Reconstructing Six Sigma barriers in manufacturing and service organizations

The effects of organizational parameters

Mohamed Gamal Aboelmaged
Faculty of Commerce, Ain Shams University, Cairo, Egypt

Received March 2010
Revised October 2010
Accepted December 2010

Abstract

Purpose – The purpose of this paper is to empirically validate how the effectiveness of the most influential barriers to Six Sigma implementation may vary in relation to dimensions of organizational factors in a developing country.

Design/methodology/approach – An empirical survey, using 500 self-administered questionnaires, was conducted. Data about 47 Six Sigma barriers and specific organizational parameters from 132 usable questionnaires, with a response rate of 26.4 per cent, were collected and analyzed by means of statistical data analysis package.

Findings – The results highlight the key role of soft impediments, i.e. knowledge and support, and hard impediments, i.e. professionals and finance, as the most influential barriers to Six Sigma implementation. The analysis clearly shows that only specific barriers are significantly influencing Six Sigma implementation in relation to dimensions of organizational factors.

Practical implications – Decision makers and quality managers should not waste their resources on overcoming all Six Sigma barriers. High attention should be given to the most obstructing barriers in relation to organizational context. Before implementing Six Sigma projects, managers are advised to activate and boost the level of Six Sigma knowledge and support by means of knowledge management functions such as Six Sigma knowledge acquisition, sharing, storing, revealing, etc. among organizational members.

Originality/value – The paper is one of the first studies which examines a large number of Six Sigma barriers and their effectiveness in relation to dimensions of organizational factors in a developing country.

Keywords Six Sigma, Quality, Organizational behaviour, Developing countries, United Arab Emirates

Paper type Research paper

Introduction

The last two decades have witnessed a growing emphasis on the implementation of Six Sigma quality as a mean for improving company's competitive position. It was initially developed by Motorola in the 1980s and then adopted by companies such as Allied Signal, IBM, and General Electric to improve work processes, expand employees' skills and produce high-level strategic results. Now, Six Sigma methodology and tools are well established in almost every industry and many organizations worldwide. There are two major improvement methodologies in Six Sigma. The first methodology, DMAIC, is used to improve already existing processes and can be divided into five phases; define, measure, analyze, improve and control. Several studies have shown successful cases of DMAIC application in a variety of contexts such as healthcare (Dreachslin and Lee, 2007), thermal power plants (Kaushik and Khanduja, 2008),

International Journal of Quality & Reliability Management
Vol. 28 No. 5, 2011
pp. 519-541

0265-671X
DOI 10.1108/02656711111132562

retailing (Kumar *et al.*, 2008a), financial services (Kumar *et al.*, 2008b) and manufacturing process (Li *et al.*, 2008; Tong *et al.*, 2004). In contrast, the second methodology, design for Six Sigma (DFSS), is used for new processes or when the existing processes are unable to achieve business objectives. DFSS methodology can also be divided into five phases (DMADV); define, measure, analyze, design and verify (Banuelas and Antony, 2003). Antony (2002) refers to DFSS as a powerful approach to design products and processes in a cost effective and simple manner.

When Six Sigma is implemented successfully, it will offer many benefits to the business unit. The most cited benefit of Six Sigma in the literature is customer satisfaction (e.g. Behara *et al.*, 1995; Chen *et al.*, 2005; Das *et al.*, 2006; Desai, 2006; Douglas and Erwin, 2000; Ganesh, 2004; Kuei and Madu, 2003; Kumar *et al.*, 2007; Rylander and Provost, 2006). Freiesleben (2006) suggested that successful application of Six Sigma quality is positively correlated with better financial performance and profit generation. In the manufacturing context, Six Sigma has a positive impact on productivity and profitability as a result of reduction in process variability, inventory, maintenance time, and cost of poor quality (Antony *et al.*, 2005; Kwak and Anbari, 2006). Service organizations adopting Six Sigma strategy will have improved service delivery as a result of accurate allocation of resources and reduced defects and variability in service processes (Antony, 2006; Kwak and Anbari, 2006).

Despite these benefits deriving from Six Sigma quality, successful implementation of Six Sigma is not easily achieved. Rather, the organization is confronted, by many serious challenges, such as limited resources, lack of support, inadequate selection of Six Sigma projects, and inadequate organizational structure (Snee, 2001). While there is a little amount of research targeting the obstructive role of barriers to Six Sigma implementation, the impact of organizational factors on these barriers, particularly in a developing country context, has been given scant attention.

This paper presents new data and new empirical insights into the barriers to Six Sigma implementation in United Arab Emirates (UAE), a Middle Eastern country situated in the southeast of the Arabian Peninsula in Southeast Asia. Consequently, understanding how barriers to Six Sigma implementation are influenced by specific organizational factors may inform management decisions regarding quality improvement resources, processes, operating procedures and information flows.

The remainder of the paper is organized as follows: the paper first reviews previous empirical research on barriers to Six Sigma implementation; it subsequently sets out the research questions; then the research methodology adopted for the present study is explained; next the study findings are analyzed and discussed from overall and organizational perspectives. Finally, several conclusions are derived from this study, as well as implications for quality managers.

Literature review

Although its popularity as a powerful strategy, Six Sigma still lacks a theoretical underpinning with other management theory (Antony, 2008b). However, Linderman *et al.* (2003, 2006) attempt to enhance the underlying theory by linking Six Sigma to goal theory. They develop a set of propositions, which need further empirical verification. Other Six Sigma challenges are related to its application. While Six Sigma was launched and developed in manufacturing, many authors have reported serious problems and difficulties associated with its application in a manufacturing setting.

McAdam and Evans (2004) claimed that Six Sigma program is weak in transforming customer needs into products. Antony (2008a), Antony *et al.* (2005) and Kumar *et al.* (2009a, b) focused on lack of physical and professional resources such finance and training as the key inhibitors of Six Sigma implementation in small- and medium-sized UK manufacturing enterprises.

Moreover, Martins *et al.* (2006) investigated enablers and inhibitors of Six Sigma project in a Brazilian cosmetic factory. They pointed to the vital impact of planning and measurement barriers such as difficulty of acquiring quality data, poor estimation of financial gain, and inadequate measurement skills on Six Sigma implementation. On the other side, Six Sigma implementation in the service sector is even more dramatic.

In their attempt to identify difficulties in implementing Six Sigma in Singaporean service organizations, Chakrabarty and Chuan (2009) recognized data collection as one of the most serious problems faced by service organizations. Also, they observed that part-time involvement in Six Sigma projects due to insufficient resources leads to major difficulties in sustaining Six Sigma projects that are considered to be complex process.

In addition, Antony (2004) and Antony *et al.* (2007) specified a number of managerial and technical challenges that hinders Six Sigma implementation in UK service organizations. While managerial barriers involve resistance to change and unleashed Six Sigma business strategy, technical problems are related to lack of data acquisition and analysis regarding DPMO processes and parameters.

Taner *et al.* (2007) presented an overview of Six Sigma applications in healthcare industry. Accordingly, impediments to Six Sigma implementation were mainly related to large investment in six-sigma training, poor statistical competence, mismanagement of Six Sigma implementation time, and unclear project selection criteria.

Using multiple case studies representing various sectors from Thailand, Hendry (2005) and Nonthaleerak and Hendry (2008) identified a number of difficulties associated with Six Sigma implementation process, which are concerned with selection criteria, applied tools, and sustainability of improvements. Furthermore, Antony and Desai (2009) affirmed that internal resistance, lack of physical, and professional resources, intangibility of results are among the core barriers that hinder Six Sigma implementation in Indian industry. Table I summaries empirical research on barriers to Six Sigma implementation. There are 47 Six Sigma barriers, which were identified in the literature.

Research questions

Several research questions provide the focus and framework of this paper, namely:

(1) How can barriers to Six Sigma implementation identified from literature review be classified into conceptually meaningful groups?

(2) What is the relative importance of barriers to Six Sigma implementation?

(3) How do barriers to Six Sigma implementation vary in relation to dimensions of specific organizational factors (i.e. industry type, organization size, implementation of Six Sigma, and ownership type)?

