Six sigma in small- and medium-sized UK manufacturing enterprises
Some empirical observations

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Abstract
Purpose – Six sigma for small- and medium-sized enterprises (SMEs) is an emerging topic among many academics and six sigma practitioners over the last two to three years. Very few studies have been reported about the successful applications of six sigma in SMEs. The purpose of this paper is to provide an analysis of six sigma implementation in UK manufacturing SMEs.

Design/methodology/approach – This paper presents an extensive literature review based on the experiences of both academics and practitioners on six sigma within an SME environment. The paper highlights the strengths and weaknesses associated with SMEs, followed by the results of a six sigma survey in UK manufacturing SMEs. The results of the study are based primarily on descriptive statistics.

Findings – The results of the study show that many of the SMEs are not aware of six sigma and many do not have the resources to implement six sigma projects. It was also found that lean sigma was not generally popular among SMEs. Management involvement and participation, linking six sigma to customers and linking six sigma to business strategy are the most critical factors for the successful deployment of six sigma in SMEs.

Originality/value – This paper reports the first study on the status of six sigma implementation in UK SMEs. The paper will yield a great value to academics, consultants, researchers and practitioners of six sigma.

Keywords Quality programmes, Small to medium-sized enterprises, Critical success factors, United Kingdom

Paper type Research paper

Introduction
Six sigma is a well-established approach that seeks to identify and eliminate defects, mistakes or failures in business processes or systems by focusing on those process performance characteristics that are of critical importance to customers (Snee, 2004). Six sigma provides business leaders and executives with the strategy, methods, tools and techniques to change their organisations. Six sigma has been on an incredible run for the last five years producing significant savings to the bottom-line of many large UK manufacturing organisations. There are four aspects of the six sigma strategy that are not emphasised in other business improvement methodologies and total quality
management (TQM). First of all, six sigma places a clear focus on bottom-line impact in hard dollar savings. No six sigma project will be approved unless the team determines the savings generated from it. Second, six sigma has been very successful in integrating both human aspects (culture change, training, customer focus, etc.) and process aspects (process stability, variation reduction, capability, etc.) of continuous improvement. Third, six sigma methodology (define-measure-analyse-measure-control or DMAIC) links the tools and techniques in a sequential manner. Finally, six sigma creates a powerful infrastructure for training of champions, master black belts, black belts, green belts and yellow belts (Harry and Schroeder, 2000; Pande et al., 2000; Adams et al., 2003).

Although six sigma has been implemented with success in many large corporations, there is still less documented evidence of its implementation in smaller organisations. Due to growing importance of supply chain management issues in global market environment, large firms are heavily dependent on small- to medium-sized enterprises (SMEs) for the provision of high quality products and/or services at low costs. The increasing demand for high quality products and highly capable business processes by large organisations has left no choice on the SMEs to consider the introduction of six sigma business strategy.

This paper examines the status of six sigma implementation in UK manufacturing SMEs by investigating how six sigma was introduced to them, who was involved in such initiatives, how long UK manufacturing SMEs have been engaged in six sigma initiative and how the successes and failures of six sigma projects were perceived. The paper will also examine whether the six sigma critical success factors (CSFs) considered by large organisations are valid for SMEs. Although this study is primarily focused on manufacturing SMEs, most of the considerations and suggestions can be applied to service SMEs.

Small and medium-sized enterprises
SMEs are the life-blood of modern economies. The importance of SMEs to the economy of the UK and the industrialised world as a whole cannot be over emphasised. A short summary of relevant statistics available from the Small Business Service (SBS), an agency of the Department of Trade and Industry (DTI), shows the vital role that SMEs play:

- There were estimated 4.0 million business enterprises in the UK at the start of 2004. More than 99 percent of these enterprises were SMEs. In this research, we consider an organisation to be an SME if it employs less than 250 employees and has turnover of less than £11.2 million (DTI, 2003).
- SMEs employ approximately 58 percent of the total workforce in the UK.
- It is estimated that SMEs are responsible for 52 percent of the combined turnover of UK businesses.
- The SME manufacturing sector alone, in which this study is focused on, accounts for over 35 percent of the estimated combined turnover of UK businesses.
- UK SMEs combined annual turnover is around £1 trillion (Holden et al., 2003).

