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Adoption of Six Sigma: Review of Empirical Research

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Organizations are increasingly adopting Six Sigma in a bid to improve the quality of their processes and products, and thus achieve competitive advantage. However, despite the apparent popularity of Six Sigma, very little is known about the extent to which Six Sigma is actually being adopted by organizations. Since 2004, a number of empirical studies have been undertaken in different countries and industry sectors to address these gaps in our knowledge of Six Sigma adoption. The majority of these studies are reviewed and summarized in this paper. Our conclusions are that Six Sigma is only a distant second to Lean in terms of popularity. During the period 2003 to 2007, Six Sigma was implemented in 5% to 15% of the organizations.

Field of Research: Quality Management

1. Introduction

Organizations are increasingly adopting Six Sigma in a bid to improve the quality of their processes and products, and thus achieve competitive advantage. Six Sigma was developed by Motorola in the 1980s, but gained momentum after its adoption by General Electric in the mid 1990s. Six Sigma is a disciplined approach for dramatically reducing defects and producing measurable financial results (Goh et al., 2003). It provides an organizational structure in which improvement projects are led by so called Black Belts (BBs) and Green Belts (GBs), typically selected from middle management. To guide Black Belts and Green Belts through the execution of an improvement project, the program provides a collection of long standing management and statistical tools and a problem solving methodology known as DMAIC (Define - Measure - Analyse - Improve - Control).

However, despite the apparent popularity of Six Sigma, very little is known about the extent to which Six Sigma has actually been adopted by business firms in the world, the patterns of adoption across industrial sectors and occupational groups, and the factors that differentiate firms that heavily adopt Six Sigma from those who do not. A number of empirical studies have been undertaken in different countries and industry sectors to address these gaps in our knowledge on the adoption of Six Sigma. The majority of these studies are reviewed in this paper. The review will include the extent of Six Sigma adoption in industry, and the benefits and major hurdles in implementing the programme. This research paper will conclude with a brief review of methodological limitations in these studies and how future research can address them.

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2. Review of Empirical studies

Empirical studies on Six Sigma have been undertaken since 2004 and continue to be published. The authors reviewed seventeen studies, which the authors believe constitute most of the published empirical studies on implementing Six Sigma (see Table 1). Nine of these are research journal articles and the others include a PhD thesis and research reports published by research, consulting or professional organizations such as Aberdeen Group, IW/MPI (Industry Week / Manufacturing Performance Institute), EIU (Economic Intelligence Unit) and CC (Celerant Consulting). IW/MPI undertakes research on performance improvement programmes on a yearly basis, with Six Sigma being one of these. These empirical studies on Six Sigma have been undertaken in UK, USA, Canada, India, Brazil, Singapore, and Taiwan. The extent of implementation in these countries will be described in the following sections. Empirical studies covered all sectors of industries including healthcare, financial institutions, information technology as well as the SME sector.

3. Summary of Findings of Empirical Studies

3.1 Extent of Six Sigma Adoption

Out of the 17 surveys examined, it was possible to estimate the percentage of organizations implementing Six Sigma based on only eight studies (Figure 1 and Table 1). Five of these were conducted in the US, two in the UK and one in India. Of these eight, four used large sample sizes to estimate the level of Six Sigma implementation. All these four studies were undertaken during 2005 to 2007 in the US with Six Sigma implementation ranging from 5.0% to 15.5%. The estimates of the remaining four studies, all of which had very low response rates, ranged from 15.6% to 30.0%.

Only two of these eight studies targeted all types of organizations (small and large, manufacturing and service). Another two of these studies were related to the implementation of Six Sigma in manufacturing SMEs, both of which were conducted in the UK. There was one study on healthcare organizations conducted in the US. The estimates of the extent of Six Sigma adoption varied considerably. Based on the four large sample studies we could conclude that the uptake of Six Sigma among organizations has been low, ranging from 5.0% to 15.5%.