Six sigma barriers	Source
Narrow view of Six Sigma as data driven approach	Antony *et al.* (2005), Feng and Manuel (2008)
Lack of dedicated Six Sigma professionals	Buch and Tolentino (2006), Taner *et al.* (2007)
Resistance to change	Antony *et al.* (2005), Feng and Manuel (2008), Taner *et al.* (2007)
Intangibility of Six Sigma results	Antony and Desai (2009)
Incompetent Six Sigma skills	Buch and Tolentino (2006) Martins *et al.* (2006)
Complex Six Sigma tools and techniques	Hendry (2005), Hensley and Dobie (2005), Sinthavalai (2006)
Judgmental quality decision making	Antony *et al.* (2007)
No cross-functional team	Martins *et al.* (2006), Sinthavalai (2006), Snee (2001)
Inadequate specialized Six Sigma training	Hendry (2005), Kwak and Anbari (2006), Snee (2001)
Difficulty to sustain Six Sigma improvements	Hendry (2005), Chakrabarty and Tan (2007)
Inadequate measurement skills	Antony *et al.* (2007) Martins *et al.* (2006)
Weak understanding of customer wants	McAdam and Evans (2004), Kumar *et al.* (2009a, b)
Lack of top management support	Dahlgaard and Dahlgaard-Park (2006), Snee (2001), Taner *et al.* (2007)
Insufficient time to work on Six Sigma projects	Antony *et al.* (2005), Buch and Tolentino (2006), Chakrabarty and Tan (2007), Feng and Manuel (2008), Taner *et al.* (2007)
Weak presentation of Six Sigma findings	Feng and Manuel (2008)
Full-time effort required from professionals	Sinthavalai (2006)
Lack of awareness regarding Six Sigma value	Chakrabarty and Tan (2007), Feng and Manuel (2008)
Lack of statistical competence	Antony (2004), Sehwail and DeYong (2003), Taner *et al.* (2007)
Lack of supportive organizational culture	Dahlgaard and Dahlgaard-Park (2006), Sehwail and DeYong (2003)
Expensive start-up cost for Six Sigma projects	Antony (2004), Kumar *et al.* (2009a, b), Sinthavalai (2006)
Expensive application of Six Sigma results	Antony (2004, 2008a)
Large investment in Six Sigma training	Taner *et al.* (2007)
Poor communication of quality data	Antony *et al.* (2007a)
Uncertainty of Six Sigma results	Martins *et al.* (2006), Sehwail and DeYong (2003)
Unclear aspects of critical to quality (CTQ)	Antony (2004, 2008a)
Misunderstanding of process and sub-processes	Antony *et al.* (2007), Chakrabarty and Tan (2007)
Lack of identifying DPMO processes	Antony *et al.* (2007)
Lack of knowledge about Six Sigma	Buch and Tolentino (2006), Kumar *et al.* (2009a, b)
Non standardized certification of belt system	Antony (2004, 2008a)
Unclear cost of poor quality	Antony (2004, 2008a)
Mismanaging Six Sigma implementation time	Feng and Manuel (2008), Taner *et al.* (2007)
Difficult to obtain performance baseline data	Antony *et al.* (2007), Taner *et al.* (2007)
Unclear prioritization of Six Sigma projects	Antony (2004, 2008a), Hendry (2005), Taner *et al.* (2007)
Unleashed Six Sigma business strategy	Antony *et al.* (2007) Martins *et al.* (2006)
Insufficient financial resources	Antony *et al.* (2005), Feng and Manuel (2008) Taner *et al.* (2007)

(*continued*)

Table I.
Empirical research on barriers on Six Sigma implementation

Six sigma barriers	Source
Poor estimation of financial gain	Martins *et al.* (2006)
Complexity of data analysis	Hensley and Dobie (2005), Taner *et al.* (2007)
Large Six Sigma projects are usually delayed	Kumar *et al.* (2009a, b)
Less emphasis on the voice of customers	Kumar *et al.* (2009a, b), McAdam and Evans (2004)
Bureaucratic Six Sigma structure	Antony (2004, 2008a), Kumar *et al.* (2009a, b)
Poor measurement of customer satisfaction	Martins *et al.* (2006), Hensley and Dobie (2005)
Satisfaction with other quality programs	Antony and Desai (2009), Kumar *et al.* (2009a, b)
Ill-defined statistical assumptions	Antony (2004, 2008a)
Inadequate Six Sigma planning and alignment	Kwak and Anbari (2006), Martins *et al.* (2006)
Inadequate dealing with customer variability	Sehwail and DeYong (2003)
Poor selection and measurement of metrics	Sehwail and DeYong (2003)
Difficult to identify process parameters	Antony *et al.* (2007), Chakrabarty and Tan (2007)

Table I.

Research methodology

A flow diagram of the detailed research process is illustrated in Figure 1. Six Sigma barriers are defined in this study as all those constraints (e.g. operational, structural, attitudinal, etc.) that hinder the firm's ability to implement Six Sigma quality approach or to achieve successful results from the current Six Sigma implementation. A total of 47 Six Sigma barriers were identified and adapted from the literature (see Table I). All barriers were set on a five-point Likert scale where 5 = extremely important, 4 = very important, 3 = important, 2 = somewhat important, and 1 = not important. Since this paper aimed to examine the effects organizational factors on Six Sigma barriers, a cross-sectional survey targeting CEOs, operations or quality managers in various organizational settings and types was applied. A total of 500 questionnaires were sent to randomly selected organizations, which were drawn from economic and commercial directories published by chambers of commerce and economic directorates in seven UAE Emirates including Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Quwain, Ras Al Khima and Fujairah. Method of questionnaire distribution, follow up, and collection was varied (e.g. via e-mail, mail, fax, or manually) according to the degree of internet connectivity, responsiveness, distance, time and cost. A total of 151 completed questionnaires were returned. A total of 19 questionnaires were discarded because of incomplete data, leaving 132 usable questionnaires for this study with a response rate of 26.4 per cent. The profile of respondents' demographics is presented in Table II.

Among the 132 organizations, 72 per cent were service and 28 per cent were manufacturing. The primary position of the respondents was operation manager/officer, representing 33.3 per cent; the other positions of the respondents CEO/director/general manager (22 per cent), quality manager/officer (15.9 per cent), and other administrative positions such as purchasing, marketing, etc. (28.8 per cent). More than half of the organizations were small- and medium-sized (SMEs) (64.4 per cent), while 35.6 per cent were large organizations. Six Sigma quality, was not implemented in the majority of organizations (88.6 per cent), and about 11.4 per cent were implementing Six Sigma quality. With regard to type of ownership, 73.5

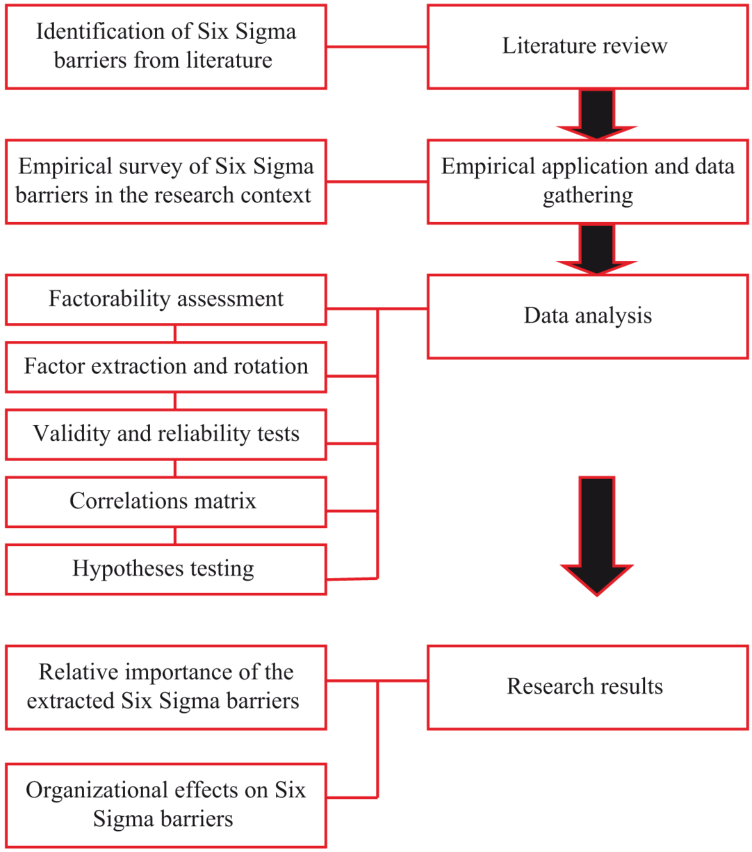

Figure 1.
A flow diagram of the detailed research process

per cent were local organizations and 26.5 per cent were multinational organizations.

