International Journal of Lean Six Sigma

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Received 7 April 2017
Revised 9 July 2017
Accepted 12 August 2017

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Abstract

Purpose – Literature reviews are a pervasive aspect in research. An ever mounting field such as Lean Six Sigma requires a perpetual touch on the subject to accentuate insights that can be researched about. The purpose of this paper is to address the published literatures in the field of Lean Six Sigma through multiple criterion for an enhanced understanding of the subject matter through summarizing its current trends, uncovering existing literature gaps and revealing opportunities for future research in the field.

Design/methodology/approach – The literature review on Lean Six Sigma field spans around 17 years that includes peer-reviewed journals from management, business, engineering, healthcare, manufacturing, military among the many disciplines. The study uses a content analysis approach in which several dimensions of the literature were analysed: purpose or focus of study, years of publication, journal name or publications, methodologies, theories used, country of study, industry sub-sectors, active authors in the field, critical success factors, barriers and challenges and the most contribution of Lean Six Sigma papers by universities.

Findings – Eleven important findings from the analysis were summarized among them; the field of Lean Six Sigma had begun to grow significantly since the new millennium particularly after the 2004-2007 or 2008 period; standalone concepts of Lean and Six Sigma are highly researched compared to the integrated concepts; large proportion of perspective, conceptual and descriptive based studies; lack of empirical validity on the fusion between Lean and Six Sigma; lack of theoretical based studies, etc.

Research limitations/implications – The study is limited to 102 journals in commonly searched databases in the subject matter which produced 261 journal papers. This study seeks to broaden the summary of studies done under the keyword "Lean Six Sigma".

Originality/value – The review analysis uses a content analysis approach in search of valuable gaps in existing research. The study found 261 papers from 102 journals that were published over the past seventeen years (2000-2016). This paper provides scholars, practitioners and managers with insights on the present trends and focus of Lean Six Sigma in addition to what else are lacking in the subject matter, which could pave the way for future research and practical endeavours.

Keywords Six sigma, Lean six sigma, Content analysis, Lean

Paper type Literature review

International Journal of Lean Six Sigma
Vol. 9 No. 1, 2018
pp. 2-49

2040-4166
DOI 10.1108/IJLSS-04-2017-0028

1. Introduction

The mounting trend and concern of competition in the business industry led to the approach of seeking better ways of doing things in the management purview. Quality management used to be a peripheral expanse to the core management structure within organizations. This however changed the course of how quality used to be seen which now, is more of an overriding management phenomenon that organizations use to manoeuvre business objectives effectively. Among the many quality management and process improvement systems available in the industrial layouts, Lean and Six Sigma are commoners and vastly known. Lean is a direct extrapolation of the Toyota Production System (TPS) which became known to the world as the "machine that changed the world" (Womack *et al.*, 1990). Lean is an embedment within the culture and DNA of Toyota which focuses on the elimination of waste. As it is, wastes refer to all that are non-value adding activities categorized in seven forms which customers are unwilling to pay for. This leads to a cordial structuring of the process that focuses only on the things that customers would look for from the provider. Formed in Motorola, Six Sigma on the other line of the quadrant emphasizes variation (Antony, 2011). Variation in process' performance is something inherent no matter how perfect the process underlies; thus, focus is placed on minimization of such variation, common and special causes alike. Six Sigma's orientation of handling process improvement is more structured and data oriented, objectively specifying the underlying root causes before a decision is made through every phase of the projects.

The traditional approach to quality had placed emphasis on either increasing speed or reducing variation within the process. Should waste be eliminated, it provides speed to the process however the level of quality could be compromised at the course of the action, as things are moving fast and cannot guarantee quality. On the other hand, reducing variation consumes more time, as it requires careful identification of the vital few factors prior to summarizing a viable solution for improvement wherein the question of quality is undebatable nevertheless time factor is conceded. The changing business environment necessitates improvised option that effectively impels sustainable adaptation. Thus, the fusion or hybrid of Lean Six Sigma was lately deemed prolific. As competition heightens, more and more businesses centre on the deliverance of customer value at the highest order and at a timely manner. This explains the integration of Lean and Six Sigma that has been receiving attention lately (Yadav and Desai, 2016). Antony *et al.* (2016) elucidated the industry concern on adapting both Lean and Six Sigma into the management strategy. Meanwhile, there are also concerns within the industry on which strategy between the two or both is inclusive (Snee and Hoerl, 2007). Authors such as Arnheiter and Maleyeff (2005) and Salah *et al.* (2010) had preached about the integration of both concepts' advantages that explain the benefits of same. Arnheiter and Maleyeff (2005) explains that Lean companies are investigating Six Sigma meanwhile Six Sigma companies are examining Lean in search of competitive advantage. They went on to imply that although with disparate roots, Lean and Six Sigma are effective in their own ways and the combination of both leads to the betterment of competitive advantage.

