Multiple case-study analysis of quality management practices within UK Six Sigma and non-Six Sigma manufacturing small- and medium-sized enterprises

M Kumar[1] and **J Antony**[2]*
[1]School of Management and Law, Napier University, Edinburgh, UK
[2]Design Manufacture and Engineering Management, University of Strathclyde, Glasgow, UK

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Abstract: Although the benefits of Six Sigma are widely reported in many large organizations, research has shown that its implementation in UK small- and medium-sized enterprises (SMEs) is still less evident. This paper attempts to perform a multiple case-study analysis of the quality management practices within the UK Six Sigma and non-Six Sigma manufacturing SMEs. It was found from the case studies that strong leadership, management commitment, communication, education, and training were critical in introducing and driving any culture-change initiatives such as Six Sigma within SMEs. Resource constraints, several changes in management, lack of management commitment, and resistance to change were considered as impeding factors for successful introduction of change initiatives such as Lean or Six Sigma. The Six Sigma firms realized a significant improvement in the performance of operational metrics (such as scrap rate, cycle time, on-time delivery, and yield) and strategic metrics (such as sales, profit, customer satisfaction) after its successful implementation as compared with non-Six Sigma companies. Academic institutions can play a vital role in facilitating Six Sigma implementation in SMEs. The article concludes with the statement that there are critical differences in quality management practices of Six Sigma and non-Six Sigma SMEs, affecting their business performance.

Keywords: Six Sigma, Lean, SMEs, ISO, case study, critical success factors

1 INTRODUCTION

In the last two decades there has been an explosion of research into the role of the small- and medium-sized enterprises (SMEs) within a national and global context, resulting in a considerable body of academic literature and thinking [**1**]. The SMEs constitute the bulk of enterprises, with a major contribution to private-sector output and employment in all economies of the world [**2**–**6**]. SMEs not only contribute to employment and turnover but also play a major part in enhancing the competitiveness of larger organizations by being an essential element of their supply chain and providing high-quality input [**3**, **4**].

To keep abreast with the increasing competition from the low-labour-cost economies, SMEs need to have unprecedented focus on high product quality and consistent and reliable delivery service to their customers [**7**]. In the quest for process improvement, organizations have pursued formalized change programmes or quality initiatives such as total quality management (TQM) and continuous improvement methodologies such as Kaizen [**8**], breakthrough improvement methodologies such as business process re-engineering (BPR) [**9**], and more recently Six Sigma [**10**, **11**]. Six Sigma has evolved significantly and continues to expand since its inception at Motorola in the mid-1980s to improve the process performance, enhance business profitability, and increase customer satisfaction [**11**]. Six Sigma is considered as one of the most effective process improvement methodologies among a large number of multinational organizations, with its adoption showing an upward trend [**12**]. It provides business executives and leaders with the

*Corresponding author: CRISSPE, Design Manufacture and Engineering Management, University of Strathclyde, Glasgow G1 1XJ, UK.
email: jiju.antony@strath.ac.uk

strategy, methodology, infrastructure, tools, and techniques to change the way businesses are run [**13**].

The adoption of Six Sigma as a business strategy by large multinational corporations such as General Electric, Honeywell, Motorola, Seagate Technology, Caterpillar, Raytheon, ABB, Bombardier, and Sony had a significant impact on the working culture and bottom-line benefits of these organizations. In spite of a number of Six Sigma success stories in large organizations, many SMEs are yet to be convinced of the benefits from the introduction, development, implementation, and deployment of Six Sigma. In order to explore the practicality of Six Sigma implementation within UK SMEs, this research attempts to compare the quality management practices within Six Sigma and non-Six Sigma SMEs through a multiple case-study analysis. The next section discusses the research methodology adopted to explore the quality management practices in UK SMEs.

2 RESEARCH METHODOLOGY

The objective of the study is to assess the status of Six Sigma implementation in UK manufacturing SMEs and compare the quality management practices of Six Sigma and non-Six Sigma certified firms. Given the nature of research, a case-study-based approach seemed appropriate. Yin [**14**] defines a case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. It focuses on understanding the dynamics present within single settings [**15**]. Case-study research is one of the most powerful research methods in operational management, particularly in the development of new theory [**16**]. It is argued to be a favourable strategy for attaining a broad understanding of the research context, and the procedures being announced [**17**]. In addition, the multiple sources of confirmation are emphasized and are viewed as critical in terms of securing data [**18**].