Data analysis and findings

Preliminary analysis

To reduce the list of major Six Sigma barriers into more manageable number, factor analysis was conducted on all 47 barriers presented in Table I. Prior to the factor analysis, Bartlett's test of sphericity and a Kaiser-Meyer-Olkin (KMO) test were conducted to help assess the factorability of the data. Bartlett's test of sphericity determines if the correlation matrix is an identity matrix. If there is an identity matrix, factor analysis is meaningless (Field, 2000). The KMO test measures the adequacy of a sample in terms of the distribution of values for the execution of factor analysis. The acceptable values should be greater than 0.5 (Field, 2000). Bartlett's test of sphericity should be $p < 0.05$ to be significant; whereas KMO index ranges from 0 to 1 with 0.6 as a minimum value for a good factor analysis. The result of the KMO test was 0.757 and Bartlett's test of sphericity was high at 2196.511 ($p = 0.000$). Both tests suggest the adequacy of the variables for factor analysis.

Demographics	n	(%)
Industry type		
Manufacturing	37	28
Food and beverages	12	9.1
Chemicals, rubber and plastics	9	6.8
Machinery and equipment	5	3.8
Other manufacturers	11	8.3
Service	95	72
Education and training	27	20.5
Healthcare and hospitality	16	12.1
Retail, supply and logistics	23	17.4
Finance and insurance	8	6.1
IT and communication	2	1.5
Other services	19	14.4
Size		
≤ 250 employees	85	64.4
> 250 employees	44	35.6
Position		
CEO/director/general manager	29	22
Operations manager/officer	44	33.3
Quality manager/officer	21	15.9
Other positions	38	28.8
Six Sigma implementation		
Implementing	15	11.4
Non-implementing	117	88.6
Ownership		
Local	97	73.5
Multinational	35	26.5

Table II. Profile of respondents

Factor extraction and rotation

Subsequently, eigenvalues and percentage of variance approaches were used to reveal the number of factors necessary to represent the data. According to Field (2000), factors with relatively large eigenvalues (> 1.0) are retained and those with relatively small eigenvalues are ignored. Also, all of the factors extracted should account for at least 60 per cent of total variance. Principal component analysis with orthogonal (varimax) rotation was performed to analyze the interrelationships among the 47 Six Sigma barriers. The results of factor analysis showed that the final 28 variables within seven barrier factors accounted for 67.825 per cent of total variance explained, each containing the average of the items loading at 0.514 or above (see Table III).

The first of the seven factors incorporates five Six Sigma obstacles: unclear prioritization of Six Sigma projects, lack of knowledge about Six Sigma, satisfaction with other quality programs, inadequate measurement skills, and narrow view of Six Sigma. This barrier factor is titled knowledge barrier and accounted for 16.67 per cent of the total variance. It reflects the lack of proper knowledge regarding Six Sigma as a

Table III.
Critical barriers influencing successful Six Sigma implementation

Barrier factor	Variables	Factor loading	Item-total correlation	Variance explained (%)	Cumulative (%)
B1 Knowledge barrier	Unclear prioritization of Six Sigma projects (F33)	0.725	0.668	16.671	16.671
	Lack of knowledge about Six Sigma (F28)	0.716	0.645		
	Satisfaction with other quality programs (F42)	0.652	0.577		
	Inadequate measurement skills (F11)	0.633	0.583		
	Narrow view of Six Sigma (F1)	0.514	0.412		
B2 Resources barrier	Large investment in Six Sigma training (F22)	0.794	0.681	10.723	27.394
	Insufficient time to work on Six Sigma (F14)	0.718	0.652		
	Insufficient financial resources (F35)	0.621	0.632		
	Expensive application of Six Sigma results (F21)	0.606	0.528		
	Lack of dedicated Six Sigma professionals (F2)	0.570	0.468		
B3 Support barrier	Lack of top management support (F13)	0.805	0.698	9.461	36.855
	Inadequate specialized Six Sigma training (F9)	0.764	0.661		
	Resistance to change (F3)	0.608	0.513		
	Poor communication of quality data (F23)	0.563	0.448		
B4 Complexity barrier	Difficulty in identifying process parameters (F47)	0.784	0.678	9.238	46.093
	Unclear aspects of critical to quality (CTQ) (F25)	0.739	0.664		
	Complexity of data analysis (F37)	0.685	0.580		
	Complex Six Sigma tools and techniques (F6)	0.662	0.623		
	Weak presentation of Six Sigma findings (F15)	0.550	0.477		
B5 Customer focus barrier	Poor measurement of customer satisfaction (F41)	0.723	0.638	8.292	54.385
	Weak understanding of customer wants (F12)	0.658	0.572		
	Less emphasis on the voice of customers (F39)	0.550	0.442		
	Unclear cost of poor quality (F30)	0.527	0.408		
B6 Sustainability barrier	Difficulty to sustain Six Sigma improvements (F10)	0.882	0.780	7.657	62.042
	Intangibility of Six Sigma results (F4)	0.816	0.731		
	Uncertainty of Six Sigma results (F24)	0.677	0.580		
B7 Alignment barrier	Unleashed Six Sigma business strategy (F34)	0.829	0.731	5.783	67.825
	Poor Six Sigma planning and alignment (F44)	0.712	0.625		

philosophy and a methodology to the extent that it can be perceived as similar to other quality programs such as total quality management and ISO.

The second factor accounted for 10.7 per cent of the total variance and conceptually links five impediments: large investment in Six Sigma training, insufficient time to work on Six Sigma, insufficient financial resources, expensive application of Six Sigma results, and lack of dedicated Six Sigma professionals. These barriers denote handicaps in financial and managerial resources that obstruct the firm from successfully implementing Six Sigma projects. This factor is titled resource barrier.

The third factor accounted for 9.46 per cent of the total variance and is heavily loaded with four variables that demonstrate the role of supportive culture including lack of top management support, inadequate specialized Six Sigma training, resistance to change, and poor communication of quality data. Support barrier provides an appropriate label to capture the underlying dimension of these variables. The fourth factor accounted for 9.23 per cent of the total variance and reflects the complexity of applying Six Sigma tools and presenting its results.

This complexity barrier engages five Six Sigma hurdles: difficulty in identifying process parameters, unclear aspects of critical to quality (CTQ), complexity of data analysis, complex Six Sigma tools and techniques, and weak presentation of Six Sigma findings.

The customer focus barrier, the fifth factor, accounted for 8.29 per cent of the total variance and is deeply loaded with four variables representing the role of poor measurement of customer satisfaction, weak understanding of customer wants, less emphasis on the voice of customers, and unclear cost of poor quality in challenging successful Six Sigma adoption and implementation.

The sixth factor signals the organizational failure to prolong Six Sigma results and benefits. This sustainability barrier accounted for 7.65 per cent of the total variance and is loaded with three variables involving difficulty to sustain Six Sigma improvements, intangibility of Six Sigma results, and uncertainty of Six Sigma results. Interestingly, this factor highlights that the intangibility and uncertainty problems of Six Sigma results are interrelated to its sustainability. The seventh factor combines the two remaining variables, unleashed Six Sigma business strategy and poor Six Sigma planning and alignment. This factor could, therefore, best be described as alignment barrier since it signifies the fragmentation or poor fit between Six Sigma strategy and overall business strategy. This final factor accounted for 5.78 per cent of the total variance.

Reliability test

To ensure the reliability of each factor, Cronbach's coefficient alpha was estimated to test the internal consistency among the items included in each of the formative scales. Table IV shows that the resulting alpha values for the final seven barrier factors are ranged from $\alpha = 0.63$ to $\alpha = 0.85$, which are acceptable according to Nunnally and Bernstein's (1994) guidelines for exploratory research, making all factors reliable.

