Six Sigma in Healthcare: A Systematic Review of the Literature

Abstract

Purpose- The purpose of this paper is to illustrate the systematic role played by Six Sigma methodology in improving the quality of healthcare. The literature review identifies the relevant opportunities for successful introduction and development of Six Sigma approach in healthcare sector.

Design/ Methodology/ Approach - A systematic methodology to identifying literature on Six Sigma in healthcare is presented. Web of Science, Medline, Emerald Insight, ASQ and ProQuest databases (1998-2016) were searched, and 68 papers of fair methodological quality were identified.

Findings - The findings of the systematic review reveal a growing interest in research on Six Sigma adoption in healthcare. Our findings indicate that Six Sigma applications in healthcare have been focussed on the entire hospital with no real focus on a particular department or function. The key findings on benefits, success factors, challenges and common tools of Six Sigma from the existing literature are also presented in the paper.

Research limitations/ implications - The papers included in the systematic review were peer-reviewed papers available in English. Due to these limitations, relevant papers may have been excluded. Moreover, the authors have excluded all conference and white papers for their inclusion in this study.

Originality/ Value - This paper can serve as a guide on how Six Sigma approach can be applied to improve the quality of healthcare. The authors also believe that this is possibly the most comprehensive systematic literature review on the topic and will set the foundation for various research avenues based on the key findings of this study.

Keywords:

Six Sigma, Systematic Review, Benefits, Success factors, Challenges, Six Sigma tools

Introduction

While there have been discernable improvements in the efficiency and effectiveness of care in some settings, patients still experience unacceptable harm and often struggle to have their voices heard; processes are not as efficient as they could be; and costs continue to rise at alarming rates while quality issues remain (Berwick, 2013). Perhaps of most concern, recent public reports into health system failures continue to document a widespread lack of attentiveness to patient concerns, a culture of denial and wide- spread lack of professionalism (Keogh, 2013).

High-performing healthcare organizations differentiate themselves by focusing relentlessly and continuously on process-improvement initiatives to advance patient care. Continuous quality improvement offers a powerful way of thinking about how to transform clinical operations and healthcare teams to this end. Continuous quality improvement (CQI) and sig sigma are both a management philosophy and a management method. It offers an approach, a set of tools, and a way of thinking about how to more effectively assess and study clinical flow and operations to achieve better results for patients, providers and healthcare delivery systems (Sollecito and Johnson, 2013).

The last decades of the twentieth century witnessed a considerable expansion of Six Sigma into international locations, especially in the food, pharmaceutical, electronic, and aerospace industries. This growth in globalization, and the management challenges it brings, has been an inspiration for both academicians and practitioners. Six Sigma goes beyond national boundaries, concentrating on the process and CQI performance characteristics that are of critical importance to customers by identifying and minimizing defects, mistakes or failures in business processes or systems (Snee, 2004).

Six Sigma is receiving increasing attention in business as it plays an imperative role in quality improvement initiatives (Pepper and Spedding, 2010; Mader, 2008). Some organizations view it as a management activity that can help business leaders and

executives with the strategy, methods, tools and techniques for changing their business processes while others may use it as a basis for improving their efficiencies and customer satisfaction, minimizing operating costs and increasing profit margins (Sin et al. 2015; Laureani et al., 2013; Ho et al. 2008). The implementation of Sig Sigma can also help generate hard cash savings as reported by Motorola, General Electric (GE), and AlliedSignal/Honeywell, to name a few (Gijo et al., 2014; Hendricks and Kelbaugh, 1998). For instance, adoption of Six Sigma by Motorola triggered a five-fold growth in sales, with an increase of 20% profit and $14 billion cumulative savings (Pande et al., 2000). Motorola recently reported savings in excess of $20 billion over 20-plus years of deploying Six Sigma (Motorola, 2011). Recognizing the importance of Six Sigma in improving cost and quality, a variety of companies have adopted it including healthcare organizations (Guinane and Davis, 2004; Woodard, 2005; Liberatore, 2013).

In healthcare organizations, “Six Sigma engages senior leaders and leverages dedicated resources against the quality improvement projects with the biggest patient care and financial impact” (Black and Revere, 2006; p. 265). The concept of Six Sigma in healthcare was first implemented by the Commonwealth Health Corporation (CHC) in partnership with GE. This approach has given CHC a profit of $1.2 million, improved radiology throughput by 33% and decreased cost per radiology procedure by 21.5% (Thomerson, 2001). Despite the lack of proven success in India, Simplified Health Care, a prominent healthcare provider, has successfully launched Six Sigma with other IT initiatives including Electronic Health Care Records (Kapoor et al., 2012).

Researchers have attempted to assess the implementation of Six Sigma in healthcare (Martin and McLennan, 2005; Antony et al., 2007; Feng and Manuel, 2008). More recently, topics such as Six Sigma application to improve medication management, productivity and performance (Liberatore, 2013; Bhat et al., 2014) have gained a perch in healthcare. However, a systematic literature overview that captures the impact of Six Sigma tools in healthcare has not yet been provided.

The aim of this study is to systematically review six sigma interventions that were

tested and that aimed to improve patient outcomes and to evaluate the overall effects of these interventions. We aim to answer the following research questions: *How does Six Sigma in healthcare services evolve in terms of time and geographical perspective? What are the benefits, critical success factors and challenges in Six Sigma application in healthcare services and does geographical location have an influence on them? What are the top five Six Sigma tools used in the DMAIC (Define-Measure-Analyse-Improve-Control) roadmap? Are they significantly used in different continents/countries?*

Methods

Data Sources and Search strategy

We searched systematically for English-language studies (Downing, 2016) articles published between 1998 and 2016, using the following full text databases academic databases *Web of Science, Medline, Emerald Insight, ASQ and ProQuest* . The search strategy followed Tranfield et al.'s approach (2003) which seeks to create a reliable knowledge stock by synthesizing the relevant body of literature. This research did not collect primary data, but gathered secondary data from reliable database sources. The following search string was applied to search all the aforementioned databases: "Six Sigma" AND "Health" OR "Healthcare". Table 1 provides a detailed listing of search terms. The references of the selected studies were manually checked to identify additional relevant studies that were missed in the database search. We excluded the grey literature (conference papers, magazine related articles, workshops, books, editorials, prefaces, poster sessions, panel discussions and commentaries).