Caution must be exercised in generalizing the results presented in this paper, as most of the surveys examined have serious limitations which made it difficult to trust the findings of these surveys. Common issues with these studies are: small sample size, discrepancies between population and sampling frame, lack of information on how the sampling was conducted, poor data analysis, and poorly written articles.

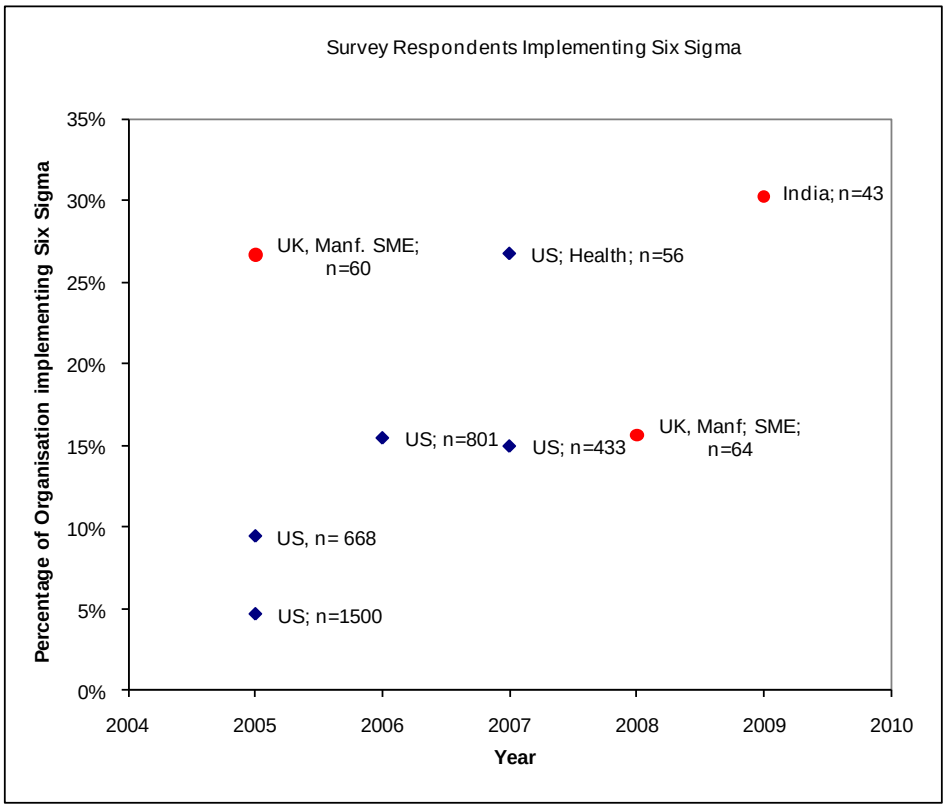
Table 1. Six Sigma Empirical Studies Examined In This Research

#	Reference (Authors and Year)	Research journal article /Research Report	Country where survey was undertaken	Industry sector	Survey Population	# of question-naires sent	Total responses	Usable responses	Respon-dents implement-ing Six Sigma	Survey methodology issues
1	(Antony, 2004)	Research journal article	UK	Service organizations	UK Service companies	200	28	23	16 (70%)	Does not mention what percentage of the respondents were implementing Six Sigma; small sample size
2	(Antony, Kumar & Madu 2005)	Research journal article	UK	Manufacturing SMEs	Manufacturing SMEs	400	66	60	16 (27%)	Small sample size
3	(Jung-Lang, 2007)	Research journal article	Taiwan	Members of Chinese Society for Quality implementing some form of Six Sigma	Members of Chinese Society for Quality implementing some form of Six Sigma	39	21	19	19	Small sample size
4	(Antony *et al.,* 2007)	Research journal article	UK	UK service organizations	UK service organizations	200	25(12.5%)	?	?	Does not make clear how many respondents were implementing Six Sigma; small sample size
5	(Feng & Manuel, 2008)	Research journal article	US	Healthcare organizations	US Healthcare organizations	3261	56 (1.7%)	56	15 (27%)	Small sample size
6	(Paulo Augusto Cauchick & João Marcos, 2009)	Research journal article	Brazil	Six Sigma companies	Selected sigma companies	121	78 (64.5%)	78?	78? (100%)	Survey was targeted to Six Sigma companies