SMEs act as suppliers to large organisations and therefore the “footprint” of SMEs is much larger than may be seen at a first glance. They form the foundation upon which
the economy of the UK is based. With such an important place in the UK economy, it is in the best interests of all SME stakeholders, whether employees, customers or suppliers, to adopt the best management practice in order to compete in today’s global marketplace. Moreover, due to the growing importance of supply chain management issues, SMEs should provide high quality products or services at low cost to larger firms. One way in which this can be achieved is through the adoption of quality management and the principles of continuous improvement.

There is a noticeable dearth of previous work that examines the implementation of six sigma within SMEs. This section explores the key strengths and weaknesses of SMEs prior to initiating a six sigma program. Table I presents some of the strengths and weaknesses of SMEs. The table was constructed by reviewing existing literature on SMEs and quality management practices such as TQM (Yusof and Aspinwall, 2000; McAdam, 2000; Ghobadian and Gallear, 1997; Noci and Toletti, 1998; Levy and Powell, 2000).

**Research background**

Harry and Crawford (2004) clearly demonstrate the importance of white belts for SMEs and the focus of this new belt system on creating value to customers. A white belt

<table>
<thead>
<tr>
<th>SMEs strengths</th>
<th>SMEs weaknesses</th>
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</thead>
<tbody>
<tr>
<td>Flexible and hence changes can be introduced fairly quickly</td>
<td>Low degree of standardisation and formalisation</td>
</tr>
<tr>
<td>Flat with few layers of management and fewer departmental interfaces</td>
<td>Focus is on operational matters rather than planning</td>
</tr>
<tr>
<td>Top management highly visible and hence provide leadership by example</td>
<td>There are chances that management lay off employees when the work becomes superfluous. This makes SMEs work harder to retain a high calibre staff</td>
</tr>
<tr>
<td>Absence of bureaucracy in management teams</td>
<td>Limited investment in IT</td>
</tr>
<tr>
<td>Tend to have high employee loyalty</td>
<td>No incentive or reward programs in many cases due to budget and resources constraints</td>
</tr>
<tr>
<td>Managers and operatives are more likely to be directly involved with the customers</td>
<td>Lack of strategic planning and inspiring vision</td>
</tr>
<tr>
<td>Rapid execution and implementation of decisions</td>
<td>Responsible for many facets of the business and many decisions. Decisions are generally made for short-term profitability</td>
</tr>
<tr>
<td>Training likely to be focused</td>
<td>Lack of skills, time and resources; no specified training budget</td>
</tr>
<tr>
<td>Culture of learning and change rather than control</td>
<td>Incidence of “gut feeling” decisions more prevalent; often operate in a fire-fighting mode for survival</td>
</tr>
<tr>
<td>People oriented</td>
<td>Not systems oriented</td>
</tr>
<tr>
<td>More responsive to market needs and more innovative in their ability to meet customers' demand</td>
<td>Extent of training and staff development in SMEs is limited and informal</td>
</tr>
<tr>
<td>Likely to deploy improvements quickly and gain rapid benefits</td>
<td>Adamant and dictatorial nature of owner can damage new initiatives</td>
</tr>
<tr>
<td>Loose and informal working relationships and absence of standardisation</td>
<td>Formation of strategy process is intuitive rather than analytical</td>
</tr>
</tbody>
</table>

Table I. Strengths and weaknesses of SMEs
offers a much quicker return on investment. A white belt is expected to complete up to 12 projects in a year with the potential savings of $25,000 (on average) on each project. This implies a total of about $300,000 savings a year from a white belt.