Study Selection

The initial search identified 1623 articles. Duplicates were removed and full text was retained if the abstracts stated that the study was related to Six Sigma and its applications in a healthcare context. Two reviewers independently assessed inclusion eligibility of the retrieved studies using the search strategy. (Won et al., 2016). The initial selection for inclusion was based on the title and abstract of the study (see inclusion and exclusion criteria specified below). When the title and abstract provided insufficient information to

determine the relevance, a full- text copy of the article was retrieved and reviewed. For the final selection, a full-text copy of the study was examined to determine whether it fulfilled the inclusion criteria. Dis-agreement about inclusion was solved by discussion. All discrepancies were resolved by reaching consensus with a third reviewer.

Studies were excluded from the final set for analysis if they focused exclusively on Lean Thinking and Lean Six Sigma. Research on quality management, ISO 9001, and other Continuous Improvement (CI) related papers such as Kaizen in healthcare services were also excluded. Additionally, studies that were not published in peer-reviewed journals were also excluded. Table 1 shows the inclusions and exclusions utilized for this research. This process yielded 68 studies for final inclusion in this review.

Insert Table 1 Here

Data extraction

The process of the extraction and synthesis of data was performed by using a 'best fit' framework synthesis method which provides 'a means to test, reinforce and build on an existing published model, conceived for a potentially different but relevant population' (Carroll et al., 2013, p.1). The data were managed by Mendeley and MS Excel spreadsheets and in order to precisely record information concerning the data, the authors independently reviewed each paper and coded them using a meta-framework. The data extracted from the studies comprised a description of objectives, design, participants, intervention, and effect measures. The data which were not clear to the authors or lacked explanations were removed from the analysis. Once the data were extracted and recorded, the coding was completed in order for discrepancy to be minimized and the analysis stage was performed using quantitative and qualitative methods. The analysis proceeded under various characteristics in response to research questions, including year of publication, countries of origin, authors, journals, research methods, healthcare classifications, benefits of Six Sigma implementation, success factors of Six Sigma projects, and common tools of Six Sigma adoptions in healthcare services.

Figure 1 A summary of evidence search and selection

Data Synthesis and Analysis

We organized study outcomes in tabular form and made a qualitative assessment based on the methodological quality, sample size, intervention characteristics, outcome, statistical significance, and direction of effects observed. With the help of the proposed methodology, we filtered out 68 relevant research papers for in-depth exploratory analysis of Six Sigma application in healthcare services. In exploratory analysis, we process the

available data and compile findings using various relevant lenses and their interconnections. The insights of these publications are presented through patterns of publications and emerging themes.

Results

Patterns of publications

We present the trend of number of publications, frequency distribution of published papers in the leading selected journals, geographical distribution of the publications in the area of study, classification of studies based on research methodology and healthcare services. Two pioneering studies suggesting the scope of Six Sigma in the healthcare sector were published by Buck (1998) and Chassin (1998). Their findings claim the possibility of Six Sigma implementation in healthcare and also identify the difference between the manufacturing process and healthcare services. Figure 2 shows the trend of number of publications between 1998 and 2016, clearly reflecting that from 2003 onward, researchers have shown a keen interest in exploring various combinations of healthcare and Six Sigma. Overall, the linear trend is upward during the selected period of study.

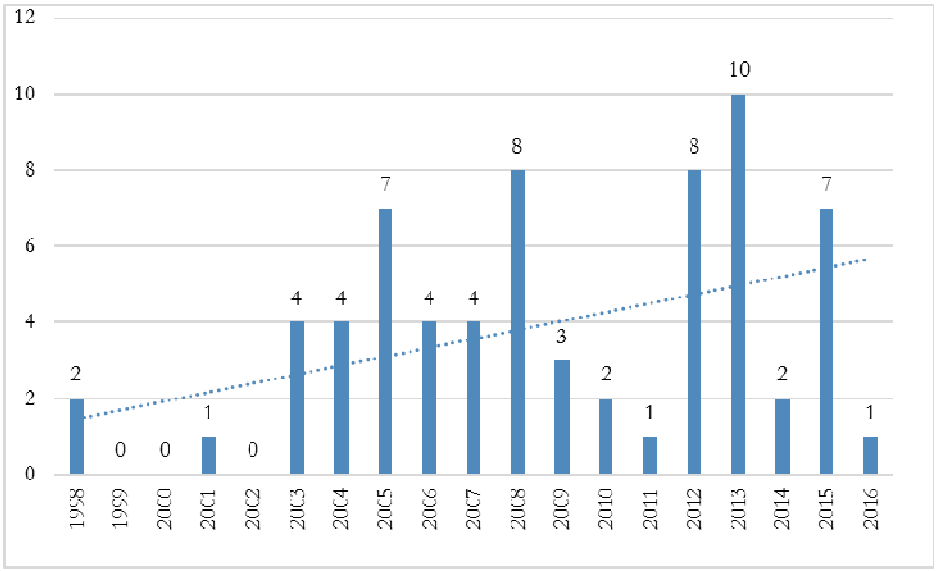

Figure 2 Trend of number of publications on six-sigma application on healthcare services

Frequency distribution of published papers in leading journals

The authors searched journals related to quality management, operations management, technology management, operations research, management science and healthcare disciplines. The thirty-one journals with 68 research articles with frequency distribution are presented in table 2 after undertaking the proposed screening process. The study reveals that the *International Journal of Health Care Quality Assurance* and *Quality Progress* are leading with 19% of selected publications in each.