In the first part of the research (which is beyond the scope of this article), the authors identified a list of SMEs implementing quality initiatives such as Lean, Six Sigma, total quality management (TQM), and Kaizen, and certification systems such as ISO 9000 or Investors in People (IIP), by conducting a survey in 500 SMEs across the UK. For more information about the findings, see reference [**19**]. SMEs that participated in the survey were randomly selected for conducting in-depth interviews with respect to their quality management practices and their impact on organizational performance. This strategy further helped in checking for bias in selecting the case-study companies.

After the identification of SMEs implementing Six Sigma/Lean and ISO, multilevel case studies were conducted in four SMEs. Selection criteria were based on size, type of industry, location, and type of quality practices in the SMEs. Semi-structured interviews were conducted for data collection, targeted at three levels in the organization, i.e. senior managers, middle managers, and shop-floor employees, with each interview lasting for about 90 min, to get more in-depth knowledge on the quality management practices prevalent in Six Sigma and non-Six Sigma firms. The questionnaire was designed by reviewing the past literature on quality management practices in SMEs [**2–4**, **6**, **20–26**]. The interview questionnaire covered: demographic details of the firms; the type of quality initiatives in the sample firms; critical success factors and barriers to implementation; and linking the quality initiative to organizational performance. The questionnaire was pilot tested with a sample firm, as suggested by Yin [**14**], and the questionnaires were revised on the basis of interaction with several management people in the pilot firm. Some questions were added and others deleted, but the theme of the study remained the same. The next section discusses the findings from in-depth case studies in four SMEs.

3 CASE-STUDY ANALYSIS

3.1 Demographic details of the companies

3.1.1 Company A

Company A was established in 1984, specializing in the design and manufacture of PC data communications hardware. It employs 36 people, with an annual turnover of £3.4 million in 2007. The company has won several awards in the last two decades on account of its success in maintaining a growing manufacturing capability that embraces Lean and Six Sigma.

3.1.2 Company B

Company B was formed in 2002 from the merger of two parent companies (each of the parent companies employed less than 50 people) in England. Presently, there are 106 employees generating an annual turnover of £5 million. The company specializes in the design and manufacture of high-temperature metal seals, gaskets, CNC machined components, and complementary products for the aerospace, automotive, and industrial sectors.

3.1.3 Company C

Company C was formed in 2002 after splitting from its parent company which had been in business for nearly 70 years. The parent firm employed 300 people in 1977, and the headcount of company C after the

Table 1 Company demographic details

Company	Manufacturing activity	Company type	Annual sales turnover	Location	Number of employees
A	Electronics and semiconductor	Independent	£3.4 m	England	36
B	Mechanical	Independent	£5 m	England	106
C	Paper, printing, and packaging	Independent	£20 m	Scotland	88
D	Electrical	Independent	£6.5 m	Scotland	86

split was 88. The company manufactures products that ranges from different types of paper (including adhesives and liners) to thermally coated tags and tickets for the food industry, airline ticketing, and other packaging industries.

3.1.4 Company D

Company D employed 2200 employees in the late 1970s, being the sole market leader in providing appliances for boilers and central heating. It currently employs 86 people, with an annual turnover of £6.5 million. Its products, ranging from room and hot-water thermostats to central heating programmers, represent over 60 years of excellence in serving the domestic heating industry.

Other demographic details of the companies are provided in Table 1. All four case-study companies are local independent firms, not being part of multinational corporations. The types of manufacturing activity in the sample firms range from electrical and electronics to mechanical and packaging. Companies A and B are young firms, while firms C and D have existed for nearly seven decades.

3.2 Understanding the quality management practices in SMEs

3.2.1 History of quality initiatives in SMEs

Company A started with accreditation of BS 5750 in 1994, followed by ISO 9001:2000 certification in its effort to standardize the process and improve its market share. Extending its continuous improvement (CI), the company started Lean implementation in 2000, IIP certification in 2002, and embarked on the Six Sigma journey in 2003. The company failed to implement Lean successfully in its first attempt in 1998 owing to poor communication and no involvement of employees at the shop-floor level. The lessons learned from this mistake helped the company successfully to implement Lean in 2000 by introducing it at shop-floor level. All the employees in the company attended a one-day workshop on the basics of Lean and its impact on business performance at both strategic and operational levels. Once the employees realized the benefits of Lean implementation and started believing in the principles of continuous improvement, the management decided to embark on Six Sigma to tackle the variation problems existing in their business processes. Hitherto, the management is committed to continue investing resources in Six Sigma training not only in the production department but also in support functions of the business such as finance, human resources, and sales and marketing.