Wessel and Burcher (2004) in their study identify the specific requirements for implementation of six sigma based on a sample of SMEs in Germany. This study also examines how six sigma has to be modified to be applicable and valuable in an SME environment. This is the first study of its kind to be carried out on six sigma survey in SMEs.

Rowlands (2004) argues that the traditional six sigma approach to black belt training and deployment is not desirable in the case of SMEs. Therefore the six sigma deployment needs to be considered based on the company’s available resources and skills base. He suggests the use of Porter's value chain analysis and the five forces model to analyse businesses processes prior to applying six sigma methodology. These models could be used to provide strategic alignment to the business objectives as well as identifying training needs and project selection prioritisation in SMEs.

Snee and Hoerl (2003) argue that there is nothing inherent in six sigma that makes it more suitable for large companies. They also suggest that the greatest barrier to implementation in small companies to date has been the way the major six sigma training providers have structured their offerings. More recently, as more and more sets of deployment guides and training materials have become available, the pricing structures have begun to change. Today, it is much easier for SMEs to obtain good external resources without a large up-front payment.

Tennant (2001) argues that, in small organisations, if one visible and important person is actively against six sigma, then this attitude must change or the initiative must be a non-starter. In other words, in small companies, the top management team need to be visibly supportive of every aspect of six sigma initiative and they must demonstrate by their active participation, involvement and by their actions that such support is more than lip service. He also accentuates the point that it is far more important for small- and medium-sized enterprises to ensure that every iota of effort is directed exactly where it is needed for maximum benefit, so an overall quality strategy plan is vital right from the start of the six sigma initiative. Six sigma is about overall management strategy, culture and change, and the organisation needs to build all of this into a sound corporate strategy plan.

Once an owner of the business (in small firms) is convinced of the advantages conferred by six sigma and visualises the benefits, it is much easier to implement six sigma at smaller firms and to realise its benefits (Adams et al., 2003). They suggest that the initial focus on SMEs can be to reduce quality costs or waste in the system. Effort and investment, as well as results in smaller companies, are more visible within a short time.

Waxer (2004) looked at four major requirements for successfully implementing six sigma within any organisation, regardless of the size of the organisation:

1. management team buy-in and support;
2. education and training;
3. resource commitment; and
4. link to compensation.
As small companies are more agile, it is much easier to buy-in management support and commitment, as opposed to large organisations. The education and training component is much harder for smaller companies. Moreover, small companies do not have the slack to free up top talented people to engage in training followed by execution of six sigma projects as they are crucial to the day-to-day operations and problem solving within the company. Being able to link compensation to six sigma implementation is much easier in small companies compared to a large company.

Davis (2003) pointed out that the problem arises in SMEs when they solicit deployment proposals from six sigma consulting companies only to learn that the traditional six sigma implementation approach in large companies can require millions of dollars investment, dedication of their best people on six sigma projects, and training of the masses. He also argues that using a yellow belt approach allows SMEs to implement six sigma at a less costly, more manageable pace. He also added that the “one size fits all” six sigma black belt deployment model is not practical for every company.

Six sigma can be an effective methodology for smaller organisations and plays a major role in continual improvement based on the ISO 9001:2000 requirements. Gnibus and Krull (2003) illustrate a very interesting example on price and delivery quotations for equipment returned to a medium-sized company for repairs. The company discovered that limiting six sigma training to the green belt training level, during the continual improvement program, still provided the resources required to address their business problems.

Process Quality Associates (PQA), a six sigma and quality engineering training and consulting service provider, explains a practical framework for implementation of six sigma in SMEs (Process Quality Associates, 2003). To make the framework more applicable and suitable for SMEs, the company had developed a set of CSFs, which have been integrated into each phase of the six sigma methodology. These CSFs include:

- top management leadership and commitment;
- a well-implemented customer management system;
- education and training system;
- a well-implemented process management system;
- a well-developed strategic planning system;
- a well-developed supplier management system; and
- a well-developed human resource management system.