Insert Table 2 Here

Geographical distribution of the publications

In this descriptive analysis, the selected papers were classified based on the country of the first author and, then, the countries were categorized and counted continent-wise. In case of multiple authors, only the first author's country was considered and counted. Six Sigma studies in healthcare have been reported from six continents in the world: North America, Europe, Asia, South America, Africa, and Australia. Figure 3 shows that North America has the highest number of publications with 38 papers in this review; it was also the first continent to report the application of Six Sigma in healthcare. Europe is the second ranked continent with 21 publications selected for review under Six Sigma adoption in healthcare. The third most popular region reporting Six Sigma adoption in healthcare was Asia with 10 studies in this review. Other continents such as South America, Africa, and Australia have rarely published papers on Six Sigma adoption in healthcare services; South America has reported two, whereas, Africa and Australia have only one paper each.

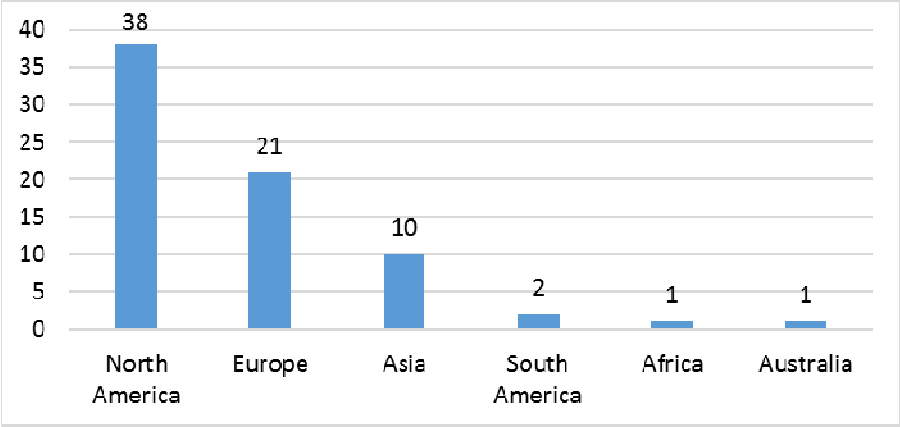

Figure 3 Frequency distribution of continent-wise Six Sigma application in healthcare services

It is interesting to note that the first two pieces of literature originated from different countries and continents. Buck (1998) published his study from the United Kingdom in Europe and Chassin (1998) published his study from United States in North America. We also found that in North America all studies were published from the USA whereas, in Europe, many countries such as the United Kingdom, Sweden, Italy, Turkey, Netherlands and Finland contributed to the literature.

In Asia, Chen et al. (2005) from Taiwan firstly reported Six Sigma methodology in a radiology department. The studies on Six Sigma adoption in healthcare have been published consistently and cover various countries in Asia, for instance, Taiwan, India, South Korea, Jordan, Pakistan and Singapore. This study revealed that, overall, the United States of America in North America, the United Kingdom in Europe, and India in Asia are the leading countries with a significant contribution in terms of setting examples and publishing research on Six Sigma application and adoption in healthcare.

Characteristics of Included Studies

The literature studied in Six Sigma adoption in healthcare services ranged from theoretical-conceptual literature, to empirical studies (e.g., survey), to case studies. Figure 4 presents the distribution of literature by research method. Accordingly, action research (AR),

case study (CS), theoretical-conceptual (TC), and survey (S) are at 54%, 22%, 18%, and 6% respectively.

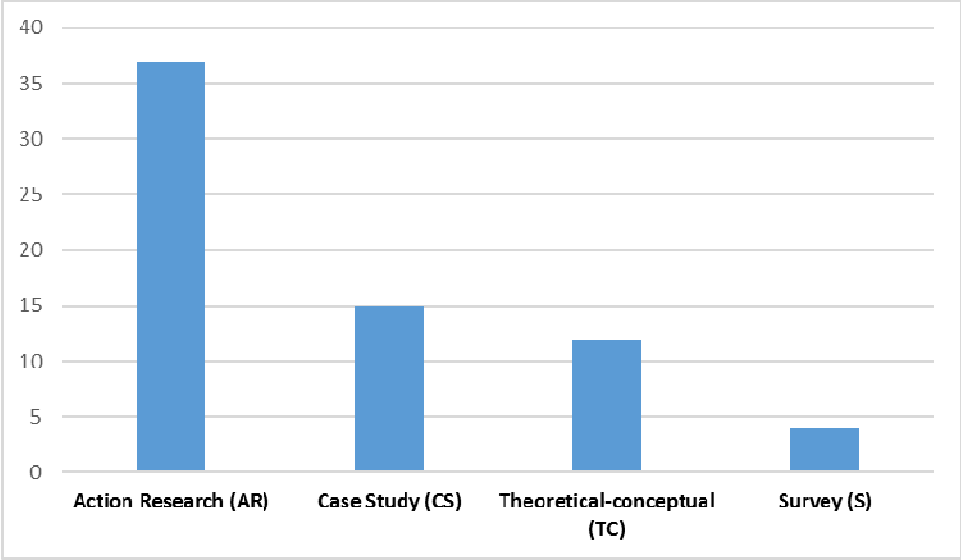

Figure 4 Frequency distribution of research method based papers on Six Sigma in healthcare services

Classification of healthcare services

The review of literature revealed that Six Sigma has been adopted in various types of healthcare services. Two studies have applied Six Sigma in the intensive care unit (ICU) by increasing the hand hygiene compliance rate by 80% (Eldridge et al., 2006 and Silich et al., 2012). We found 15 different activities in healthcare services where Six Sigma practices have been adopted. It is necessary to classify healthcare services into groups according to their commonality or synergy. Mazzocato et al. (2010) classify healthcare services into three major categories: clinical specialties, diagnostic services, and others. In this review, we propose a revised classification scheme which is adopted from Mazzocato et al. (2010). Table 3 presents the revised classification with five groups: *general, hospital, clinical specialties, diagnostic services, and other services.* The general group represents the literature which does not specify the area of application and the hospital group has been derived from studies which consider the entire hospital as a sample unit.