Before Company B was formed by the merger of two parent companies, they achieved the AS 9100 certification required for the aerospace industry and the TS 16949 certification for the automotive industry. After the merger, the firm acquired ISO 9001:2000 certification in 2003, followed by Lean implementation in 2005. In early 2007, Six Sigma principles were embraced after streamlining the business functions using the Lean concept. At the time of interview, the company had already started applying Lean and Six Sigma principles in the administrative and finance processes.

Companies C and D had gone through the route of ISO 9001:2000 accreditations in order to sustain their business in the global market. Both these companies have existed for more than 50 years, witnessing several changes in management, acquisition and merger into different groups, and transition in size from a large organization to the SME category. Total quality management (TQM) was introduced in company C in 1994 but failed owing to restructuring of the company and change at the top management level. Company D had recently started applying Lean principles to minimize waste at the shop-floor level.

Table 2 summarizes the quality initiatives undertaken in the case-study companies to date.

3.2.2 Motivation behind embarking on quality initiatives

Table 3 provides information on the motivation behind implementation of CI initiatives such as Lean and Six Sigma or certification systems such as ISO 9001:2000 in the case-study companies. In both companies A and B, the implementation of initiatives such as Lean and Six Sigma was supported by the managing director (MD) of the company. The MD in both firms communicated the need by addressing the entire organization and setting out the competitive advantages provided by the Lean and Six Sigma business strategies. The MDs were committed to keeping the business sustainable on a long-term basis, resulting in the implementation of CI initiatives

Table 2 History of quality initiatives in the case-study companies

	Company A	Company B	Company C	Company D
History of quality programme (QP) or certification achieved and the corresponding year	BS 5750 (1994)	AS 9100 (1992)	ISO 9000 (1992)	ISO 9000 (1993)
	ISO 9001:2000 (2001)	TS16949 (1994)	TQM (1994)	ISO 9001:2000 (2003)
	Lean (2001)	Total quality management (TQM) (late 1990s)	ISO 9001: 2000 (2003)	Lean (2007)
	Investors in People (IIP) (2002)	IS 9001:2000 (2003)		
	Six Sigma (2003)	Lean (2005)		
		Six Sigma (2007)		
Existing QP	Six Sigma; Lean	Six Sigma; Lean	ISO 9001: 2000	ISO 9001: 2000; Lean

Table 3 Reasons to embark on CI initiatives or certification systems

	Company A	Company B	Company C	Company D
Motivation to implement existing QP	*Lean*	*Lean*	*ISO 9001:2000*	*ISO 9001:2000*
	To improve workflow	Optimal utilization of workspace at new factory site	Pressure from market place	Improving market share
	Results are quickly visible	Minimize waste	Customer led rather than company led	Retaining existing customer
	Good for first round of improvement		Holding on to existing client	Provides guideline for standardization
		Six Sigma	Preferred supplier status	
	Six Sigma	Some problems difficult to resolve using Lean tools	Standardization of procedures	*Lean*
	To inculcate process thinking	To reduce variation in administrative processes		Organization of the shop floor
	Eliminate variation			
	Structured methodology	Good for resolving complex problems with unknown solution		Cleanliness of shop floor
	Projects linked to bottom line	Customer focus		Good control over inventory
	Customer-focused approach			Minimization of floor-space utilization

and allocating resources to drive improvements in quality, performance, and customer satisfaction. Other reasons cited by companies A and B for embarking on the Lean and Six Sigma journey are presented in Table 3. The management team in company A took the view that 'if Six Sigma is good enough for GE and other world class companies, why should we not consider it'. The success of any CI initiative hinges on the commitment and buy-in from the top management to devote time and resources and break down stumbling blocks in the implementation process, as seen in companies A and B.

For companies C and D, the main objective behind achieving ISO certification was to improve their market share and retain existing customers. Similar reasons were cited by researchers in the past as the motivation, driving SMEs to obtain ISO certification. However, interviewees in all four firms believed that accreditation also facilitated documentation and standardization of the procedures in place.