Content validity

Content validity deals with how representative and comprehensive the items are in creating the scale. It is assessed by examining the process by which scale items are generated. Content validity in this study should be relatively acceptable since the various parts of questionnaire were all based on the literature review and on the opinions of several experts who examined the items. As suggested by Cooper and Schindler (2003), a panel of persons can be interviewed to judge how well the instrument meets the standards. Thus, the researcher conducted independent interviews with four experts who had more than five years experience in quality management. The panel was asked to comment on the length of the instrument, the format, and the wording of the scales. They suggested that the procedure and Arabic translation of the questionnaire were appropriate, with minor modifications in the translated version of the questionnaire. Respondents who had participated in the pre-test were excluded from the subsequent study. Therefore, it is asserted that the Six Sigma barriers questionnaire had content validity.

Construct validity

To test for construct validity, the unifactorial determination method was performed. The validity of a construct's measure is realized when the values for the average variance extracted exceed the 0.5 cut-off limit (Fornell and Larcker, 1981). Table IV shows the percentage of variance explained by each of Six Sigma barrier factors. The average variance extracted for each factor ranged from 0.5218 to 0. 7182 for seven factors, which demonstrated to be unifactorial. Furthermore, the suitability of the sample for each unifactorial determination has been examined by the Kaiser-Meyer-Olkin (KMO) test and indicated that all factors were within the acceptable range from 0.604 to 0.810.

Convergent validity

According to Carr and Pearson (1999), convergent validity is when different variables are used to measure the same construct and the variables are strongly correlated to each other, while discriminant validity is when different variables are used to measure different constructs, and the correlations between the variables of different constructs are relatively weak. To evaluate convergent construct validity in the present study, the correlation of each item to the sum of the remaining items is computed. As suggested by Park and Kim (2003), factors with an item-to-total correlation score lower than 0.4 were removed. Table III shows that the item-to-total correlations for variables within the final seven factors ranged from 0.408 to 0.780.

Table IV.
Construct reliability and validity tests of Six Sigma barrier factors

	Six Sigma Barrier	Average variance extracted (AVE)	KMO	Reliability Cronbach's (α)
B1	Knowledge barrier	71.82	0.634	0.81
B2	Resources barrier	60.03	0.662	0.76
B3	Support barrier	56.21	0.718	0.83
B4	Complexity barrier	64.45	0.604	0.85
B5	Customer focus barrier	71.78	0.636	0.76
B6	Sustainability barrier	52.18	0.810	0.68
B7	Alignment barrier	64.36	0.664	0.63

Discriminant validity

Discriminant validity can be established when constructs are separate and distinct from one another, whether or not a predictive or causal relationship exists between them. It was evaluated in the present study by comparing the squared correlations between each of the constructs to the average variation extracted for these constructs. Discriminant validity is demonstrated when the average variance extracted for each construct is greater than the square of the correlation between the constructs (Fornell and Larcker, 1981). Table V shows an evidence of discriminant validity among different Six Sigma barrier factors since the highest squared correlation value between the constructs was 0.3136 and that the lowest average extracted variance value was 0.5218 (Table IV).

The relative importance of the extracted Six Sigma barriers

Ranking of the 28 extracted Six Sigma barriers according to their level of importance is illustrated in Figure A1. Lack of knowledge about Six Sigma (4.67) was considered as the most influential barrier encountered by participant organizations. This result confirms earlier research (e.g. Antony *et al.* 2005; Buch and Tolentino, 2006; Kumar *et al.*, 2009a, b).

Lack of dedicated Six Sigma professionals (4.15) was also a crucial impediment. The importance of this barrier, was also emphasized by Antony *et al.* (2005), and Taner *et al.* (2007). Interestingly, both first and second barriers reflect the vital role of Six Sigma thinking tank, in terms of knowledge and professionals, as important assets that create the desirable Six Sigma awareness and facilitate the need for its implementation.

The third important barrier was insufficient financial resources (3.91). In contrast, Antony and Desai's (2009) study on Six Sigma implementation in Indian industry did not find lack of financial resources as a reason for not implementing Six Sigma. The same study, however, considered lack of resources (this includes financial resources, human resources, time, etc.) as the first impeding factor faced by Indian organizations in implementing Six Sigma strategy. Other studies (e.g. Antony *et al.*, 2005; Chakrabarty and Chuan, 2009; Feng and Manuel, 2008; Taner *et al.*, 2007) highlighted the importance of resources in fostering and inhibiting Six Sigma quality initiative.

Lack of top management support (3.87) was ranked fourth although its popularity in quality literature as a significant barrier to Six Sigma implementation (e.g. Buch and Tolentino, 2006; Feng and Manuel, 2008, Hendry, 2005; Kumar *et al.*, 2009a, b, Snee, 2001; Taner *et al.*, 2007). The main reason may be related to the knowledge factor where top management cannot support any new quality initiative without being exposed to enough knowledge and awareness about it.

	B1	B2	B3	B4	B5	B6	B7
B1	–						
B2	0.12	–					
B3	0.56**	0.51**	–				
B4	0.32**	0.14		–			
B5	0.34**	0.20*	0.23**	0.33**	–		
B6	0.28**	0.08	0.42**	0.41**	0.25**	–	
B7	0.36**	0.23**	0.26**	0.29**	0.37**	0.19*	–

Notes: $^{*}p < 0.05$, $^{**}p < 0.01$

Table V. Correlations between the Six Sigma barrier factors

While given little attention in Six Sigma literature, satisfaction with other quality programs (3.62) was ranked the fifth impediment. This finding confirms earlier research (e.g. Antony and Desai's, 2009; Kumar *et al.*, 2009b). The sixth position, was shared by both complex Six Sigma tools, and techniques, and uncertainty of Six Sigma results (3.47). While uncertainty of Six Sigma results did not receive enough attention, Sehwail and DeYong (2003) stated that companies have found difficulty with quality initiatives, which did not demonstrate certain value, so that Six Sigma projects may be quickly abandoned soon after implementation for the same reason. Other barriers were perceived as less inhibiting barriers to Six Sigma implementation. Most of these barriers were operational in nature focusing on analysing, presenting and communicating Six Sigma data. This highlights the critical role of such strategic barriers as knowledge, support and change management in Six Sigma implementation. Results of ranking Six Sigma barriers according to their importance are presented in the Appendix (see Figure A1).

Organizational effects on Six Sigma barriers

Based on the seven factors extracted from the principal component analysis, the effect of a number of organizational variables was next examined. These were identified from the Six Sigma literature and referred to as industry type, size of the organization, Six Sigma implementation and ownership type. To identify differences between organizations in relation to the influence of Six Sigma barriers, each of the organizational variables was dichotomized into two groups and the Student *t*-test for two independent samples was employed (see Table VI).

Among the identified organizational variables investigated, size of the organization exhibited the greatest effect overall. There were significant difference between SMEs and large organizations in the influence of four Six Sigma barriers including knowledge barrier ($t = 3.67, p < 0.01$), support barrier ($t = 4.06, p < 0.01$), resources barrier ($t = 3.23, p < 0.01$) and complexity barrier ($t = 2.48, p < 0.05$). In all cases, the inhibiting effect of these factors was greater among SMEs than large organizations.

Interestingly, type of ownership had also a serious discriminating effect regarding three Six Sigma barriers including knowledge barrier ($t = 2.17, p < 0.05$), support barrier ($t = 3.13, p < 0.01$) and strategic integration barrier ($t = 2.32, p < 0.05$). Compared to multinational organizations, local organizations were shown to exhibit greater effect of these three mentioned Six Sigma barriers.

Analysis of Six Sigma implementation experience revealed that the relative impact of Six Sigma barriers was significantly different between organizations implemented Six Sigma and those which are not implementing Six Sigma quality regarding two barriers: knowledge barrier ($t = -3.21, p < 0.01$) and support barrier ($t = -3.05, p < 0.01$). Specifically, organizations, which are not yet implementing Six Sigma demonstrated greater obstructing impact of lack of knowledge and support than organizations which implemented Six Sigma quality.