Insert Table 3 Here

The review highlights that Six Sigma's application in hospitals without a specific department or service elicited the maximum share (approximately 49%) followed by clinical specialties (18%). The category of general application, with no specific healthcare area, ranked third at 16%. Most of the literature in this classification consisted of theoretical-conceptual studies related to the benefits of Six Sigma implementation in healthcare services.

Emerging Themes on Six Sigma in Healthcare

In this section, we have highlighted some emerging themes such as benefits drawn from Six Sigma application in healthcare, tools used in different phases of Six Sigma implementation and adoption challenged faced, and factors leading to success.

Benefits

This section of the study attempts to answer the first concern about the outcomes or benefits associated with Six Sigma application in the healthcare sector. The benefits are categorized into five perspectives based on major stakeholders such as customers, shareholders, employees and government or regulating body (Donaldson and Preston, 1995), these are: *customer or patient focus, financial improvement, operation excellence, people, and compliance*. To gain a better understanding and clarity, these perspectives are further classified into 16 sub-categories, as shown in Table 4.

Insert Table 4 Here

Figure 5 presents the frequency distribution of 16 benefits categories. Each benefit referred to in the selected literature counts as one; therefore, the total of all the benefits is more than 68 due to multiple benefits found in many studies. This counting system is applied to success factors, challenges and common tools as well.

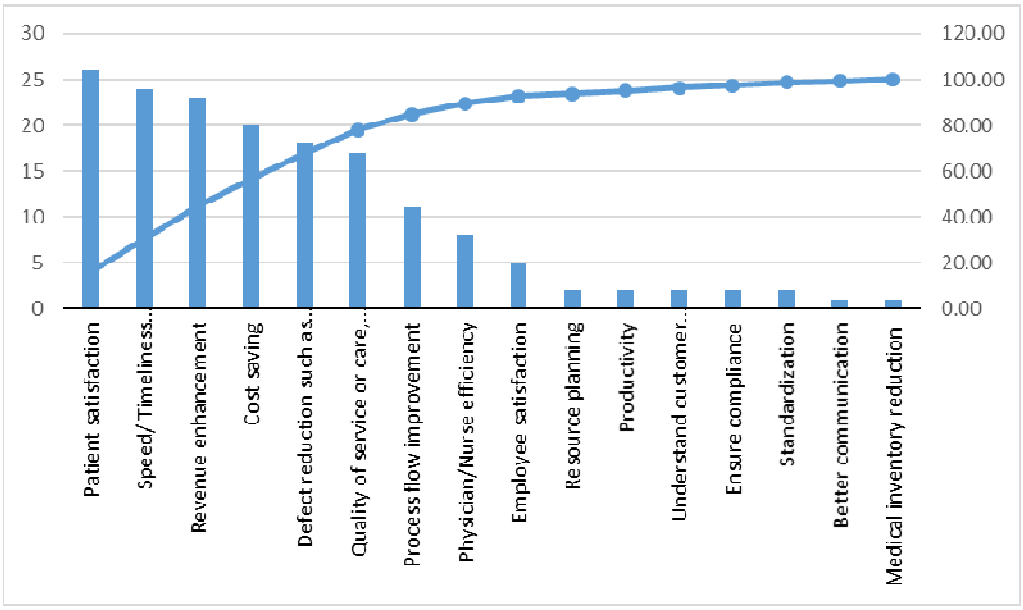

Figure 5 Pareto chart for benefits derived from Six Sigma adoption in Healthcare services

We found that among the 16 benefits, the top five include patient satisfaction, process speed (reduction of process cycle time), revenue enhancement, cost savings, and defect reduction respectively (Fig. 9). These top five benefits account for 68% of the total benefit categories.

Do different continents influence the outcomes or benefits in different ways from Six Sigma adoption? In this study, we have made an attempt to answer this question. Table 5 shows how the benefits of Six Sigma vary from one continent to another. It is important to note that these benefits are derived from a few case studies published in the literature and therefore our findings are not conclusive due to low sample size.

Insert Table 5 Here

It is clear from table 5 that the most important outcome from each continent is not necessarily the same. In North America and Asia, the top rated benefit from Six Sigma adoption is patient satisfaction whereas, in Europe, the most claimed benefit is speed (referred to as timeliness). However, in North America, Europe and Asia, the top five claimed benefits are quite similar, they include patient satisfaction, speed, revenue enhancement, defect reduction and cost savings, only the ranking of each benefit varies from one continent

to another. In Africa, the top benefit is revenue enhancement and cost saving while in Australia we found the top benefit is revenue enhancement and employee satisfaction. Moreover, the top and only benefit reported in South America is quality of care, which is claimed as the second benefit in North America.

Common Six Sigma tools

Various tools are usually deployed across all stages of the DMAIC roadmap and implemented in every Six Sigma project. For implementation of Six Sigma, it is possible to use more than one tool in each stage. In this review, tools mentioned in the literature are recorded against each phase of DMAIC.