Wilson (2004) identifies the following advantages for small-businesses embarking on six sigma initiative.

- stronger, more intimate relationships with customers;
- a limited number of sites;
- fewer layers in the management hierarchy;
- faster and effective internal communication; and
- strong owner influence.
Burton (2004) proposes alternative six sigma deployment models that allow SMEs to implement six sigma at a pace where they can digest the methodology and achieve benefits, without significant resource commitment and overhead structure of the traditional six sigma. As a result, SMEs are sometimes able to achieve faster and more impressive benefits than their large customers. He also recommends an eight-step methodology for successful deployment of six sigma within SMEs.

As many SMEs operate their business processes at the “two to three sigma quality level”, an improvement of even one sigma represents a huge step in improving customer satisfaction and reducing costs (Spanyi and Wurtzel, 2003). For instance, if a customer order fulfilment process is operating at three sigma quality level (i.e. 66,800 defects per million opportunities) and if we improve the sigma quality level to four sigma quality level (i.e. 6,210 defects per million opportunities), then this process would realise a ten-fold improvement in performance. Assuming each error or mistake cost $5 to fix (on average), the resulting cost savings would be in the range of $300,000. Spanyi and Wurtzel (2003) have identified the following elements for successful launch of a six sigma initiative in an SME environment:

- visible management commitment;
- clear definition of customer requirements;
- shared understanding of core business processes and their critical characteristics;
- rewarding and recognising the team members;
- communicating the success and failure stories; and
- selecting the right people and the right projects.

Although there are “start-up” costs to the deployment including training, leadership alignment and customer focus, a properly designed and deployed six sigma program should provide ample cost benefits rather quickly, even for smaller companies (Keller, 2003). Keller argues that six sigma offers many SMEs the same benefits as larger companies: an improved bottom line.

**Research objectives and methodology**

The fundamental objective of this study is to “examine the extent to which six sigma is being implemented within UK manufacturing SMEs”. In order to do this effectively, the general objective is further divided into a number of specific research questions as follows:

- To what extent are UK manufacturing SMEs implementing six sigma?
- To what extent are the UK manufacturing SMEs familiar with the tools and techniques of six sigma?
- To what extent do UK manufacturing SMEs actually use the tools and techniques and how useful do they think they are?
- What benefits have been brought to the UK manufacturing SMEs through six sigma implementation?
- What are the CSFs for implementation of six sigma in UK manufacturing SMEs?
- What are the common barriers in the implementation of six sigma in SMEs?
In this study, a survey questionnaire was constructed drawing upon prior literature. Focus is on operational matters rather than planning (Antony and Banuelas, 2002; Ghobadian and Gallear, 1996; Lee and Oakes, 1995; Klefsjo et al., 2001; McAdam and Lafferty, 2004; Parkin and Parkin, 1996; Snee, 2004; Wessel and Burcher, 2004; Yusof and Aspinwall, 1999; Antony and Fergusson, 2004). The survey questionnaire was developed to provide a baseline for six sigma practices by SMEs in UK. It consists of four parts:

1. Surveyed SMEs’ demographic information.
2. SMEs experience with six sigma program.
3. Tools and techniques of six sigma used by SMEs.
4. Critical success factors for six sigma implementation in UK SMEs.

**Sampling method and procedure**
The questionnaire was mailed out to 400 SMEs in UK, which were randomly chosen from the Glasgow Caledonian University’s FAME database. Of the 400 questionnaires mailed, 66 completed questionnaires were returned in less than one month. This represented a response rate of 16.5 percent, which was rather regarded as satisfactory. A total of six of the responses were not useable due to incomplete data. This resulted to only 60 questionnaires used in the final analysis of this paper.