The hybrid methodology of Lean Six Sigma is relatively a new philosophy, especially since the new millennium. Thus, research on the field is expanding through scholarly articles. However, very few comprehensive and systematic literature reviews are done on Lean Six Sigma in the course of the research; however, many reviews are indeed available on the isolated methodology of Lean or Six Sigma. With this new emergence, there is an increasing need to understand the present trend of research in the field of Lean Six Sigma that generates the momentum in knowing the impact of the subject to the scholarly world. The ability to view the studies done in this field would likely provide clear paths for future

endeavours. Although there are a number of articles on Lean Six Sigma which reviewed the literature, a thorough analysis on the literatures' content is necessary yet beneficial. Therefore, the purpose of this paper is twofold. First, this study intends to stretch the previous work in the Lean Six Sigma field by examining the literature through a content analysis with greater depth and breadth than previous studies. The second objective is to scrutinize the extant literatures that portray the current and past trends in the study of the subject that reveals notable gaps in the existing and past researches. In doing so, the summary is hoped to enlighten practitioners and scholars on where the field of research stands currently, what type of research are predominant and which area seems to be increasing in concern.

This paper comprises of seven sections. The foregoing introductory Section 1 provided a general idea about the research topic. Section 2 gives an overview of all the concepts' evolution and the summary of existing literature reviews. Section 3 elicits the summary of existing literature reviews in Lean Six Sigma. Meanwhile, Section 4 provides the research methodology used for the study. Section 5 displays the results of the content analysis according to the classification framework, whereas Section 6 delivers the discussion segment, and finally Section 7 offers conclusion and limitations of the study.

2. Overview of concepts

2.1 Lean

Lean is typically associated with the automobile company Toyota. This is because of the fact that the essentials of Lean were derived from the basis of TPS which the parent company used as reference in running their day-to-day operations in dealing with their strategic management. Waste is an inherent feature in processes. In undertaking and executing tasks, most of the time humans tend to be ignorant of the wastes that underlie their activity. The Japanese call waste as "Muda". Although many articles had implied on this, not many have explicated the depth of waste as Toyota did, which had two more dimensions to it – "Mura" which means unevenness in the process such as unstandardized or disrupted practice and "Muri" which means overburden in executing tasks that likely lead to wastes (Hines and Lethbridge, 2008; Ohno, 1988; Womack and Jones, 1996). Thus, elimination of waste became the prime motive in Lean. Every practice, every activity and functions that are likely to impede the flow of a process are specified as wastes and are targeted for elimination. Deriving from this term, their focus of attention was driven to what customer wants (Womack and Jones, 2010) instead of what the firm wants to provide. This sets up the notion of value in the flow or the value stream in processes moving towards customer in the form of end product or service provision.

Shah and Ward (2007) went on to address that Lean is not just a bundle of tools but instead an integrated socio-technical system. Hadid *et al.* (2016) stressed on this purview by investigating the interaction term between Lean's social practices and technical practices against the performance measures of financial and operations. This support on social and technical aspect of Lean brings back to the ideology promoted by Toyota where it did not only focus on productivity efficiency by waste elimination but also on an equal respect for humanity as mentioned by Ohno (1988). Most companies' practice of Lean mainly focused on the technical portion that may have caused their downfall as the proponents of Toyota argue. It's more than just the Japanese method of working; it was a way of life with work being a part of it (Liker, 2004; Ohno, 1988; Womack and Jones, 1996).