We found 23 tools which are important and account for approximately 80% of the total number of tools. The tools are: data collection strategy, monitoring and control plan, process mapping, control chart, critical to quality linkage or CTQ, Pareto diagram, root cause analysis, cause and effect or fishbone diagram, Voice of Customer analysis or VOC, SIPOC (Supplier-Input-Process-Output-Customer) analysis, brainstorming, Failure Modes Effect Analysis (FMEA, Implementation plan, process flowchart/value stream mapping, project charter, cost-effectiveness analysis, graphical tools (box plot, dot plot, histogram, matrix plot etc.), Quality Function Deployment (QFD), Statistical Process Control (SPC), baseline measurement, correlation analysis, regression analysis and Design of Experiment (DoE).

These tools are used in both qualitative and quantitative methods in Six Sigma implementation. The tools are selected depending upon the nature of the problem at hand. In this study, we extracted 62 Six Sigma tools and techniques and selected top five against each stage of DMAIC, as shown in Table 6. In the defining phase, 20 tools are identified, based on 80/20 analysis, five important tools are identified consisting of process mapping, voice of customer analysis (VOC), problem definition, understanding of CTQ characteristics, SIPOC diagram. There are 26 tools recorded in measure phase. However, the Pareto chart identifies the five leading tools. These include data collection, baseline measurement, CTQ characteristics, control chart, Pareto diagram.

Insert Table 6 Here

In the analysis phase, approximately 17 tools are identified from the existing literature. The most popular five tools discovered in this review are Pareto analysis, cause and effect analysis or fishbone diagram, root cause analysis, FMEA, brainstorming. It is important to note that the Pareto chart is explored as a popular tool in both Define (to ensure that the right problem is chosen for investigation through the prioritization exercise) and Analysis (to separate the vital few from the trivial many) phases.

Table 6 depicts the type of tools utilized in the improve phase of the Six Sigma methodology. Most of the tools being applied are basic such as brainstorming, error proofing, simulation tools, creative thinking, except, design of experiment as advanced tool. The list of tools utilized in the control phase of the Six Sigma methodology include monitoring and control plan, control charts, SPC, benchmarking, histogram (to compare before and after scenarios).

In this section, we have analysed the variation in the use of tools across various continents. Table 7 illustrates the top five common tools used in various phases of the DMAIC methodology across each continent. In the Defining phase, process mapping has been used in every continent, except South America and Australia. Similarly, the VOC analysis tool is popular in North America, Asia, and Africa, but is less utilized in Europe, South America, and Australia. Moreover, the SIPOC diagram is common only in Europe and Asia. Project management tools such as project charter is adopted profusely in North America and Europe, but not chosen at all in other continents.

Insert Table 7 Here

In the Measuring phase, top five common tools in each continent are presented in table 7. It is quite clear that data collection scheme is used across continents in this phase. In Australia, a study implemented Design for Six Sigma methodology (DFSS); thus, tools

used from this continent are different from others. Interestingly, there is no tool used in this stage from South America.

In the Analysis phase, Pareto chart (T5) is used by every continent (Table 7). Other commonly used tools include FMEA and cause and effect fishbone diagram, which are quite similar in nature. In Europe, brainstorming, ANOVA, multi-regression analysis, simulation tool, cost effectiveness analysis, and root cause analysis are the most utilized tools.

We found that the Improvement phase deployed monitoring and control plan across the continents, as depicted in Table 7. Some graphical tools such as the control charts are utilized in the top three continents of North America, Europe, and Asia. Benchmarking is used in the improvement phase only in Australia, and Europe applied the highest number of tools. In the final stage, i.e., the Control phase, cause and effect fishbone diagram is used mainly in North America, Europe, and Asia. As with the improvement phase, the maximum number of tools are used by Europe in the control phase also (refer Table 7).

Challenges

In healthcare, the challenges faced during Six Sigma application are quite important for senior managers and practitioners to understand prior to implementation. The authors have identified 19 challenges in the current literature. Further, for simplification, these challenges are grouped into five perspectives for simplification: Six Sigma related challenges, project implementation challenges, people related challenges, post-implementation, and other challenges as presented in table 8.

Insert Table 8 Here

The analysis shows that eight challenges from a total of 16 identified from the literature account for 80% of the total. These are: availability of data, cultural issues, resistance to change, sustainability of results, insufficient resources, inadequate knowledge of Six Sigma, complexity of current practice and lack of leadership commitment. Moreover, five researchers reported that availability of quality data is the most significant challenge they

were confronted with in the use of Six Sigma within healthcare services. (Elbireer et al., 2013; Southard et al., 2012; El-Banna, 2013; Kureshi et al., 2010; McFadden et al., 2015).

We further analysed these challenges across the six continents (See Table 9) and it is quite interesting to note that availability of quality is the biggest challenge across the five continents. Australia is an exception with few studies on Six Sigma in Australian healthcare found in the current literature.

Insert Table 9 Here

Success factors of Six Sigma implementation in healthcare services

The reported success factors in the literature are classified based on the following five perspectives: organizational oriented, people oriented, financial oriented, customer oriented, and Six Sigma project management oriented. We further divided these perspectives into 16 categories. These 16 success factors have been explored in this systematic review and their frequency distribution, presented in the form of a Pareto chart as shown in figure 6. This analysis reveals that among all studies is the understanding of Six Sigma tools and techniques is the most important success factor. Moreover, the first seven factors, accounting for 80% of the total include: understanding of Six Sigma tools and techniques, management involvement and commitment, communication, organisation infrastructure and culture, training, patient focus and cultural change.

Bowerman et al. (2007) report nine success factors for the implementation of Six Sigma in the healthcare sector: management involvement and commitment, communication, training, project prioritization and selection, goal based approach, clear performance metrics, effective leadership, financial return, and organizational readiness.