**Survey results and analysis**
The analysis of the first part of the questionnaire (i.e. demographics) provided a better understanding of the findings of the study. Therefore, aspects such as the number of employees in the organisation responded to the survey, the position occupied by the respondents, the areas of industries, the status of six sigma implementation and the number of years responded companies have been utilising six sigma.

**Number of employees and position of respondents**
The majority of companies had between 50 and 150 employees (75 percent), 15 percent of the companies responded had less than 50 employees and 10 percent of the companies responded had between 150 and 250 employees. No micro-sized companies (less than ten employees) responded to the questionnaire. The questionnaires were completed by Project Champions, black belts, green belts or yellow belts who have first-hand knowledge and expertise with the six sigma programme.

**Areas of industry**
The type of industries participated in this study included the chemical (8 percent), plastics (9 percent), automotive (18 percent), aerospace (16 percent), electronics and semi-conductors (14 percent), mechanical (10 percent), pharmaceuticals (7 percent), food (5 percent), textiles (5 percent) and others (8 percent).

**Status of six sigma and other quality initiatives of companies**
Only 16 out of 60 SMEs (i.e. about 27 percent) were actively involved in a six sigma programme. These companies have been using six sigma for over one year on average. This clearly illustrates the point that six sigma is a relatively new concept in UK manufacturing SMEs. It was observed that more than 80 percent of the SMEs
responded to the study implemented ISO 9000 quality management system with a mean duration of nine years. It was interesting to note that many companies view ISO 9000 as the major achievement of product and service quality. Nearly 25 percent of the companies had partially and fully implemented TQM with a mean duration of eight years. It was also found that about 5 percent of the companies responded were using a lean production system (LPS).

Reasons for not implementing six sigma
One of the questions that was included in the questionnaire was to identify the reasons companies are not implementing six sigma. Figure 1 illustrates the common reasons SMEs give.

The most important reason is that companies do not know about six sigma (35 percent). This is followed by the insufficiency of resources (26 percent). Also, those companies that already have quality system in place perceive such systems to be adequate (20 percent).

SMEs experience with six sigma program
Sigma level of core business processes
It was found from the analysis that majority of SMEs participated in the study (about 70 percent) had their core processes operating at sigma quality levels between 2.8 to 4.0 (based on 16 responses). A total of 23 percent of companies responded to the survey had their processes operating at sigma quality levels over 4.0. It was interesting to note that one company never estimated the sigma quality level of its core processes.

Number of project champions, black belts, green belts and yellow belts
It was observed that more than 35 percent of the responded companies using six sigma have no six sigma project champions. Moreover, less than 10 percent of the responded companies actively involved in six sigma have yellow belts. One company has a master black belt and about 80 percent of the companies utilising six sigma are using green belts. About 45 percent of the companies are using black belts to lead and deploy projects. It was also noted that the highest number of green belts and black belts were found in automotive, aerospace and electronics industries whereas the lowest number of green belts and black belts were found in textiles industry.
Common six sigma metrics used by manufacturing SMEs
A metric is a specification or attribute against which the outputs of a process are compared and declared acceptable or unacceptable. Table II presents the key metrics of six sigma and their percentages that were commonly used by the companies that participated in this pilot study.

The results of the study revealed that the most commonly used six sigma metrics by participating SMEs were number of complaints and percentage scrap. The least commonly used metrics were first time yield (FTY) and throughput yield (TPY). In fact, these two metrics (FTY and TPY) are the fundamental metrics of six sigma.

Six sigma methodologies used by manufacturing SMEs
The respondents were asked whether they use six sigma, design for six sigma, lean sigma or combination of these methodologies for tackling process and product related problems. Figure 2 presents the results obtained on the use of six sigma methodologies.

The majority of SMEs (69 percent) that responded to the survey were utilising the DMAIC methodology for continuous improvement. Only 19 percent of the companies were utilising design for six sigma (DFSS), 6 percent were using lean sigma and another 6 percent were employing both six sigma and DFSS methodologies.

