be of benefit to some and they cannot know before they have tried it, at least in exploratory mode.

**6σ provides no benefits**

The argument that 6σ did not provide any benefits for construction SMEs was the fourth most important explanation for not implementing 6σ programmes. Given that none of the SMEs had ever implemented 6σ, this view can only have arisen from a theoretical, or even prejudiced, perception. While it is possible that 6σ may not provide benefits, it is difficult to sustain the stance without any practical evidence. Evidence from large organisations in the construction industry and other industries suggests that 6σ is, at least, worth trying. Furthermore, bespoke programmes can be designed to take into consideration specific organisational contexts (Pfeifer, Reissiger and Canales 2004; Harry and Crawford 2004; and Wessel and Burcher 2004).

**Lack of resources**

Lack of resources was the fifth most important explanation for not implementing 6σ programmes (the same reason is considered to be more important among manufacturing SMEs (Antony and Kumar 2005)). This may be explained on the grounds that construction SMEs did not appreciate the level of resources required to implement a 6σ programme. 6σ programmes involve two main approaches:

*1 Define, Measure, Analyse, Improve and Control (DMAIC)*
The DMAIC approach involves:

- Defining what should be done, why it should be done, how it should be done, and what results are expected (Persse 2006);
- Measuring procedures that include the following steps: preparation to measure, measure and protect data (Persse 2006);
- Analyzing data to determine the root causes of defects and problems and then to establish an empirical basis for improving the process (Persse 2006);
- Improving the process/situation on the basis of the data collected and subsequent analysis (Pande and Holpp 2002); and
- Controlling with a carefully designed control plan that describes the change(s), who will be affected by the change(s), when the changes will happen and what resources are in place to support new elements.
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*2 Design for 6σ*
This approach also has five steps: define, measure, analyze, design, and verify (Gitlow 2005). According to Kwak and Anbari (2006) the steps can be described as follows:

- Define – initiate and plan the project;
- Measure – capture customer needs;
- Analyse – develop design concepts;
- Design – develop detailed design; and
- Verify – implement full scale processes.

Clearly, 6σ implementation requires significant quantitative data collection and analysis and can be costly and time consuming. It requires large data sets –these are easily realised in repetitive activities. In the construction industry, the key performance indicators (KPIs) agenda has provided a significant number of variables that can be measured at organisational and project level. Furthermore, the move towards framework agreements that ensure a supply of reasonable work loads over relatively long time periods provides increasing opportunities for repetitive activities that are suitable for generation of large data sets. It can be argued that the construction industry is increasingly getting aligned to 6σ implementation. Furthermore, it is possible to minimise costs associated with implementing 6σ. For example, Sinthavalai (2006) suggests the following cost reduction measures:

- Use of an internet based model to support the application of 6σ in SMEs;
- Avoid the costs of hiring consultants and training specialists by developing a coaching system and self-learning as an alternative solution for SMEs;
- Avoid complicated systems by adopting appropriate tools or methods; and
- Time the employees spend on training could be reduced by integrating 6σ activities as part of regular jobs without any external training courses.

### End users not prepared to pay for 6σ programme

The argument that end users were not prepared to pay for 6σ programmes was identified by one SME as an important reason that explains why 6σ has not been implemented. The fact that it was raised suggests that the SME was prepared and believed in 6σ but did not get the cooperation of its customers. This is further evidence of the construction industry's key players playing laggard.

## CONCLUSIONS

The work reported in this paper was undertaken to explore the extent to which 6σ is implemented in construction SMEs and to identify the reasons that explain the state of affairs. This was pursued using an online questionnaire targeted at a random sample from a population of construction SMEs in a widely used and relatively large company database (FAME – which contains information about over 3 million companies in the United Kingdom and Ireland).

It was found that none of the SMEs in the sample implemented a 6σ programme in their organisation. The industry lags behind other major industries such as manufacturing and automotive in this respect. There is a tendency to explain the construction industry's performance relative to other industries on account of its uniqueness. While the uniqueness of the construction industry can be understood, it should be noted that there are developments taking place in the construction industry, such as increasing competitiveness, framework agreements and 'enlightenment' that are continually diminishing the uniqueness argument.

The reasons advanced for not implementing 6σ from the sample were, in descending order of importance, as follows: lack of knowledge about 6σ programme; lack of resources (human, time, money); 6σ programme not required by customers; other sufficient quality system in use; 6σ provides no perceived benefits; and end users not prepared to pay for 6σ programme. These reasons highlight three main issues: the external environment within which construction SMEs operate, the mode of delivery of construction industry products (project work) and the nature of 6σ as a quantitative approach to managing quality.

The external environment within which construction SMEs operate does not promote 6σ. Despite the evidence from some large construction organisations such as Bechtel Corporation (and other industries) of the benefits of 6σ, the construction industry appears rather slow in responding to 6σ (and other new initiatives). One may even say that it is no wonder that the construction industry continues to lag behind other industries such as manufacturing and automotive. However, the industry is only a sum of constituent organisations, including SMEs. These organisations should be seeking competitive advantage by looking at the environment beyond the immediate industry to identify ways and means with which they can differentiate their products and/or services. Although 6σ will not be the panacea for each and every SME, the very least that can be done is to explore its potential in the context of each organisation and make informed judgments accordingly.

The mode of delivery of construction industry projects – the idea that output is in the form of individual unique projects – often underpins explanation for mismatch between the construction industry and other industries. Yet, many construction industry processes are repeated from one project to another. In addition, the increasing emphasis on framework agreements that involve working with the same partners over a relatively long time period diminishes the uniqueness argument.

The nature of 6σ as a quantitative approach should not obscure the fact that the construction industry is better placed to generate the quantitative data necessary. The KPIs drive has defined a significant number of standard quantitative variables that can be used. Furthermore, the move towards framework agreements that ensure a supply of reasonable work loads over relatively long time periods provides increasing opportunities for repetitive activities that are suitable for generation of large data sets.

This paper has highlighted the potential of 6σ for construction SMEs. It has also challenged construction SMEs to take the initiative to innovate and not wait for prescribed solutions from other project stakeholders.

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