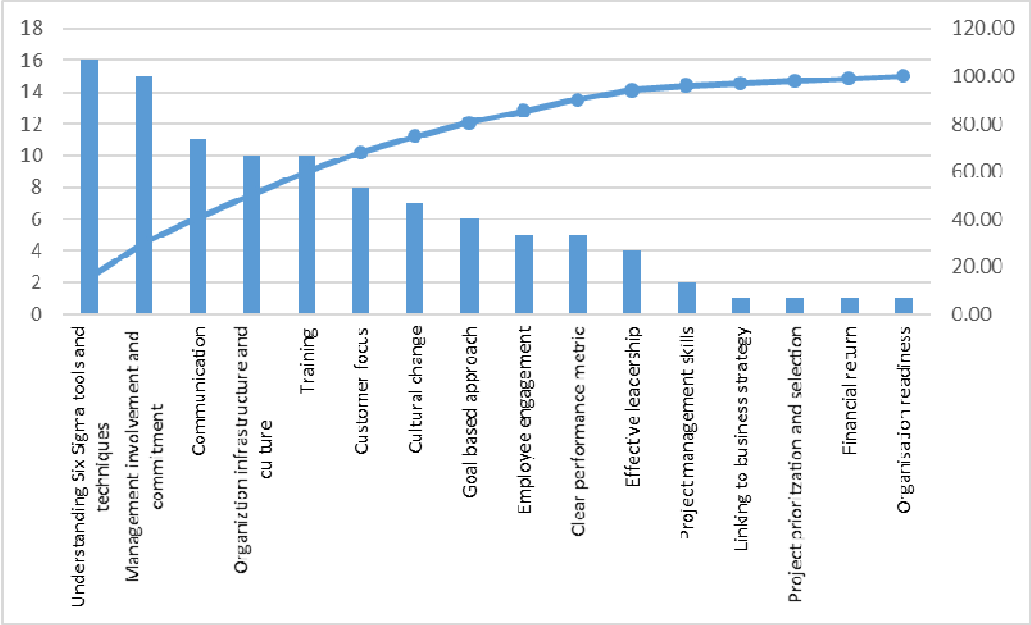

Figure 6 Pareto chart for success factor in Six Sigma adoption in healthcare services

Table 10 presents the success factors of Six Sigma across the six continents. Although an understanding of Six Sigma tools and techniques appears to be the most important success factor in the Pareto chart, it is quite interesting to observe that this factor ranks top for Asia and South America. Nevertheless, America, Europe and Australia account for management involvement and commitment as the most important success factor. Interestingly, Asia, which is third in terms of number of publications, does not report management involvement and commitment in the top five success factors.

Insert Table 10 Here

Discussion

To our knowledge, this is the first systematic review of the use of Six Sigma and its overall impact in healthcare. Our systematic review of the literature found 68 research papers drawn from 31 refereed journals from various established databases. The descriptive analysis reveals that the literature has been following an upward linear trend with a steep rise during 2012-13, which is quite aligned to the findings of Mason, Nicolay, and Darzi (2015). The continents which are driving this growth are North America (38), Europe (20)

and Asia (10). Within these continents, USA (37), UK (5) and India (4) are the leading countries in the number of publications. It is important to note that most of these studies (~49%) have been developed to analyse the relevance of Six Sigma application within an entire hospital rather than a particular unit or function.

We identified the most common benefits, challenges, success factors and the commonly applied tools within each phase of the Six Sigma methodology in the healthcare sector by conducting an exploratory analysis of the referred literature. It appears that the benefits of Six Sigma implementation in healthcare services include patient safety, process speed improvement, and revenue enhancement. In terms of success factors, we found that knowledge/awareness of Six Sigma methodology and top management involvement and their commitment are identified to be the most crucial for successful execution of Six Sigma projects. We identified over 60 tools and techniques from the literature which could be applied to different stages of DMAIC. Among them, the most commonly used tools include data collection plan, monitoring and control plan, implementation plan, brainstorming, and root cause analysis. Nevertheless, graphical tools such as Pareto chart, control chart, fishbone diagram, and FMEA are also widely used in different phases of DMAIC.

Managerial and policy implications

This review has significant implications for senior managers and policy makers in healthcare to understand the benefits and success factors related to the implementation of Six Sigma as a business strategy for operational and service excellence. Senior managers and policy makers need to reflect more fully on the importance of the powerful problem solving methodology (DMAIC) and the associated tools which are integrated into the methodology. Although a number of successful case studies were published, virtually no papers were found that discuss failure stories of Six Sigma. Perhaps it is essential to understand some of the failed applications of Six Sigma in the healthcare sector in order to develop best-in-class practice. Moreover, there is a dearth of literature on sustainability of Six Sigma initiatives in a hospital setting and this would be beneficial to many healthcare practitioners and policy makers. To address the quality/safety related issues in healthcare

systems, analysis of the impact of the culture of the organization and country culture on Six Sigma adoption is a key to success. However cultural change in any organizational setting would not happen without the involvement of an engaged workforce which is a result of charismatic and visionary leadership. The authors feel that there is very little research being carried out on the VOC (i.e., patients in a hospital setting) and this should be the major focus of research in forthcoming years. Although the Kano model has been used widely to elicit customers' service quality requirements and improve customer satisfaction, the implementation of the Kano model in healthcare remains in its infancy and there is ambiguity in patients' needs related to healthcare services.

Our study has limitations. As we know, a systematic literature review is performed to reduce bias and minimize error of data extraction and quality of assessment phases. However, there is a mismatch in the number of papers which dealt with the mentioned themes. For instance, papers dealing with challenges in Six Sigma adoption in healthcare are minimal and therefore, robust findings could not be found. We found great variability in control conditions, patient populations, out-come definition, methods of outcome measurement, and outcome assessment times and a high degree of clinical diversity, which makes synthesizing results and drawing conclusions difficult. Our review may have been influenced by publication bias; unpublished studies on this subject may be more likely to have negative results. Finally, our search strategy was limited to English-language studies and did not include unpublished abstracts from conference proceedings or non-indexed journals.