#	Reference (Authors and Year)	Research journal article /Research Report	Country where survey was undertaken	Industry sector	Survey Population	# of question-naires sent	Total responses	Usable responses	Respon-dents implement-ing Six Sigma	Survey methodology issues
7	(Chakrabarty & Chuan, 2009)	Research journal article	Singapore	Top 1000 Service organizations	Top 1000 best performing service organizations	250	84	50	11 (22%)	Small sample size
8	(Antony & Desai, 2009)	Research journal article	India	All Businesses	All businesses in Gujarat State, India	290	43 (15%)	43	13 (30%)	Not clear how survey sample was selected; small sample size
9	(Tran, 2006)	MBA Thesis	Canada	Medium and large (75-100) manufacturing organizations	Pre-selected companies	230	?	?	35	Sample selection appeared to be a convenient sample
10	(Maneesh & Antony, 2008)	Research journal article	UK	Manufacturing SMEs	UK manufacturing SMEs	500	75	64	10 (15.6%)	Small sample size
11	(Anonymous, 2005a)	Research report	Worldwide	All organizations	"Exclusive Worldwide Six Sigma Survey .."?	?	?	?	?	Does not explain the sampling method or provide sample size
12	(Anonymous, 2005b)	Research report	US	All organizations	US, all organizations?	?	?	1500	71 (5%)	Unable to access the original report; not sure of sampling method
13	(David, 2006)	IW/MPI Research report	US	All manufacturing organizations	All US manufacturing organizations	?	?	668	9.5%	Appeared to be on-line survey
14	(AberdeenGroup, 2006)	Aberdeen group Research Report	US?	"Aerospace, defence, automotive, high-tech, industrial products, and other industries."	"Aerospace, defence, automotive, high-tech, industrial products, and other industries."	418?	?	418?	52%?	Sampling methodology not explained. Appeared to be on-line survey?

#	Reference (Authors and Year)	Research journal article /Research Report	Country where survey was undertaken	Industry sector	Survey Population	# of question-naires sent	Total responses	Usable responses	Respon-dents implement-ing Six Sigma	Survey methodology issues
15	(David, 2006)	Research report	US	All manufacturing organizations	All US manufacturing organizations	?	?	801	15.5%	Appeared to be on-line survey?
16	IW/MPI Manufacturers Survey (2007)	Research report	US	All manufacturing organizations	All US manufacturing organizations	?	?	433	15%	Appeared to be on-line survey?
17	(Jutras, 2009)	Aberdeen Group Research report	US?	All businesses	US manufacturing and non-manufacturing industries pursuing business improvement initiatives.	?	?	600	45%	On-line survey combined with interviews with select respondents.

Figure 1. Percentage of Organizations Implementing Six Sigma



3.2 Six Sigma Implementation Compared To Other Performance Improvement Programmes

How popular is Six Sigma compared to other performance improvement programmes such as Lean and TQM (Total Quality Management)? The surveys undertaken by EIU and CC (Anonymous, 2005b) and IW/MPI (David, 2006) provide an insight into this question (see Table 2).