Six sigma projects completed by companies and their financial impact
The analysis of results revealed that about 69 percent of the companies had completed between one and five six sigma projects. About 25 percent of the companies had completed between five and ten six sigma projects, while one company had completed more than 20 projects. About 62 percent of the companies experienced financial benefits of up to £250,000 per annum. A total of 13 percent of the companies experienced financial benefits of between £250,000 and £500,000 per annum.

<table>
<thead>
<tr>
<th>Six sigma metrics</th>
<th>Percentage of companies using the metric (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of complaints</td>
<td>94</td>
</tr>
<tr>
<td>Percentage scrap</td>
<td>81</td>
</tr>
<tr>
<td>Cost of poor quality</td>
<td>75</td>
</tr>
<tr>
<td>Defect rate</td>
<td>75</td>
</tr>
<tr>
<td>Process capability</td>
<td>63</td>
</tr>
<tr>
<td>First time yield</td>
<td>25</td>
</tr>
<tr>
<td>Throughput yield</td>
<td>13</td>
</tr>
</tbody>
</table>

Table II.
Six sigma metrics used by SMEs

Six sigma methodologies

![Figure 2. Six sigma methodologies used by responded SMEs](image-url)
Somewhat surprisingly, 25 percent of the participated companies never quantified the financial bottom-line impact from six sigma projects. Yet, six sigma places considerable emphasis on cost savings achieved through its implementation.

Benefits of six sigma in surveyed companies
The respondents were asked to rate the benefits that six sigma had brought to their organisations since implementation. The respondents were asked to rate on a Likert scale of 1 to 5, where 1 = no benefit from six sigma implementation and 5 = excellent benefits from six sigma implementation. Table III summarises the key benefits gained from the implementation of six sigma projects. The areas that have experienced the greatest benefits are reduction in process variability, increase in profitability, reduction of operational costs, reduction in the cost of poor quality (COPQ), etc. On average, these scores suggest that participating companies perceive six sigma to have benefited their processes.

Impeding factors in implementation of six sigma by UK manufacturing SMEs
Although the pressure for the implementation of six sigma has been increased over the last few months, there are some factors impeding the development of six sigma programme in UK SMEs. Companies were asked to identify the top five inhibiting factors that were felt to be barriers to six sigma implementation. The results of the analysis show that about 80 percent of the responding firms stated that lack of resources was one of the impeding factors to the successful introduction of a six sigma initiative in UK SME. Lack of resources covered a large number of aspects including financial resources, human resources, time, etc. This was followed by lack of leadership, poor training/coaching, internal resistance, poor project selection, etc. The other frequently mentioned impeding factor was lack of knowledge about six sigma methodologies.

Six sigma tools and techniques within SMEs
One of the success factors of six sigma is its ability to integrate both statistical and non-statistical tools and techniques within the DMAIC (define, measure, analyse, improve and control) framework in a systematic and disciplined manner. Table IV illustrates the most commonly used statistical and non-statistical tools and techniques used in six sigma projects by manufacturing SMEs. The table was developed with the purpose of showing information in three areas; familiarity with the tools and

<table>
<thead>
<tr>
<th>Benefits to business</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in process variability</td>
<td>4.067</td>
</tr>
<tr>
<td>Increase in profitability</td>
<td>3.733</td>
</tr>
<tr>
<td>Reduction of operational costs</td>
<td>3.667</td>
</tr>
<tr>
<td>Reduction in COPQ</td>
<td>3.600</td>
</tr>
<tr>
<td>Increase in productivity</td>
<td>3.533</td>
</tr>
<tr>
<td>Reduction of cycle time</td>
<td>3.467</td>
</tr>
<tr>
<td>Reduction of customer complaints</td>
<td>3.465</td>
</tr>
<tr>
<td>Improved sales</td>
<td>3.333</td>
</tr>
<tr>
<td>Reduced inspection</td>
<td>3.267</td>
</tr>
</tbody>
</table>