Conclusions

The findings of the systematic review reveal a growing interest in research on Six Sigma adoption in healthcare. Most of the selected studies belong to or are based on countries such as the USA (37), UK (5) and India (4). The authors found that the literature on Six Sigma applications in healthcare have been focussed on the entire hospital with no real focus on a particular department or function. The results of the systematic review suggest that the most common benefits of Six Sigma implementation in healthcare are improvement

in patient safety, improvement in process speed (i.e., increased productivity) and revenue enhancement (i.e., bottom-line savings). Among the various challenges analysed in the use of Six Sigma within healthcare services, it was observed that the availability of data is the most prominent for Six Sigma implementation in the healthcare sector. In term of success factors, we found that knowledge and awareness of Six Sigma methodology and top management involvement/commitment are the most crucial aspects for successful execution of Six Sigma projects.

We observed that Six Sigma adoption in healthcare has ample opportunity for development. The authors feel there is no roadmap in the current literature on the deployment of Six Sigma in a hospital setting and this could be an interesting topic for further research and would require empirical settings through action research. Moreover, a readiness assessment model would be very useful before hospitals embark on the journey of Six Sigma. The literature demonstrates that healthcare has a variety of services which become influenced by organizational culture. We notice that there is an explicit gap in the literature that demonstrates the impact of culture on performance through the adoption of Six Sigma.

The findings of our study also suggests that the most commonly used Six Sigma tools include data collection planning and strategy, monitoring and control plan, implementation plan, brainstorming and root cause analysis. Moreover, graphical tools such as Pareto analysis, control chart, fishbone diagram, and FMEA are also profusely used across various phases of DMAIC methodology. Although Six Sigma has been embraced by a number of hospitals across the world, the authors feel that no standard curriculum has been developed for various systems; moreover, there is no set standard for projects and expectations on the outcomes of such projects. The authors anticipate a number of research avenues along these lines in the forthcoming years for sustainability of Six Sigma as a powerful business process improvement methodology in the healthcare sector.

References

Table 1 Inclusion and exclusion criteria

Inclusion criteria	**Exclusion**
Academic peer-reviewed journal articles.	Grey literature (conference proceedings, dissertations, text books, magazine related articles, etc.).
Articles published in high quality journals and articles from specialized healthcare journals.	Articles published in non-refereed journals
Articles that discuss solely Six Sigma implementation and practice focusing on healthcare services.	Articles discussing ISO 9000, lean thinking, quality management, and other continuous improvement (CI) methodologies (e.g., Kaizen) in healthcare services and other sectors.
Articles published in English.	Articles published in languages other than English.
Articles from all publication years until present (i.e., 1998 – 2016).	Articles published before 1998 (authors could not identify any Six Sigma related articles before 1998).

Table 2 List of Journals with article counts reviewed

Journal Title	Abbreviation	Article count	%
International Journal of Health Care Quality Assurance	IJHCQA	13	19%
Quality Progress	QP	12	19%
Journal of Healthcare Management	JHM	4	6%
International Journal of Six Sigma and Competitive Advantage	IJSSCA	3	4%
Quality and Reliability Engineering International	QRE	3	4%
Benchmarking: An International Journal	BIJ	2	3%
Journal for Healthcare Quality	J Healthc Qual	2	3%
Leadership in Health Services	Leadersh Health Serv	2	3%
Milbank Quarterly	MILBANK Q	2	3%
Quality Engineering	QE	2	3%
Quality Management in Health Care	Qual Manag Health Care	2	3%
BMC Medical Informatics and Decision Making	BMC Med Inform Decis Mak	1	1%
Business Process Management Journal	BPMJ	1	1%
Engineering Management Journal	EMJ	1	1%
International Journal of Pharmaceutical Sciences and Research	IJPSR	1	1%
International Journal of Services and Operations Management	IJSOM	1	1%

Journal Title	Abbreviation	Article count	%
Joint Commission Journal on Quality and Patient Safety	Jt Comm J Qual Patient Saf	1	1%
Journal of Cases on Information Technology	JCIT	1	1%
Journal of Clinical & Diagnostic Research	JCDR	1	1%
Journal of General Internal Medicine	J. Gen. Intern. Med.	1	1%
Journal of Healthcare Engineering	J Healthc Eng	1	1%
Journal of Hospital Librarianship	J Hosp Librariansh	1	1%
Journal of The National Comprehensive Cancer Network	JNCCN	1	1%
Journal of the Operational Research Society	J. Oper. Res. Soc.	1	1%
Managing Service Quality: An International Journal (Current as Journal of Service Theory and Practice)	MSQ	1	1%
Nursing Economics	Nurs Econ	1	1%
Operations Management Research	OMR	1	1%
Psychiatric Services	Psychiatr Serv	1	1%
Quality Management Journal	QMJ	1	1%
Total Quality Management & Business Excellence	TQMBE	1	1%
TQM Magazine	-	1	1%
Total Number of Articles		**68**	**100%**

Table 3 Healthcare service classification

Healthcare service classification	Definition	Inclusion	Count of literature	%
General	Not-specific area	Literatures do not specify the healthcare area	11	16%
Hospital	Entire hospital application	Entire hospital services	33	49%
Clinical specialties	Services in hospital, which is mainly relationship between patients, doctors, and nurses	Inpatient, Outpatient, Intensive Care, Dental care, Emergency, and Surgery	12	18%
Diagnostic services	Services related to diagnosing patient sickness	Cardiology, Radiology, Laboratory service	9	13%
Other	Other healthcare services	Nursing, Blood transfusion centre, Telemedicine	3	4%