Similar results apply to the industry type. Surprisingly, a significant segregating effect was found in only two Six Sigma barriers including sustainable outcomes barrier ($t = -2.41, p < 0.05$) and complexity barrier ($t = 2.55p < 0.05$). The impeding effect of both the sustainable outcomes and complexity barriers was significantly greater among service organizations than among manufacturing organizations.

Table VI. Effects of organizational parameters on Six Sigma barriers

Organizational parameters	Six Sigma barriers[a] Knowledge barrier	Support barrier	Resources barrier	Sustainable outcomes barrier	Strategic integration barrier	Customer focus barrier	Complexity barrier
Industry type							
Service ($n = 95$)	3.95	3.10	3.40	3.12	2.74	2.44	4.04
Manufacturing ($n = 37$)	3.71	2.84	3.22	2.54	2.56	2.27	3.58
t-value	1.53	1.28	1.19	*2.41* *	0.65	1.08	*2.55* *
Size							
SMEs ($n = 85$)	4.71	4.54	3.62	2.94	2.24	3.88	4.36
Large ($n = 44$)	3.55	3.23	3.06	2.67	2.28	4.13	3.82
t-value	*3.67* **	*4.06* **	*3.23* **	1.34	−0.53	−1.86	*2.48* *
Six Sigma implementation							
Implementing ($n = 15$)	3.55	2.67	4.23	3.18	3.37	3.71	4.64
Non implementing ($n = 117$)	4.69	3.13	3.91	3.33	3.24	3.96	4.82
t-value	−*3.21* **	−*3.05* **	−1.53	−1.27	−1.06	−1.11	−1.43
Ownership type							
Local ($n = 97$)	4.11	4.64	4.07	3.66	3.01	4.08	3.85
Multinational ($n = 35$)	3.70	3.02	3.90	3.24	2.73	4.05	3.71
t-value	*2.17* *	*3.13* **	1.48	1.57	*2.32* *	0.21	0.55

Notes: [a]Mean score is the average on a five-point Likert scale where 5= extremely important, 4= very important, 3= important, 2= somewhat important, and 1= not important. *$p < 0.05$; **$p < 0.01$

The previous analysis clearly shows that only specific types of barriers are significantly influencing Six Sigma implementation bearing in mind the role of organizational parameters. Interestingly, the effect of knowledge and support barriers was the most evident impeding factor that distinguishes between organizations with regard to Six Sigma implementation. These barriers were evident when differentiating between SMEs and large organizations, implementing and non-implementing organizations, and local and multinational organizations. This is followed by the effect of perceived complexity of Six Sigma that was significant when discriminating between service and manufacturing organizations, and SMEs and large organizations. Surprisingly, resources barrier shows a limited evident segregating impact and that when differentiating between SMEs and large organizations. Similarly, sustainable outcomes barrier was only significant when differentiating between service and manufacturing organizations. Also, strategic integration barrier was only evident when differentiating between local and multinational organizations. On the contrary, customer focus barrier was surprisingly insignificant differentiating obstacle between organizations with regard to Six Sigma implementation.

Discussion

The present findings suggest that organizational parameters are important variables for understanding the influence of Six Sigma implementation barriers. First, with regard to organization size, the results of this research are consistent with Six Sigma literature, which emphasized the paramount effect of organizational size on successful Six Sigma implementation. This confirms Wessel and Burcher's (2004) study which asserted that Six Sigma has to be modified to be applicable and valuable in an SME environment. According to Thakkar *et al.* (2009), the characteristics of processes and systems at SMEs are different from those at large organizations. Compared to large organizations, SMEs are more cash focused, short-term and instil better communications and incentives for exploiting internal knowledge. Adams *et al.* (2003) and Tennant (2001) argued that Six Sigma implementation in SMEs is much influenced by the business owner or decision makers and their understanding of visible benefits of Six Sigma program. This issue highlights the critical role of knowledge sharing and organizational support among SMEs business leaders with regard to Six Sigma methodology and its benefits.

This is consistent with Antony *et al.* (2005) who indicated that lack of knowledge about Six Sigma methodologies is one of main impeding factors in implementation of Six Sigma by UK manufacturing SMEs. Also, Kumar (2007) identified lack of training and resources as two major stumbling blocks encountered during Six Sigma implementation in SMEs. Relevant literature suggested that insufficient resources in SMEs might hinder the implementation of quality programs such as TQM and Six Sigma. Thakkar *et al.* 2009 argued that the lack of financial safety to absorb the impact of short-term fluctuations resulting from change is paramount in SMEs. Snee and Hoerl (2003) suggested that the greatest barrier to implementation in small companies to date has been the way major Six Sigma training providers have structured their offerings. They pointed out that the problem of Six Sigma implementation arises in SMEs when they solicit deployment proposals from Six Sigma consulting companies only to learn that the traditional Six Sigma implementation can require expensive investment, dedication of their best people on Six Sigma projects, and training of the masses. SMEs also tend to have a lean organisation and, therefore, they find it difficult to have resources to maximize their intellectual capacity by appointing quality facilitators or providing internal training for the implementation process (Thomas and Barton, 2006; Thomas and Webb, 2003). Lack of resources in these aspects requires careful analysis of which strategy that is both suitable to SMEs but is not so generic that it fails to provide adequate direction and guidance.

With regard to complexity barrier, Deleryd *et al.* (1999) identified that SMEs need to make decisions and improve their processes based on accurate and timely information relating to the performance of their process. Thakkar *et al.* (2009) suggested a simplified version of Six Sigma methodology along side its conceptual principles for SMEs. The idea of using simplified Six Sigma in SME through basic training, simple tools and laser focusing in projects and methodology stages has been unanimously supported by the academics (Antony and Kumar, 2005; Mortimer, 2006). Thomas and Barton (2006) claimed that understanding statistical concepts such as causes of variation, process control theory, experimental design, and product reliability have a major part to play in SMEs and the application of these concepts must come from continued training and development of the workforce. They asserted that the major reason behind the relatively low application of statistical methods in SMEs is related to leaders and employees' fear and insufficient knowledge to apply statistical tools.

Second, with regard to experience with Six Sigma implementation, Feng and Manuel (2008) stated that the most-referred reason, which prevents Six Sigma implementation in organizations, is lack of leadership support. They emphasized the critical role of leadership in the Six Sigma initiation. Chakrabarty and Chuan (2009) indicated that the organizations who have not implemented Six Sigma do not know about it, feel Six Sigma is irrelevant to them and are highly satisfied with current applied systems in tackling quality issues. Moreover, Antony *et al.* (2005) confirmed that the most important reason for not implementing Six Sigma program is that companies do not know about Six Sigma and already have quality system in place perceiving such systems to be adequate. Not surprisingly, organizations that do not use or plan to implement Six Sigma program in the future showed their lack of knowledge and support. In contrast, Antony *et al.* (2005) mentioned insufficiency of resources as the second major barrier after lack of knowledge for not implementing Six Sigma. This barrier, however, is not supported in our study. This may be due to the focus in Antony *et al.*'s (2005) study being on SMEs while our study surveyed cross-sectional organizations including large and SMEs. Therefore, insufficient resources *per se* may not obstruct Six Sigma initiation in organizations and the involvement of organizational factors like size is crucial to demonstrate such significant impact. Other barriers that were insignificant between implementing and non-implementing Six Sigma organizations include sustainable outcomes, strategic integration, customer focus and complexity. These findings highlight the vital role of knowledge and support for developing Six Sigma initiatives.

Third, with regard to industry type, service or manufacturing, this study showed significant difference between manufacturing and service contexts concerning barriers related to complexity and sustainable Six Sigma outcomes. This result supports Hendry's (2005) argument regarding the complexity of Six Sigma tools which very much depends on employees' background. She indicated that the manufacturing engineers have no difficulty in understanding the application of the tools and feel comfortable using statistical tools in their projects compared to those from service. On the contrary, Tanco *et al.* (2009) confirmed that technical barriers such as statistical jargon, complexity of tools and lack of methodologies to guide users impede engineers as well when they involve in quality improvement or developing new products. If engineers are facing such difficulties in applying quality tools and techniques, this draws the attention to the magnitude of the technical load on non-engineers particularly in service settings. Moreover, Six Sigma literature pointed out to the difficulty of data collection, quantification and measurement for sub-processes in service settings (Chakrabarty and Chuan, 2009; Hensley and Dobie, 2005). This may be explained by the nature of transactions in service contexts, which focus on frontline problems, face-to-face interactions, customer contact, non-continuous process and other less visible activities (Benedetto, 2003; Breyfogle, 2003; Does *et al.*, 2002). As service processes often deal with discrete data, the data collection process takes more time due to the need for a large sample size for statistical validity reasons (Antony *et al.*, 2007). Consequently, service organisations struggle to identify processes, which can be measured in terms of defects per million opportunities (Sehwail and DeYong, 2003). This distinctive nature of service organizations creates more technical complexities concerning information process for Six Sigma projects.