Table III. Key benefits of six sigma to SMEs
techniques, usage and usefulness of tools, techniques and problem-solving methods. Respondents were asked to rate the application of tools and techniques (i.e. usage) on a Likert scale of 1 to 5, where “1” indicates “never been used” and “5” indicates “used continuously”. Similarly, the degree of perceived usefulness was also rated on a scale of 1 to 5, where “1” implies “not useful” and “5” implies “extremely useful”. As can be seen from the table, non-parametric tests (e.g. Mann-Whitney test), affinity diagram, project charter, SIPOC model, quality costing analysis, run charts, measurement system analysis and QFD were not popular in many SMEs. The most popular tools and techniques include process mapping, histogram, cause and effect analysis, FMEA and process capability studies.

The most commonly used tools were histogram, cause and effect analysis, and process mapping. The most useful tools and techniques include process mapping, cause and effect analysis, histogram, run chart, control chart, FMEA, process capability analysis, and Poka-yoke. It appears that tools that offer visual representation, identify root causes of problems, are easier to use, and appeal more to users than the more sophisticated and complex statistical tools.

**Critical success factors of six sigma implementation in SMEs**

The respondents were asked to rank the 11 CSFs on a scale of 1 to 5 (1 = least important, 2 = less important, 3 = important, 4 = very important and 5 = crucial). The CSFs used in this pilot study were derived from existing literature of TQM and six sigma (Badri et al., 1995; Black and Porter, 1996; Breyfogle et al., 2001; Adams et al., 2003; Oakland, 2003; Snee, 2000; Antony and Banuelas, 2002; Antony, 2004; Yusof and Aspinwall, 1999; Hoerl, 1998). The aim was to determine the CSFs that

<table>
<thead>
<tr>
<th>Tools/techniques</th>
<th>Familiar (%)</th>
<th>Unfamiliar (%)</th>
<th>Usage</th>
<th>Usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process mapping</td>
<td>100</td>
<td>0</td>
<td>4.438</td>
<td>4.600</td>
</tr>
<tr>
<td>Project charter</td>
<td>44</td>
<td>56</td>
<td>3.857</td>
<td>3.500</td>
</tr>
<tr>
<td>Cause and effect analysis</td>
<td>100</td>
<td>0</td>
<td>4.188</td>
<td>4.333</td>
</tr>
<tr>
<td>Histogram</td>
<td>100</td>
<td>0</td>
<td>4.125</td>
<td>4.357</td>
</tr>
<tr>
<td>Scatter plot</td>
<td>94</td>
<td>6</td>
<td>2.333</td>
<td>2.462</td>
</tr>
<tr>
<td>Run charts</td>
<td>56</td>
<td>44</td>
<td>3.111</td>
<td>4.200</td>
</tr>
<tr>
<td>Control charts</td>
<td>94</td>
<td>6</td>
<td>3.267</td>
<td>4.154</td>
</tr>
<tr>
<td>ANOVA</td>
<td>88</td>
<td>12</td>
<td>3.429</td>
<td>3.538</td>
</tr>
<tr>
<td>Regression analysis</td>
<td>94</td>
<td>6</td>
<td>1.800</td>
<td>3.167</td>
</tr>
<tr>
<td>Design of experiments</td>
<td>88</td>
<td>12</td>
<td>3.071</td>
<td>3.230</td>
</tr>
<tr>
<td>Taguchi methods</td>
<td>81</td>
<td>19</td>
<td>2.846</td>
<td>3.100</td>
</tr>
<tr>
<td>MSA</td>
<td>63</td>
<td>37</td>
<td>2.700</td>
<td>3.500</td>
</tr>
<tr>
<td>Non-parametric tests</td>
<td>25</td>
<td>75</td>
<td>2.000</td>
<td>2.333</td>
</tr>
<tr>
<td>Hypothesis testing</td>
<td>94</td>
<td>6</td>
<td>1.867</td>
<td>3.571</td>
</tr>
<tr>
<td>Quality function deployment</td>
<td>69</td>
<td>31</td>
<td>3.273</td>
<td>3.889</td>
</tr>
<tr>
<td>FMEA</td>
<td>100</td>
<td>0</td>
<td>3.938</td>
<td>4.200</td>
</tr>
<tr>
<td>Poka-Yoke</td>
<td>94</td>
<td>6</td>
<td>3.067</td>
<td>4.083</td>
</tr>
<tr>
<td>Process capability analysis</td>
<td>100</td>
<td>0</td>
<td>3.188</td>
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<td>Affinity diagram</td>
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<td>Benchmarking</td>
<td>94</td>
<td>6</td>
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<td>Quality costing analysis</td>
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<td>3.000</td>
<td>3.667</td>
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<td>SIPOC model</td>
<td>44</td>
<td>56</td>
<td>3.286</td>
<td>3.167</td>
</tr>
</tbody>
</table>