Lean is clearly the most popular performance improvement programme with 36% to 40% of the respondents implementing this programme. Six Sigma is the second most popular performance improvement programme with just over 15% of the respondents implementing it in 2006 and 2007. In recent years, the third most popular programme has been TQM. Other improvement programmes include Agile manufacturing, TOC, and Toyota Production System. According to the EIU and CC studies (Anonymous 2005b), during 2003 to 2005, only 71 out of 1500 (5%) respondents indicated that they were implementing Six Sigma. However, according to this study, for companies with sales turnover greater than US$1 billion, Six Sigma is a top initiative along with corporate organization realignment. Also according to this study, Six Sigma is the second most likely initiative to be pursued in Telecom, Life Sciences and Healthcare organizations. Although Six Sigma ranked lowest among the total number of initiatives, according to this study, 25% of the organizations surveyed undertook a Six Sigma project during the period 2003 to 2005. Overall, the perceived success rate of the projects was 89% for large

organizations and 69% for small organizations. In summary, Six Sigma is a distant second to Lean in terms of popularity.

Table 2. Six Sigma Versus Other Performance Improvement Programmes

	EIU & CC (Anonymous 2005b) (n = 1500)	IW/MPI (David 2006) (n = 668)	IW/MPI (David 2006) (n = 801)	IW/MPI (2007) (n = 433)
Six Sigma	5%*	9.5%	15.5%	15%
Lean manufacturing		35.7%	40.5%	40%
TQM		15.9%	9.9%	10%
TOC		4%	3%	3%
Agile		4.4%	3.8%	4%
Toyota Production System		1.5%	3.1%	3%

*Implementation during three years before the survey was undertaken.

Who has been implementing Six Sigma? Is Six Sigma more popular with larger organizations or is it equally implemented in SMEs? This is an important question as it was argued in the literature that Six Sigma is primarily adopted by large organizations and that small organizations find it difficult to adopt Six Sigma due to lack of resources. Only three surveys addressed this issue. According to Antony (2004), 80% of the Six Sigma respondents (UK service organizations) in his survey have over 1,000 employees. In Feng and Manuel's study (2008), 14 out of 15 Six Sigma respondents (healthcare organizations) have 500 or more employees. In Chakraborty and Chuan's study (2009) in Singapore, 7 out of 11 Six Sigma respondents have 500 or more employees. Clearly, Six Sigma is predominantly adopted by large organizations.

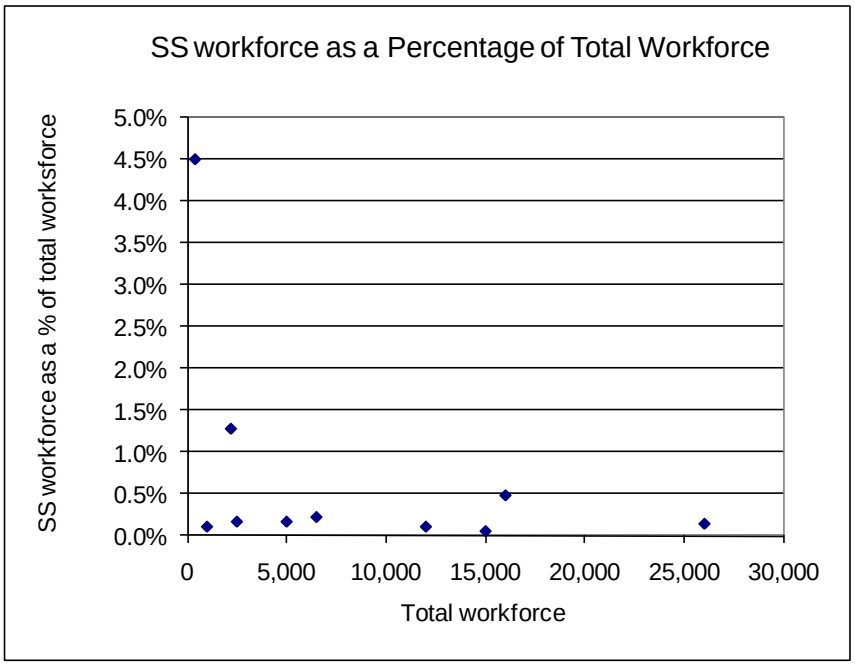
3.3 Extent Of Six Sigma Training And Six Sigma Specialists