Moreover, Chakrabarty and Chuan (2009) considered insufficient resources as the second major challenge faces service organizations. However, this is not in agreement with the result of our research which revealed no difference between service and manufacturing in perceiving four Six Sigma barriers including insufficient resources, inadequate knowledge and support, strategic alienation and poor customer focus. Alternatively, our study confirms Chakrabarty and Chuan's (2009) claim regarding sustaining Six Sigma as a major barrier to service organizations. For service organizations, sustaining the outcomes of Six Sigma projects is a challenging and complex task. This process requires deciding on the scope of projects, extension of project timeline, attaching incentives to the successfully completed Six Sigma projects, quantification of savings and managing staff turnover (Chakrabarty and Chuan, 2009). This barrier is obvious particularly when resistance to change in service settings is comparatively higher than in a manufacturing setting due to the high involvement of soft issues related uncontrollable psychological, sociological and personal factors (Antony *et al.*, 2007).

Finally, Six Sigma adoption among multinational organizations as an effective improvement drive is showing an upward trend (Desai, 2006). This study shows that although both multinational and local organizations share some obstacles in implementing Six Sigma, they also show significant differences in relation to three Six Sigma barriers; knowledge, support and strategic integration. These barriers were more evident in local UAE organizations than in multinational organizations. This result is in harmony with Cheng (2007a, b) who asserted that organizational culture and knowledge of Six Sigma differ significantly between local and multinational organizations in Taiwanese context. He confirmed that local Taiwanese enterprises should focus on integrating corporate strategy with Six Sigma systems. This may be explained by the differences in the type and level of forces that surround local and multinational organizations. Multinational organizations seem to be more influenced by strong global competitive forces that sharpen their awareness regarding quality strategy and lead them to successfully implement Six Sigma approach to improve business operations (Krishna *et al.*, 2008).

Conclusions and implications for future research

The basic rationale behind this paper is our belief that successful Six Sigma implementation is not a secured green field in various organizational contexts. While there is a little amount of research targeting the obstructive role of barriers to Six Sigma implementation, the impact of organizational factors on these barriers, particularly in a developing country context, has been given scant attention. Thus, the purpose of this article has been to identify the most influential barriers to Six Sigma implementation, measure the relative importance of these barriers and examine how the effectiveness of these barriers may vary in relation to dimensions of specific organizational factors.

By means of principal component analysis with orthogonal (varimax) rotation, 47 Six Sigma barriers were reduced into 28 valid barriers. Among these barriers, lack of knowledge, professionals, financial resources, and top management support have been regarded by participant organizations as the most influential barriers to Six Sigma implementation. Remarkably, this result reflects the key significant role played by both soft barriers (i.e. knowledge and support) and hard barriers (i.e. professionals and finance) to successful Six Sigma implementation. Further analysis has revealed seven barrier factors accounted for 67.825 per cent of total variance explained. These barrier factors include knowledge, support, resources, sustainable outcomes, strategic integration, customer focus and complexity. The analysis clearly shows that only specific types of barriers are significantly influencing Six Sigma implementation in relation to dimensions of organizational factors. Size of the organization exhibited the greatest effect overall. The inhibiting effect of four Six Sigma barriers including knowledge, support, resources and complexity was significantly greater among SMEs than large organizations. Interestingly, examining the discriminating effect of ownership type revealed that local organizations were shown to exhibit significant greater effect of three Six Sigma barriers involving knowledge, support and strategic integration compared to multinational organizations. More surprisingly, only two significant barriers were differentiating between Six Sigma implementing and non-implementing organizations. Organizations which are not yet implementing Six Sigma demonstrated significant greater obstructing impact of knowledge and support barriers than organizations, which implemented Six Sigma quality. Similarly, with regard to industry type, the impeding effect of two barriers (i.e. sustainable outcomes and complexity) was significantly greater among service organizations than among manufacturing organizations.

These results suggest that organizations should not waste their resources preparing for overcoming all Six Sigma barriers. High attention should be given to the most obstructing barriers in relation to organizational factors. For example, large service organizations should be more prepared to ensure sustainability of Six Sigma outcomes. On the contrary, small service organizations should first simplify Six Sigma tools and techniques for their employees and departments. Also, boosting the level of Six Sigma awareness and knowledge among top managers is of key priority in local manufacturing organizations.

Another interesting result of this study is the emergence of knowledge and support barriers as the most evident Six Sigma impeding factors distinguishing between organizations. Knowledge and support barriers were evident when differentiating between SMEs and large organizations, Six Sigma implementing and non-implementing organizations, and local and multinational organizations. On the contrary, customer focus barrier was surprisingly insignificant differentiating obstacle between organizations with regard to Six Sigma implementation. This result suggests that lack of customer focus may be no longer a prominent barrier to Six Sigma implementation, particularly in an era of intense competition and global awareness of customer rights and service. Instead, the power of Six Sigma knowledge and support may play a vital role in facilitating successful Six Sigma implementation. This could be activated through applying tools of knowledge management functions to Six Sigma projects such as Six Sigma knowledge acquisition, sharing, storing, revealing, etc. among organizational members.

Although this study has generated a new understanding on organizational construction of Six Sigma barriers, still the work has inherent limitations associated with data collection method and generalization. As with any research, care should be taken when generalizing the results of this study. It is recommended that further empirical investigations should use a larger sample in order to have a better validation of this study, particularly when having apparently small number of organizations that are implementing Six Sigma quality. Also, the lack of implementing Six Sigma tools and methodologies across a wide range of processes or organizations may make the application of survey approach impractical. This reinforces future research to enhance the survey data by using other methods such as case study or longitudinal data to provide more in depth comparative insights into barriers to Six Sigma implementation at different contexts or time periods. Moreover, a process-based approach that focuses on barriers associated with each phase of the process through which Six Sigma project is implemented is another interesting avenue for future research.

References

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

Antony, J. (2002), "Design for Six Sigma: a breakthrough business improvement strategy for achieving competitive advantage", *Work Study*, Vol. 51 No. 1, pp. 6-8.

Antony, J. (2004), "Six Sigma in the UK service organisations: results from a pilot survey", *Managerial Auditing Journal*, Vol. 19 No. 8, pp. 1006-13.

Antony, J. (2006), "Six Sigma for service processes", *Business Process Management Journal*, Vol. 12 No. 2, pp. 234-48.

Antony, J. (2008a), "Can Six Sigma be effectively implemented in SMEs?", *International Journal of Productivity and Performance Management*, Vol. 57 No. 5, pp. 420-3.

Antony, J. (2008b), "What is the role of academic institutions for the future development of Six Sigma?", *International Journal of Productivity and Performance Management*, Vol. 57 No. 1, pp. 107-10.

Antony, J. and Desai, D. (2009), "Assessing the status of six sigma implementation in the Indian industry: results from an exploratory empirical study", *Management Research News*, Vol. 32 No. 5, pp. 413-23.

Antony, J. and Kumar, M. (2005), "Six sigma in small and medium sized UK manufacturing enterprises", *International Journal of Quality & Reliability Management*, Vol. 122 No. 8, pp. 860-74.

Antony, J., Antony, F. and Kumar, M. (2007), "Six Sigma in service organizations: benefits, challenges and difficulties, common myths, empirical observations and success factors", *International Journal of Quality & Reliability Management*, Vol. 24 No. 3, pp. 294-311.

Antony, J., Kumar, M. and Madu, C. (2005), "Six Sigma in small- and medium-sized UK manufacturing enterprises: some empirical observations", *International Journal of Quality & Reliability Management*, Vol. 22 No. 8, pp. 860-74.