The new standard ISO 9001:2000, as believed by company C, eliminates the bureaucracy, with more focus on a proactive approach to data gathering and making continuous improvement. The interviewees in companies C and D strongly accentuated the point of having standardized procedures in place to understand processes and measure process performance. If the procedures are not formalized, employees do the same things in different ways, creating confusion and chaos in the organization. It is almost impossible to implement Lean or any kind of strategic improvement initiatives without having established processes and procedures in place. It also depends on the maturity and existence of the firm: if it is a new business with 10–20 employees, ISO may help to establish the procedures. After documenting

the procedures, the company is in a position to define their process, understand the input/output, and start measuring their process by collecting data. This is the time when the company is ready to embark on Six Sigma.

Owing to several changes in the management structure, companies C and D lost focus on CI and operated in a fire-fighting mode for survival in the business. Company C tried to launch total quality management (TQM) in 1994 but failed to reap the benefit as the initiative was led by a single person, i.e the technical director of the company. There was no transferability of learning after the retirement of the technical director in 1995. The group of people who supported the initiative did not have the decision-making power to take the initiative further.

Similarly, under the leadership of a newly appointed director in the late 1990s, company D experienced a serious jolt on the CI journey. The MD believed in crisis management, was reluctant to allocate resources for training and development of employees, and discouraged staff who came up with new ideas for process improvement. As stated by one of the company employee's 'We are still suffering from the demotivation that staff developed in the period of that MD'. The current MDs and the senior management teams in companies C and D have realized the importance of initiatives such as Lean and Six Sigma but are struggling to allocate resources and time for the same.

The MD of company A viewed ISO 9000 as '*a way of retaining and winning business. If you adopt a standard, it puts some structure in your company, which you can make work for you, and align to your goal. We were better organized as to how we stored components. We had a more formal production line, everything labelled and defined (defined assembly process, inspection process, test process). I learnt that these standards are a great enabler*'. Other senior and middle management executives expressed their view that ISO helped the company in establishing the structure and implementing procedures and worked as a foundation to get started with Lean and Six Sigma. Similar findings were reported during the interview with executives in companies B, C, and D.

3.2.3 Existing organizational infrastructure in SMEs

The term 'organizational infrastructure' refers to the number of trained quality personnel responsible for implementing Lean, Six Sigma, or ISO and driving CI efforts in the company. To test the efficacy of Lean and Six Sigma on a pilot project, companies A and B trained their best people as black belt (BBs) and green belt (GBs) to carry out pilot projects. A team comprising these people was selected from cross-functional departments and was assisted by shop-floor employees (trained as yellow belt (YBs)) to execute projects. These BBs and GBs were responsible for executing projects across the business functions. Company A managed to secure funding (30 per cent of the training cost) to get started with external Six Sigma BB training in the first year of the Six Sigma implementation. Similarly, company B employees were trained as GBs by one of their customers (original equipment manufacturer (OEM)) at a discounted price. Even without external support and funding, the MD in both companies was ready to commit resources for the training of employees.

On the other hand, quality was the responsibility of the quality department in company C, and very basic training was provided to shop-floor employees to manage their processes. Company D had invested time and money in training shop-floor people and middle managers. The management was open to new ideas of process improvement such as Lean and Six Sigma. The company was getting support from a local government body in implementing the concept of Lean on the shop floor. Table 4 below provides information on the infrastructure existing to drive improvement across the business functions.

The literature identifies resource constraints as one of the barriers to the successful implementation of any change initiatives in SMEs [**2**, **6**, **11**, **19**, **27**, **28**]. However, there are other schools of thought that

Table 4 Organizational infrastructure to support quality management practices in SMEs

	Company A	Company B	Company C	Company D
Organizational infrastructure	Two BBs (externally trained)	One BB (trained in previous job)	Two YBs (external training)	Three YBs (external training)
	Two GBs (externally trained)	Three GBs (training provided by external customer)	Quality is responsibility of quality department	Project and wuality manager responsible for product quality
	All employees trained as YBs (internal training)	Nine GBs ongoing training	Employees not properly trained in ISO	Employees provided proper training whenever required
		All employees trained on basics of Lean and Six Sigma		

consider lack of knowledge and understanding of CI initiatives to be critical reasons for poor implementation, apart from the often-cited issues of cost and time [**2**, **4**].