Only two surveys provided details on the number of Six Sigma professionals and the level of training they received. Cauchick and Marcos (2009) report that of the Six Sigma respondents, 40% have Master Black Belts (MBBs), 80% have Black Belts (BBs) and 50% have Green Belts (GBs). However, they do not report the proportion of total employees in these roles, except to comment that the number of professionals involved with Six Sigma at the respondent companies was lower than the recommended numbers by Six Sigma experts. They also report that in 35% of the Six Sigma companies, MBBs were devoted to the programme full-time. Similarly 25% of the Six Sigma respondents indicated that Black Belts worked full-time on projects. Further, they reported that Six Sigma professionals in the majority of the Six Sigma organizations received the recommended 200 hours of training.

According to Feng and Manuel (2008), BBs are the driving force of the programme due to the fact that in each Six Sigma organization there is at least one BB employed. Based on 10 responses, Feng and Manuel reported that the percentages of total Six Sigma work force ranged from 0.05% (for an organization of 15,000 employees) to 4.5% (for an organization of 400

employees). Except in two companies, the percentage of Six Sigma professionals was typically around 0.2% of total work force. This percentage did not change with company size (Figure 2). These results are not as per the recommended 1 BB and 5 GB per 100 employees. There was only one organization in their respondents with less than 500 employees. Surprisingly this company had 1 MBB, 5 BB and 12 GB! Clearly, it is still possible for small organizations to take the path of Six Sigma if they wish to do so. However, this was an exception rather than the norm.

Figure 2. Six Sigma Workforce As A Percentage Of Total Workforce In Six Sigma Healthcare Organizations In US (Feng and Manuel 2008)



3.4 Projects: Selection, Duration, Problem Solving Tools And Software

Working on projects that have bottom line impact is the key aspect of Six Sigma programmes. Given this, it is important to know how organizations select projects. This aspect was addressed by only two surveys. Cauchick and Marcos (2009) report the following criteria used for project selection: “relation with the company’s strategic goals” (92%); “financial gains predicted for the project” (86%); and “increased customer satisfaction” (76%). Antony (2004) reported the following project selection methodologies in their survey: impact of the project on bottom-line; impact of the project on customer satisfaction; cost involved in running the project; COPQ (cost of poor quality); alignment of strategic business goals and objectives; risk involved in the project; and level of expertise required for project.

3.5 Problem Solving: Tools And Techniques Used

Table 3 provides a list of problem solving and quality management tools that were commonly used in implementing Six Sigma. These tools are presented in the decreasing order of their popularity of usage. Clearly the well-known seven tools of quality are the most commonly used tools. However, unlike TQM programmes, a wide variety of more sophisticated tools, such as ANOVA and probability plots, are also being used in implementing Six Sigma. This may be due to the rigorous DMAIC approach that is insisted on in Six Sigma programmes. Also, the increased availability of statistical software such as MINITAB would have encouraged the application of these tools.

3.6 Use Of Software For Problem Solving And Managing Projects

MINITAB has been recommended for use in Six Sigma programmes. Not many of these surveys reported on what software is used for problem solving and statistical analysis. Cauchick and Marcos (2009) report that 97% of the responded reported using MINITAB and 50% of the responded using EXCEL.

With more projects being undertaken, it becomes necessary to use project management software to track the projects. Qualtec survey (2005a) reports the following list of software that the responded reported to have used to track projects and performance: home-grown programmes (40.7%), EXCEL (39.5%), ProjX (7.4%), Instantis (3.7%), SixNet (1.2%).