Banuelas, R. and Antony, J. (2003), "Going from Six Sigma to design for Six Sigma: an exploratory study using analytic hierarchy process", *The TQM Magazine*, Vol. 15 No. 5, pp. 334-44.

Behara, R.S., Fontenot, G.F. and Gresham, A. (1995), "Customer satisfaction measurement and analysis using Six Sigma", *International Journal of Quality & Reliability Management*, Vol. 12 No. 3, pp. 9-18.

Benedetto, A. (2003), "Adapting manufacturing-based Six Sigma methodology to the service environment of a radiology film library", *Journal of Healthcare Management*, Vol. 48, pp. 263-80.

Breyfogle, F.W. (2003), *Implementing Six Sigma: Smarter Solutions Using Statistical Methods*, John Wiley and Sons, Hoboken, NJ.

Buch, K. and Tolentino, A. (2006), "Employee expectancies for Six Sigma success", *Leadership and Organization Development Journal*, Vol. 27 No. 1, pp. 28-37.

Carr, A.S. and Pearson, J. (1999), "Strategically managed buyer-seller relationships and performance outcomes", *Journal of Operations Management*, Vol. 17 No. 5, pp. 497-519.

Chakrabarty, A. and Chuan, T. (2009), "An exploratory qualitative and quantitative analysis of Six Sigma in service organizations in Singapore", *Management Research News*, Vol. 32 No. 7, pp. 614-32.

Chakrabarty, A. and Tan, K. (2007), "The current state of Six Sigma application in services", *Managing Service Quality*, Vol. 17 No. 2, pp. 194-208.

Chen, S., Chen, K. and Hsia, T. (2005), "Promoting customer satisfaction by applying Six Sigma: an example from the automobile industry", *The Quality Management Journal*, Vol. 12 No. 4, pp. 21-33.

Cheng, J-L. (2007a), "Comparative study of local and transnational enterprises in Taiwan and their implementation of Six Sigma", *Total Quality Management & Business Excellence*, Vol. 18 No. 7, pp. 793-806.

Cheng, J-L. (2007b), "Six Sigma business strategy in Taiwan: an empirical study", *International Journal of Six Sigma and Competitive Advantage*, Vol. 3 No. 1, pp. 1-12.

Cooper, D. and Schindler, A. (2003), *Business Research Methods*, Irwin, Boston, MA.

Dahlgaard, J. and Dahlgaard-Park, S. (2006), "Lean production, Six Sigma quality, TQM and company culture", *The TQM Magazine*, Vol. 18 No. 3, pp. 263-81.

Das, N., Gauri, S. and Das, P. (2006), "Six Sigma principles in marketing: an application", *International Journal of Six Sigma and Competitive Advantage*, Vol. 2 No. 3, pp. 243-62.

Deleryd, M., Garvare, R. and Klefsjo, B. (1999), "Experiences of implementing statistical methods in small enterprises", *The TQM Magazine*, Vol. 11 No. 5.

Desai, D. (2006), "Improving customer delivery commitments the Six Sigma way: case study of an Indian small scale industry", *International Journal of Six Sigma and Competitive Advantage*, Vol. 2 No. 1, pp. 23-47.

Does, R., Van Den Heuvel, J., De Mast, J. and Bisgaard, S. (2002), "Comparing non manufacturing with traditional applications of Six Sigma", *Quality Engineering*, Vol. 15 No. 1, pp. 177-82.

Douglas, P. and Erwin, J. (2000), "Sigma's focus on total customer satisfaction", *Journal for Quality and Participation*, Vol. 23 No. 2, pp. 45-9.

Dreachslin, J. and Lee, P. (2007), "Applying Six Sigma and DMAIC to diversity initiatives", *Journal of Healthcare Management*, Vol. 52 No. 6, pp. 361-7.

Feng, Q. and Manuel, C. (2008), "Under the knife: a national survey of six sigma programs in US healthcare organizations", *International Journal of Health Care Quality Assurance*, Vol. 21 No. 6, pp. 535-47.

Field, A. (2000), *Discovering Statistics Using SPSS for Windows: Advance Techniques for the Beginner*, Sage Publications, UK.

Fornell, C. and Larcker, D. (1981), "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*, Vol. 18 No. 1, pp. 39-50.

Freiesleben, J. (2006), "Communicating Six Sigma's benefits to top management", *Measuring Business Excellence*, Vol. 10 No. 6, pp. 19-27.

Ganesh, M. (2004), "Six sigma – time for a reality check", *Customer Management*, Vol. 12 No. 2, pp. 38-9.

Hendry, L. (2005), *Exploring the Six Sigma Phenomenon Using Multiple Case Study Evidence*, Lancaster University Management School, Lancaster, working paper 2005/056.

Hensley, R.L. and Dobie, K. (2005), "Assessing readiness for Six Sigma in a service setting", *Managing Service Quality*, Vol. 15 No. 1, pp. 82-101.

Kaushik, P. and Khanduja, D. (2008), "DM make up water reduction in thermal power plants using Six Sigma DMAIC methodology", *Journal of Scientific and Industrial Research*, Vol. 67 No. 1, pp. 36-42.

Krishna, R., Dangayach, G., Motwani, J. and Akbulut, A. (2008), "Implementation of Six Sigma approach to quality improvement in a multinational automotive parts manufacturer in India: a case study", *International Journal of Services and Operations Management*, Vol. 4 No. 2, pp. 264-76.

Kuei, C-H. and Madu, C. (2003), "Customer-centric Six Sigma quality and reliability management", *International Journal of Quality & Reliability Management*, Vol. 20 No. 8, pp. 954-64.

Kumar, M. (2007), "Critical success factors and hurdles to Six Sigma implementation: the case of a UK manufacturing SME", *International Journal of Six Sigma and Competitive Advantage*, Vol. 3 No. 4, pp. 333-51.

Kumar, M., Antony, J. and Cho, B. (2009a), "Project selection and its impact on the successful deployment of Six Sigma", *Business Process Management Journal*, Vol. 15 No. 5, pp. 669-86.

Kumar, M., Antony, J. and Douglas, A. (2009b), "Does size matter for Six Sigma implementation? Findings from the survey in UK SMEs", *The TQM Journal*, Vol. 21 No. 6, pp. 623-35.

Kumar, S., Strandlund, E. and Thomas, D. (2008a), "Improved service system design using Six Sigma DMAIC for a major US consumer electronics and appliance retailer", *International Journal of Retail & Distribution Management*, Vol. 36 No. 12, pp. 970-94.

Kumar, S., Wolfe, A. and Wolfe, K. (2008b), "Using Six Sigma DMAIC to improve credit initiation process in a financial services operation", *International Journal of Productivity and Performance Management*, Vol. 57 No. 8, pp. 659-76.

Kumar, M., Antony, J., Antony, F. and Madu, C. (2007), "Winning customer loyalty in an automotive company through Six Sigma: a case study", *Quality and Reliability Engineering International*, Vol. 23 No. 7, pp. 849-66.

Kwak, Y.H. and Anbari, F.T. (2006), "Benefits, obstacles and future of Six Sigma approach", *Technovation*, Vol. 26, pp. 708-15.

Li, M-H., Al-Refaie, A. and Yang, C-Y. (2008), "DMAIC approach to improve the capability of SMT solder printing process", *IEEE Transactions on Electronics Packaging Manufacturing*, Vol. 31 No. 2, pp. 126-33.

Linderman, K., Schroeder, R. and Choo, A. (2006), "Six Sigma: the role of goals in improvement teams", *Journal of Operations Management*, Vol. 24, pp. 779-90.

Linderman, K., Schroeder, R., Zaheer, S. and Choo, A. (2003), “Six Sigma: a goal-theoretic perspective”, *Journal of Operations Management*, Vol. 21, pp. 193-203.

McAdam, R. and Evans, A. (2004), “Challenges to Six Sigma in a high technology mass-manufacturing environments”, *Total Quality Management & Business Excellence*, Vol. 15 No. 5, pp. 699-706.

Martins, R., Mergulao, R. and Junior, L. (2006), “The enablers and inhibitors of Six Sigma project in a Brazilian cosmetic factory”, *Proceedings of the Third International Conference on Production Research – Americas’ Region (ICPR ICPR-AM06)*.