Interviewees in the four companies did not agree with findings from the past literature and argued strongly that 'leadership and management commitment to resources governs the success of a new initiative'. Scarcity of resources is just an excuse from the top management, who continue to work in a fire-fighting mode to tackle mundane problems rather than being proactive in CI. Company A with 36 employees has managed to roll out Six Sigma across the business as a result of strong leadership and management commitment. The training of BBs and GBs is indeed a heavy investment, but the savings generated from the projects outweigh the investment made. The MDs of companies A and B were in consensus with the aforementioned viewpoints.

4 CRITICAL SUCCESS FACTORS AND BARRIERS TO IMPLEMENTATION OF QUALITY INITIATIVES

Critical success factors (CSFs) are those factors that are critical to the success of any organization, in the sense that, if objectives associated with the factors are not achieved, the organization will fail, perhaps catastrophically so [**29**]. Boynton and Zmud [**30**] defined CSFs as 'those few things that must go well to ensure success'. Other researchers such as Brotherton and Shaw [**31**] define CSFs as the essential things that must be achieved by the company or the areas that will produce the greatest 'competitive leverage'. In the context of Six Sigma project implementation, CSFs represent the essential ingredients without which a project stands little chance of success [**32**].

Factors identified as critical to the success of CI initiatives or the follow-up of accreditation achieved are listed in Table 5 below. The success of companies A and B in implementing Lean and Six Sigma is attributed to strong leadership and management commitment to drive and ingrain the initiatives within the fabric of the organization. The MDs in companies A and B believed in the walk-the-talk approach rather than the talk-the-talk approach. They had managed to devote time to Six Sigma introductory training, and had also been involved in project review meetings. One of the directors in company B has carried out a GB project, which clearly reflects the commitment from the top. The MD of this company carries out a monthly 5S audit across business functions and communicates with the shop floor to discuss any personal or business issues and address the same. Also, a Six Sigma BB has been appointed to focus on the training of internal employees and developing metrics for organizational improvement. Employees in both companies are empowered to take decisions for their processes, thus giving them process ownership.

Six Sigma was included within the top three priorities of the business in companies A and B. Six Sigma was a part of everybody's job, including top

Table 5 CSFs and barriers to implementation of quality initiatives

	Company A	Company B	Company C	Company D
What aids implementation?	Strong leadership	Commitment from top level	Communication	Leadership
	Commitment from top management	Culture	Process documentation	Communication
	Commitment from middle managers	Senior management buy-in	Regular audits	Strategic vision
	Education and training	Cross-functional team		Data collection and measurement
	Communication	Empowerment of workforce		Role of middle manager
	Empowerment	Communication		
	Project selection	Full-time facilitator to drive and manage QI		
	Cross-functional team	Education and training		
	Balance between daily work and BB or GB job			
	Involvement of finance department			
What hinders implementation?	Role of middle managers	Complacency	Change in management	People prefer status quo
	BBs or GBs getting involved in other work	Training	Lack of management commitment	Lack of vision
			Poor training and coaching	Barrier between shopfloor and rest of staff
			Allocation of resources	

management and senior managers. Providing strong leadership, the top management team made resources available for training the employees and executing projects, were present in project review meetings, and broke down stumbling blocks during project execution. Communication from the top facilitated in breaking down any resistance to change in these two companies. One of the key characteristics of Six Sigma that has enticed many CEOs of world-class companies is the link between project execution and hard dollar savings, i.e the financial impact generated by the initiative [**33**, **34**]. In the last couple of years, company A has started to involve the finance department in cost-benefit analysis at the start of a Six Sigma project. The Six Sigma team now involves people from the finance and accounts department, led by the finance director (FD), to quantify the real hard benefits from the project. The FD is acting as a champion for all current Six Sigma projects in company A and is involved in the cost-benefit analysis of the project and in control of deciding where the company can make hard savings.

On the other hand, top management in company C has communicated the need for certification to employees and considered it as a goal to achieve quality improvement. The main focus in companies C and D is on regular audits that help to keep their quality records up to date, i.e. processes are mapped, metrics established, and data collected for auditing purposes. However, the process documentation and data collection strategy in companies C and D has helped in measuring performance for some of their processes. Senior managers in these two companies felt that resource allocation was the biggest hindrance in driving the certification effort or implementing initiatives such as Lean and Six Sigma. It is the absence of strong leadership, several changes in management, and the lack of vision and commitment from the top that is hindering quality improvement efforts in companies C and D.