Table 3. Quality Tools used in Six Sigma Projects

Quality Tools Used	(Antony & Fergusson, 2004)	(Antony, Kumar & Madu, 2005)*	(Antony & Desai, 2009)*	(Chakrabarty & Chuan, 2009)*
Cause and effect analysis		4.2	4.3	4.2
Brainstorming	√		4.3	4.1
Histogram		4.1	4.2	3.8
Run charts		3.1	4.1	
Pareto analysis	√		4.1	3.9
Process mapping	√	4.4	4.0	3.9
FMEA		3.9	4.0	
Control charts	√	3.3	3.9	3.1
SPIC model		3.3	3.7	
Process Capability Analysis		3.2	3.7	
COQ		3.0	3.7	3.3
ANOVA		3.4	3.6	3.1
Poka-Yoke		3.1	3.5	
Scatterplot		2.3	3.4	
Measurement systems analysis			3.3	
QFD		3.3	3.1	
Regression Analysis		1.8	3.1	
DOE		3.1	2.8	
Force field analysis			2.8	
Non-parametric tests		2.0	2.7	
Matrix Analysis			2.6	
Affinity Diagram	√	2.4	2.5	
Normal probability plot				3.4
Root cause analysis	√			3.0

*These ratings are on a scale of 1 to 5, 1 being lowest use and 5 being highest use.

3.7 Savings and Benefits

Six Sigma places considerable emphasis on cost savings through the implementation of projects. Antony, et al (2005) observes that 62% of the Six Sigma respondents (i.e. 10 out of 16 respondents) experienced financial benefits of up to £250,000 per annum and 13% of the companies (2 out of 16 respondents) experienced financial benefits of between £250,000 and £500,000 per annum. The remaining 25% Six Sigma respondents did not report any savings. Antony and Desai (2009) reported that 3 (out of 13 respondents) Six Sigma respondents reported an annual savings between US$100,000K to $200,000, while six of them reported an annual savings of over US$1 million. This information provided by Antony et al (2005) and Antony and Desai (2009) are of little value to the reader as £500,000 savings is 10% of annual revenues for an organization with annual revenues of £5M

or it could be just 0.1% of revenues for an organization with an annual revenue of £500m. Also, the authors report annual savings but do not mention over what period. Feng and Manuel (2008) reported costs and savings of four out of 15 respondents (US healthcare organizations) as shown in Table 4.

Table 4. Six Sigma Costs and Savings (Feng and Manuel 2008)

Organization	Annual costs	Annual savings	Benefits to cost ratio
A	$ 100,000	$ 5,500,000	55.0
B	$ 1,200,000	$ 6,000,000	5.0
C	$ 200,000	$ 1,500,000	7.5
D	$ 250,000	$ 1,000,000	4.0

They also report that one healthcare organization in US with 400 employees have been implementing Six Sigma for two years with annual savings of US$250,000 to US$750,000. In a yet to be published research article, one of the authors, based on a study of 27 well implemented Six Sigma companies, reports that the cumulative savings (as a percentage of revenues) over the period of Six Sigma implementation ranged from 0.03% to 6.8% with an average of 1.9%. These reported savings are obviously impressive. However, it is important to note that these are potential benefits of Six Sigma but are not representative of all Six Sigma implementations. It is quite possible that only those who had good success may have reported these figures and where savings were not substantial, the respondents are unlikely to report the results.

Only three studies Qualtec (2005a), Cauchick and (2009), and Jutras (2009) provided information on savings per project. Savings per project varied from US$25,000 to over US$250,000. These results are consistent with other literature, which states that, if properly implemented, Six Sigma savings can be US$150,000 per project (Mikel, 1998). Savings per project depends on size of the company and type of project. According to Cauchick and Marcos (2009), 80% of the Six Sigma respondents confirm that their accounting departments have validated the financial gains.

3.8 Critical Success Factors

Four surveys have identified the critical success factors in implementing Six Sigma. These are summarised in Table 5 - senior management commitment, linking Six Sigma to business strategy and customers, organizational readiness and project management skills have been identified as most important in all the studies. The other CSFs identified were: management of cultural change, company-wide commitment, integration of Six Sigma with financial accountability, understanding Six Sigma methodology, training and education, project selection and prioritisation, project tracking and reviews, incentive programmes, and linking Six Sigma to employees and suppliers.