Mortimer, A.L. (2006), “Six Sigma: a vital improvement approach when applied to the right problems, in the right environment”, *Assembly Automation*, Vol. 26 No. 1, pp. 10-17.

Nonthaleerak, P. and Hendry, L. (2008), “Exploring the Six Sigma phenomenon using multiple case study evidence”, *International Journal of Operations and Production Management*, Vol. 28 No. 3, pp. 279-303.

Nunnally, J.C. and Bernstein, I.H. (1994), *Psychometric Theory*, McGraw-Hill, New York, NY.

Park, C.H. and Kim, Y.G. (2003), “Identifying key factors affecting consumer purchase behavior in an online shopping context”, *International Journal of Retail and Distribution Management*, Vol. 31 No. 1, pp. 16-29.

Rylander, D. and Provost, T. (2006), “Improving the odds: combining six sigma and online market research for better customer service”, *SAM Advanced Management Journal*, Vol. 71 No. 1, pp. 15-19.

Sehwail, L. and DeYong, C. (2003), “Six Sigma in health care”, *Leadership in Health Services*, Vol. 16 No. 4, pp. 1-5.

Sinthavalai, R. (2006), “A methodology to support six sigma implementation in SMEs as eLearning”, *Proceedings of the Third International Conference on eLearning for Knowledge-Based Society, August 3-4, Bangkok*.

Snee, R.D. (2001), “Dealing with the achilles heel of Six Sigma initiatives”, *Quality Progress*, Vol. 34 No. 3, pp. 66-72.

Snee, R.D. and Hoerl, R.W. (2003), *Leading Six Sigma*, FT Prentice-Hall, Englewood Cliffs, NJ.

Tanco, M., Viles, E., IIzarbe, L. and Alvarez, J. (2009), “Barriers faced by engineers when applying design of experiments”, *The TQM Journal*, Vol. 21 No. 6, pp. 565-75.

Taner, M., Sezen, B. and Anthony, J. (2007), “An overview of six sigma applications in healthcare industry”, *International Journal of Health Care Quality Assurance*, Vol. 20 No. 4, pp. 329-40.

Tennant, G. (2001), *Six Sigma: SPC and TQM in Manufacturing and Services*, Ashgate Publishing, Aldershot.

Thakkar, J., Kanda, A. and Deshmukh, S. (2009), “Supply chain performance measurement framework for small and medium scale enterprises”, *Benchmarking: An International Journal*, Vol. 16 No. 5, pp. 702-23.

Thomas, A. and Barton, R. (2006), “Developing an SME based six sigma strategy”, *Journal of Manufacturing Technology Management*, Vol. 17 No. 4, pp. 417-34.

Thomas, A.J. and Webb, D. (2003), “Quality systems implementation in Welsh small-to medium-sized enterprises: a global comparison and a model for change”, *Proceedings of the IMECHE Journal of Engineering Manufacture*, Vol. 217 No. 4, pp. 573-9.

Tong, J., Tsung, F. and Yen, B. (2004), “A DMAIC approach to printed circuit board quality improvement”, *The International Journal of Advanced Manufacturing Technology*, Vol. 23 Nos 7-8, pp. 523-31.

Wessel, G. and Burcher, P. (2004), “Six Sigma for small and medium-sized enterprises”, *The TQM Magazine*, Vol. 16 No. 4, pp. 264-72.

Appendix

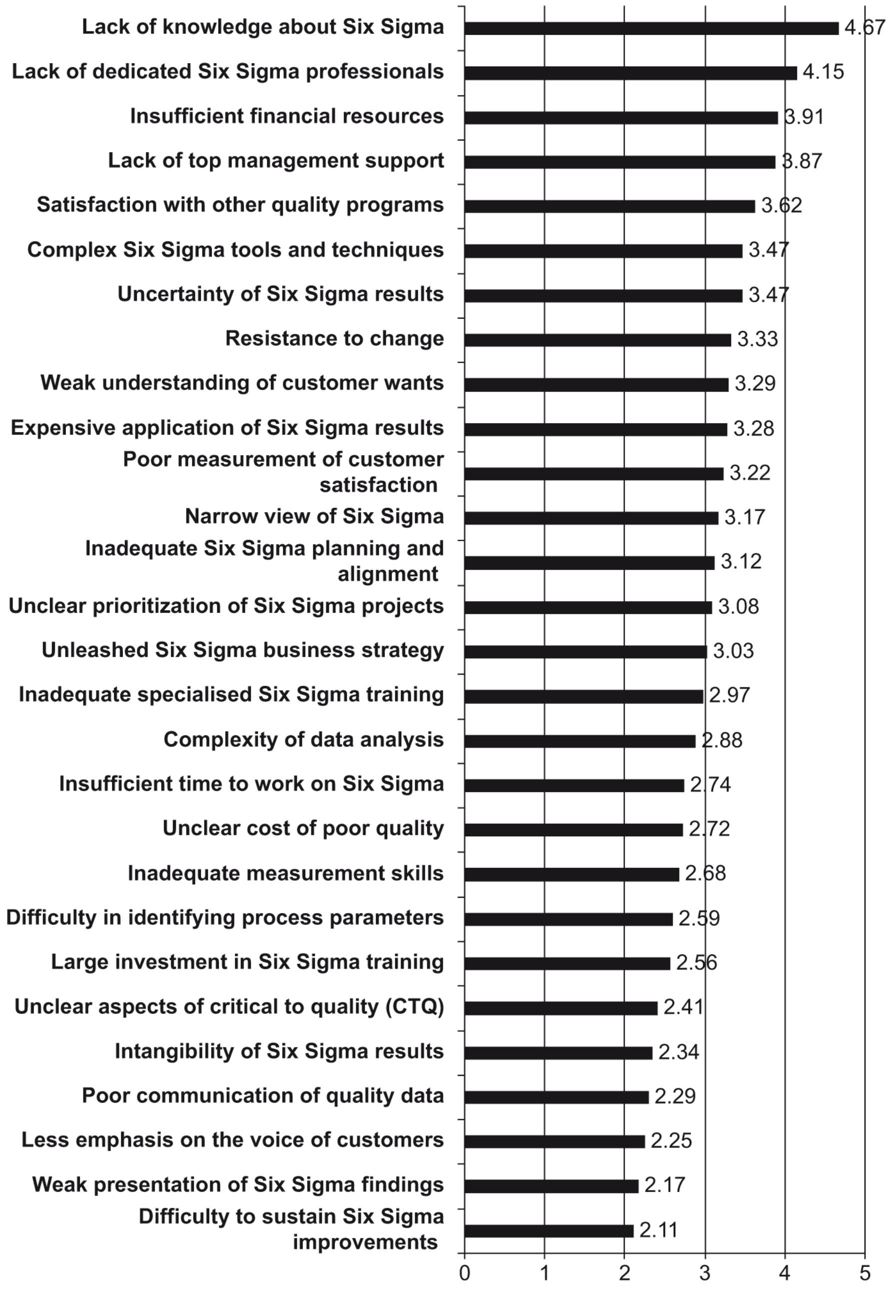

Figure A1.
Ranking of Six Sigma barriers according to their importance

About the author

Mohamed Gamal Aboelmaged has a PhD in Management Science from Lancaster University, UK, and MA in Public Policy & Administration from the Institute of Social Studies, The Netherlands. Currently, he is an Associate Professor of Management at Ain Shams University, Egypt. His research interests include quality systems, enterprise systems, and supply chain management. His work has been published in international journals and conference proceedings such as *International Journal of Quality & Reliability Management, Industrial Management & Data Systems*, *International Journal of Business Science and Applied Management*, *International Journal of Enterprise Network Management*, *Economic and Business Review Journal*, IEEE International Conference on Management of Innovation and Technology, Information Quality Conference at the Massachusetts Institute of Technology (MIT), British Academy of Management Annual Conference, The Operational Research Society Annual Conference, and Annual Global Information Technology Management World Conference. Dr Aboelmaged also gives professional training and consultancy regularly. Mohamed Gamal Aboelmaged can be contacted at: gaboelmaged@yahoo.com