One of the typical barriers encountered in company D is alienation between shop-floor employees and the rest of the staff. There are separate canteens for staff members and shop-floor employees, which further limits the interaction and friendly communication between the two groups. Another impediment in companies A and B was involvement of BBs or GBs in day-to-day activities apart from carrying out projects. Sometimes the role of middle managers in releasing their employees for training and review meetings was also a hindrance in company A.

Interviewees in companies A and B commented on the role of local universities and government bodies in supporting SMEs to embark on CI initiatives. Partial government funding encouraged company A to train more employees in Six Sigma. The employees in companies A and B never supported the idea of bringing in external consultants for Six Sigma training, often requiring large up-front investment and providing only temporary solutions to their chronic problems. From the economic and long-term sustainability perspective, collaboration with local universities through programmes such as Knowledge Transfer Partnership (KTP) was considered imperative for the success of SMEs. Antony [**35**] also stressed the role of academic institutions 'to help SMEs to meet their customer or stakeholder needs and assist them in creating value for their customer. This will ensure development of a stable, long-term, and cost-effective relationship between the organization and academic institution'.

5 IMPACT OF QUALITY PROGRAMME ON PERFORMANCE INDICATORS

Interviewees in the case-study companies were asked to rate, on a Likert scale of 1 to 5, the benefits their organizations have experienced following the implementation of quality initiatives. Table 6 shows the

Table 6 Evaluation of nine performance indicators against company policies

	Performance evaluation of companies on 1 to 5 Likert scale*			
Performance indicators	A	B	C	D
Reduction in scrap rate	5	4	3	3
Reduction in cycle time	4	3	6	4
Reduction in delivery time	3	3	3	4
Increase in productivity	4	4	4	3
Reduction in costs	4	5	3	3
Increase in profitability	4	4	3	3
Improved sales	4	5	3	3
Reduction in customer complaints	4	3	4	3
Reduction in employee complaints/grievances	3	3	6	3

*1 = negative benefit/improvement; 2 = no benefit/improvement; 3 = some benefit/improvement; 4 = significant benefit/improvement; 5 = crucial; 6 = measure not used.

Table 7 Benefits from Lean implementation

Project	Hard savings	Soft savings
Reduction in changeover time	30 % reduction	Increased employee efficiency
Reduction in rework on purchase order	50 % reduction	Cleaner and safer work environment
Reduction in technical support enquiries	15 % reduction	Proactive approach to problem solving
Reduction in floor space utilization	£10 k/year	High job retention
Reduction in scrap rate	84 % reduction	High employee satisfaction
Reduction in raw material and finished good inventory	30 % reduction	Improved technical support process

degree of improvement realized on a 1 to 5 scale after the implementation of quality initiatives. The score across each of the performance indicators reflects the improvement made by the SME after implementing the programme. The table gives information on the performance metrics existing in the company and the improvement realized after implementation of the programme. It can be seen from Table 6 that company A has realized significant improvements in operational measures (including reduction in scrap, cycle time, and delivery time, and increase in productivity) and strategic measures (including increase in sales and profit and reduction in costs) of organizational performance from the implementation of Six Sigma. Since company B implemented Six Sigma in 2007, they have started to realize improvements in the established performance metrics.

The improvement in the performance of company C is not the result of ISO certification, but of the use of tools and techniques of continuous improvement, as cited by the interviewees. The company has managed to reduce customer complaints by working close with the customer and through the nature of their personal business. The improvement can be attributed to the company's reaction to changing market forces and stiff competition. However, ISO has helped in developing process thinking, working closely with customers, and improving delivery performance.

Unlike the other three companies, company C does not use metrics such as reduction in cycle time or reduction in employee complaints. Similarly, in company D, improvement is the result of using tools and techniques, implementing the ERP system, and adhering to the basic concept of Lean manufacturing, i.e 5S practice. Typical improvements that can be achieved through Lean and Six Sigma are shown in Tables 7 and 8. The tables are based on improvements witnessed in company A.