Table 5. Critical Success Factors in Implementing Six Sigma

	(Antony, 2004)*	(Antony, Kumar & Madu, 2005)**	(Chakrabarty & Chuan, 2009)*	(Antony & Desai, 2009)*
Linking Six Sigma to business strategy	4.6	√		4.0
Linking Six Sigma to Customers (Customer focus)	4.4	√	4.1	4.1
Project management skills	4.4	√		3.6
Executive leadership and senior management commitment	4.2	√	4.5	4.2
Organizational infrastructure / readiness	4.2	√	4.3	4.2
Management of cultural change	3.7		4.4	3.6
Project selection and prioritisation	3.7	√		3.8
Integration of Six Sigma with financial accountability	3.5			
Understanding the Six Sigma methodology	3.2	√		3.8
Training and education	3.1	√	4.0	3.7
Project tracking and reviews	3.0			
Incentive program	3.0			
Company-wide commitment	2.9		3.9	
Linking Six Sigma to suppliers		√		3.3
Linking Six Sigma to employees		√		3.2

*1= least important; 5= critical to success
**These figures are read from chart

3.9 Resistance / Barriers to Implementing Six Sigma

As in many change management programmes, the Six Sigma initiatives do encounter resistance and barriers in implementation. Six surveys addressed this issue. These are summarised in Table 6, which shows that lack of senior management leadership is one of the top barriers to successful implementation of Six Sigma. The other factors most frequently cited were lack of education of the value of Six Sigma programmes, lack of resources, internal resistance (“here we go again”), and technical difficulties (project selection issues, data collection issues, etc.).

Table 6. Resistance And Barriers To Implementing Six Sigma

	(Antony, Kumar & Madu. 2005)	(Anonymous. 2005a)	(Feng & Manuel. 2008) (n=9)	(Jung-Lang. 2007)*	(Chakrabarty & Chuan. 2009)	(Antony & Desai. 2009)**
Lack of leadership from top executives		34%	78%	3.8		
Lack of knowledge about Six Sigma methodologies	√		√			
Education of value of Six Sigma			√			
Insufficient interdepartmental communication				3.7		
Lack of resources (people & budget) / time consuming	√	44%		4.0	45%	1
Committing Black belts full-time		33%				
Allowing the time for training		22%				
Lack of education and training	√			4.0		5
Internal resistance / "Here we go again"	√	24%	√			2
Overcoming business cultural barriers		54%				
Getting alignment within the organization		32%				
Too complex to use					55%	
Difficulty in identifying process parameters					45%	
Difficulty in collecting data					73%	
Poor project selection	√	26%				3

*These ratings are on a scale of 1 to 5, with 1 being lowest.
**Top five impeding factors, with 1 being the top of this list.

4. Discussion and Conclusions

In this paper we reviewed 17 empirical studies of which eight are articles published in research journals and the others include a PhD Thesis and research reports undertaken by consulting and professional organizations. These studies were undertaken in UK, USA, Canada, India, Brazil, Singapore and Taiwan and cover all industry sectors including healthcare, financial institutions, information technology. They also include large as well as SME sectors.

Six Sigma has been implemented throughout the world since around 1998 with most organizations implementing during early 2000s. Based on large sample studies, we can conclude that during 2003 to 2007, Six Sigma was implemented in 5% to 15% of the organizations. However, among the performance improvement programmes implemented, Six Sigma is only a distant second to Lean in terms of popularity. Also, it is more popular with larger organizations than with SMEs. Where applied, the Six Sigma projects have been considered as successful.

Caution must be exercised in generalising the results presented in this paper as most of the surveys examined have serious limitations, which make it difficult to trust the findings of these surveys. Common issues with these studies are: small sample size, discrepancy between population and sampling frame, lack of information on how sampling is carried out, poor data analysis and poorly written articles. The authors would like to suggest that future empirical research be conducted with care so that the results are meaningful and useful to other researchers. The authors would particularly suggest that editors of research journals should not publish articles based on weak research methodology.

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