Table IV. Tools and techniques used by SMEs utilising six sigma
SMEs felt to be important and make a comparative study with the CSFs identified from previous studies by the authors in large corporations. The 11 CSFs identified from the literature were:

1. Management involvement and participation (A).
2. Organisational Infrastructure (B).
3. Cultural change (C).
4. Training (D).
5. Linking six sigma to customers (E).
6. Linking six sigma to business strategy (F).
7. Linking six sigma to employees (G).
8. Linking six sigma to suppliers (H).
9. Understanding of six sigma methodology (I).
10. Project management skills (J).
11. Project prioritisation and selection (K).

Figure 3 illustrates the CSFs for the successful implementation of six sigma within UK manufacturing SMEs. Figure 3 shows that management involvement and participation (A), linking six sigma to customers (E) and linking six sigma to the business strategy of the organisation (F) are the most important factors for the successful implementation of six sigma followed by organisational infrastructure (B), understanding of six sigma methodology (I), training on six sigma (D), and project prioritisation and selection (K). These findings were quite similar to the findings from other previous studies carried out by one of the authors with some changes in the order of importance of these CSFs. For instance, in the service industry, the top three CSFs for six sigma implementation were linking six sigma to business strategy (F), linking six sigma to customers (E), and executive leadership and senior management commitment (A). A recent study carried out by the first author in the software industry has revealed the following three CSFs in their ascending order of importance (Antony, 2004):

![Figure 3. Critical success factors of six sigma implementation in SMEs](image-url)
Conclusion
Six sigma has evolved into a business strategy in many large organisations and its importance in SMEs is growing everyday. Six Sigma within SMEs is rapidly emerging as the new wave of change in six sigma. To the best of our knowledge, this study is among the few pilot survey conducted in the UK manufacturing SMEs. We were not able to identify any such surveys in our literature review.

Due to the limited sample size of the current study, it has been decided to carry out a large-scale survey in UK SMEs in the future for greater validity of the findings from this research. A number of semi-structured interviews will also be performed as part of the next phase of this research. The authors will take the strengths and weaknesses of SMEs into account in the future semi-structured interviews. This would enable the authors to have a deeper understanding of six sigma implementation within the SMEs. The authors also intend to conduct a longitudinal study on six sigma within SMEs in the UK and other countries. In order to assist SMEs with the implementation of six sigma, the authors are recommending a six sigma user group (SSUG) to share and exchange experiences of successful six sigma projects within SMEs as well as with similar companies which embark on six sigma programme. The results presented in this study are exploratory and are based primarily on descriptive statistics. No attempt is made to generalise the outcomes. Future studies will attempt to generalise some of the findings.

References
Adams, C.W., Gupta, P. and Wilson, C. (2003), Six Sigma Deployment, Butterworth-Heinemann, Burlington, MA.