Since the company started Lean, all core processes, from receipt of order to dispatching, have been mapped, resulting in improvements in throughput and overall equipment effectiveness (OEE). The implementation of 5S resulted in reorganization of the manufacturing line, which in turn brought savings of over £10k per annum. Some of the other improvements through the Lean initiative are listed in table 7. Since the implementation of Six Sigma, company A has executed five projects that have had a significant impact on customer satisfaction and bottom-line savings of over £180 000. Some of the benefits from Six Sigma implementation are indicated in Table 8. Similarly, company B has finished six Six Sigma projects, resulting in savings of over £200 000. The benefit from Lean implementation through eight projects has been estimated at over £150 000.

Table 8 Impact on the business from Six Sigma implementation

Project	Impact on the business
Improving OTIF (On Time In Full) for sales order delivery	Immediate improvement by 28 %
Improving raw material stock accuracy	51 % reduction
Improved finished good stock accuracy	87 % reduction
Reduction in solder shots	Immediate reduction by 98 %
Reduction in sales order defect	Currently in progress

6 DISCUSSION AND CONCLUSION

This paper has attempted to perform a comparative analysis of quality management practices in Six Sigma and non-Six Sigma SMEs by conducting multilevel case studies in four SMEs. The research demystifies the fact that Six Sigma can be implemented only in large organizations. The findings clearly demonstrate that Six Sigma can be implemented successfully in any organization, irrespective of the size of the company, as observed in companies A and B. The critical differences between Six Sigma (SS) and non-Six Sigma (NSS) firms, as identified by the case-study analysis, are reported below.

1. Strong leadership and top management commitment are the key characteristics of the successful Six Sigma firms, i.e. companies A and B. Their role in allocating resources and breaking down stumbling blocks is exemplary. The MDs of companies A and B went through Six Sigma training and project execution, leading from the

front and citing examples to the rest of the employees on the efficacy of SS methodology. These characteristics were missing in companies C and D.
2. SS SMEs selected their most talented people across the organization for training on SS and execution projects. Process improvement was the responsibility of the quality department in the NSS firms.
3. Employees in the SS firms were empowered to make decisions for their own processes. The decision-making power in the NSS firms was entrusted to middle-level managers or supervisors on the shop floor.
4. Each SS project was linked to bottom-line savings, as discussed in section 5. Also, people from the finance department were involved in cost-benefit analysis before embarking on any SS project. No such steps were taken in the NSS firms.
5. Significant differences in performance were observed in the SS and NSS firms, as discussed in section 5. The SS firm performance outweighed that achieved by the NSS SMEs.

In spite of the critical differences between the SS and NSS firms, interviewees in all four firms agreed on the role of ISO in establishing formal procedures and putting systems in place before embarking on Lean or Six Sigma. Similar findings were reported by Kumar and Antony [**19**] during a survey conducted in 64 UK manufacturing SMEs. However, these findings should be treated cautiously owing to small sample size of the SMEs. Future research will be undertaken by the authors to test the validity of the findings.

It is imperative for SMEs to have a strong management commitment and good leadership skills before embarking on the Six Sigma programme. If Six Sigma is only considered as the implementation of statistical tools and techniques to solve complex problems in the organization, it is doomed to fail owing to its very weak linkage to strategic business objectives. Six Sigma is about overall business strategy, culture, and change, and the small companies embarking on the Six Sigma initiative need to build all of this into a sound corporate strategy plan [**35**].

Networking with academic universities may facilitate knowledge transfer and enhancement of existing capabilities within the SME. The Knowledge Transfer Partnership (KTP) programme between academic institutions and industry is an effective vehicle for enabling the introduction and application of CI initiatives within SMEs. However, very few SMEs (less than 2 per cent) are acquainted with this scheme [**7**]. Knowledge of schemes such as KTP may alleviate SME concerns and dependability on external consultants for enhancing their process performance.

The next phase of the study will aim to construct a bespoke framework for SMEs to get started with Six Sigma implementation. The framework will be based on the findings from a systematic literature review, survey, and multiple case studies conducted in UK manufacturing SMEs. The framework will be further tested in 2–3 case-study companies to check its validity and robustness in different environments. The research will also attempt to check the readiness of an organization to embark on the Six Sigma journey. Future research should attempt to establish the organizational infrastructure for Six Sigma implementation in SMEs (i.e. the number of BBs, GBs, and YBs in a SME with less than 250 employees), as well as the financial savings generated from a typical BB or GB project.

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