Table 4 Benefit and outcomes classification from existing literature

Classification	*Outcomes category*
Customer/ Patient focus	Patient satisfaction
	Understand patient needs/wants
Financial improvement	Revenue enhancement
	Cost savings
Operation excellence	Speed/ Timeliness (Decrease length of stay, decrease waiting time, etc.)
	Quality of service or patient care, Patient safety
	Physician/Nurse efficiency
	Resource planning
	Defect reduction such as medication error reduction
	Process flow improvement
	Productivity
	Medical inventory reduction
	Standardization of processes/procedures
People	Employee satisfaction/Employee engagement/Morale
	Better communication between departments (less silo mentality)
Compliance	Ensure compliance

Table 5 Top five benefits of Six Sigma in healthcare services from each continent

Rank	***North America***	***Europe***	***Asia***	***Africa***	***Australia***	***South America***
1	Patient satisfaction	Speed	Patient satisfaction	Revenue enhancement,	Revenue enhancement	Quality of service or care
2	Quality of service or care	Revenue enhancement	Speed	Defect reduction	Employee satisfaction	-
3	Patient safety	Patient satisfaction	Revenue enhancement	Cost savings	-	-
4	Speed, defect reduction	Cost savings	Defect reduction	-	-	-
5	Cost savings	Defect reduction	Cost savings	-	-	-

Table 6 Top five common tools in the various phases of DMAIC methodology

No.	Define	Measure	Analyse	Improve	Control
1	Process mapping	Data collection	Pareto chart	Brainstorming	Monitoring and control plan
2	Voice of customer analysis	Baseline measurement	cause and effect analysis	Error proofing	Control charts
3	Problem definition	CTQ characteristics	Root cause analysis	Simulation tools	Statistical Process Control
4	Understanding of CTQ characteristics	Control chart	Failure Modes Effect Analysis	Creative thinking	Benchmarking
5	SIPOC diagram	Pareto chart	Brainstorming	Design of Experiment	Histogram

Table 7 Top three common tools in the various phases of DMAIC methodology across continents

	North America	*Europe*	*Asia*	*South America*	*Africa*	*Australia*
Define	1. Voice of customer analysis 2. Process mapping 3. Quality problem definition	1. SIPOC diagram 2. Process mapping 3. Process flowchart	1. Voice of customer analysis 2. Critical to Quality linkage 3. SIPOC diagram	1. Benchmarking	1. Process mapping, 2. Voice of customer analysis 3. Quality problem definition	1. Quality function deployment 2. Failure modes effect analysis
Measure	1. Data collection 2. Cost-effectiveness analysis 3. Process flowchart	1. Data collection 2. Critical to Quality linkage 3. Quality function deployment	1. Data collection 2. Critical to Quality linkage 3. Affinity diagram approach	--	1. Data collection	1. Multivariate analysis 2. Design FMEA
Analysis	1. Root cause analysis 2. Pareto diagram 3. Failure modes effect analysis	1. Pareto diagram 2. Brainstorming 3. Cause and effect fishbone diagram	1. Cause and effect fishbone diagram 2. Pareto diagram 3. Brainstorming	--	1. Cause and effect fishbone diagram 2. Pareto diagram 3. Brainstorming	--

Improve	1. Monitoring and control plan 2. Control chart 3. Statistical process control	1. Monitoring and control plan 2. Control chart 3. Cause and effect fishbone diagram	1. Monitoring and control plan 2. Control chart 3. Histogram	--	1. Monitoring and control plan	1. Benchmarking
Control	1. Root cause analysis 2. Pareto diagram 3. Failure modes effect analysis	1. Pareto diagram 2. Brainstorming 3. Cause and effect fishbone diagram	1. Cause and effect fishbone diagram, 2. Pareto diagram 3. Brainstorming	--	1. Cause and effect fishbone diagram, 2. Pareto diagram 3. Brainstorming	--

Table 8

Challenge classification and their respective codes

Classification	*Challenges category*
Six Sigma related challenge	Inadequate/insufficient knowledge of Six Sigma
	Limitation of understanding about statistics
During implementation	Availability of data
	Complexity of current practice
	Scope/Timeline change
	Resistance to change
	Poor execution of projects
	Difficulties in quantifying hard-cash savings
	Difficulty to hand over to process owners
	Insufficient resource
People related challenges	Lack of leadership commitment
	Awareness of Six Sigma benefits
	Cultural issues
	Poor communication
	Engagement of the workforce
	Psychology of the workplace
Post-implementation	Result sustainability
Other challenges	Budget constraints or Investment problem
	Regulation issues

Table 9

Top five challenges from each continent

Rank	***North America***	***Europe***	***Asia***	***South America***	***Africa***	***Australia***
1	Availability of quality data	Availability of quality data	Availability of quality data	Availability of quality data	Availability of quality data	-
2	Resistance to change	Insufficient knowledge of Six Sigma	Results sustainability	Insufficient knowledge of Six Sigma		-
3	Cultural issues	Results sustainability	Complexity of current practice	-	-	-
4	Results sustainability	Insufficient resources	Insufficient resources	-	-	-
5	Poor communication	-	Insufficient knowledge of Six Sigma	-	-	-

Table 10 Top five success factors from each continent

Rank	***North America***	***Europe***	***Asia***	***South America***	***Africa***	***Australia***
1	Management involvement and commitment	Management involvement and commitment	Understanding Six Sigma tools and techniques	Understanding Six Sigma tools and techniques	Customer focus	Management involvement and commitment
2	Organization infrastructure and culture	Communication	Training	Goal based approach	Understanding Six Sigma tools and techniques	Training
3	Cultural change	Training	Cultural change	Clear performance metric		
4	Communication	Customer focus	Organization infrastructure and culture			
5	Understanding Six-sigma tools and techniques	Understanding Six-sigma tools and techniques, Goal based approach	Customer focus, Employee engagement			