2.2 Six Sigma

Bob Galvin, Bill Smith, Mikel J. Harry, Jack Germaine, Larry Bossidy and Jack Welch are among the names that resonates profoundly in the history and development of Six Sigma. As aforementioned, the noteworthy permeation of the concept kicked off through Motorola in the USA, during its years of tribulation, much similar to the Toyota's experience. Although Six Sigma began its streak at Motorola, the global intensification came through the adoption of the concept by General Electric (GE) when Jack Welch was at the helm as CEO. The difference of Jack Welch's application of the philosophy from Motorola's initiation is that he literally made the concept an engrained culture of his organization (Pande *et al.*, 2000; Breyfogle, 2003). Business conduct among everything else is based on Six Sigma which transitioned the company's purview on a continuous improvement path. Just as with Lean's interpretation of waste being inherent in processes, another feature that's seemingly inherent and almost inevitable is variation. One of the central subsets in Deming's system of profound knowledge is knowledge about variation which he explicated through his red bead experiment (Gartner and Naughton, 1988). Deming explains that there are two types of causes in variation that exist, common and special. Common causes (also known as chance cause) are naturally in existence, whereas special cause variation occurs out of unexpected or undesired focus (Deming, 1986). Therefore, variations within process are always inborn thus almost impossible to eliminate. Bergman and Kroslid (2000) explained understanding variation is one of the most important aspect in implementing Six Sigma. Thus, Six Sigma's idea of improving process revolves around this concept of reducing variation.

The word Sigma arrived from Greek that symbolizes variation, which Greek statisticians used to measure variability (Pyzdek, 2003). In others words, it defines standard deviation (average distance) from the mean which reflects variation (McAdam and Lafferty, 2004). At sixth sigma level, the concept articulates a defect range of 3.4 on average with given opportunities for defect, also referred commonly as defects per million opportunities (Pande *et al.*, 2000; Pyzdek, 2003; Breyfogle, 2003). Six Sigma follows through a structured method known as DMAIC which stands for the phases improvement projects needs to go through; Define, Measure, Analyse, Improve and Control.

2.3 Lean six sigma

The nature of quality management has always been on the rise and evolving. From Taylor's principle to Deming's management principle, to Juran's Quality Trilogy, Feigenbaum's total quality control and so on, the field of process improvement has been indeed improving. The use of Lean and Six Sigma had somewhat reached an impasse that further improvement was seen to be barricaded. Thus, practitioners were found to be improvising or innovating the concepts at either end to resolve this stalemate. It was claimed that the first signs of integration of both popular concepts of Lean and Six Sigma came about in the USA at 1986 (Chakravorty and Shah, 2012; Salah *et al.*, 2010; Svensson *et al.*, 2015; Vinodh *et al.*, 2014); however, the term "Lean Six Sigma" was first uttered around the new millennium by Sheridan (2000) after which it was largely believed to become increasingly popular (Byrne *et al.*, 2007). Michael George is the foremost reference when it comes to Lean Six Sigma. He gives an emphatic view on why the fusion is important for the future evolution of process improvement or continuous improvement concepts. George puts forth three predominant reasons as to why the fusion is necessary:

- Lean cannot maintain process under statistical control;
- Six Sigma alone cannot dramatically improve process speed or reduce invested capital (George, 2002); and
- Lean and Six Sigma facilitates cost of complexity reduction (George, 2003).

Corresponding to that George (2002) defines Lean Six Sigma as:

> A methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed and invested capital (p. 6).

More than its differences, Lean and Six Sigma are universally complimentary as denoted by many scholars (Salah *et al.*, 2010). Combining the both largely resides in the idea that both concepts' tools, techniques, practices and methodologies could be used conjointly (George, 2002, 2003; Salah *et al.*, 2010). Laureani and Antony (2012) define this criteria in terms of tools and techniques that both concepts use. Both toolboxes get the best out of the methodology resulting in the concurrent improvement in speed and accuracy. Salah *et al.* (2010) illustrate some of the common tools or practices that can be integrated which are brainstorming, process mapping, standardization and mistake-proofing amidst the arsenal of techniques, as shown below in Figure A2. Kumar *et al.* (2006) suggested 5 why, cause and effect, Pareto analysis, change management tools, histograms, control charts and scatter diagrams as common set of tools that can be used interactively between Lean and Six Sigma.

This integration or blending of two methodologies refers to the means of getting things done faster, better, cheaper, safer and greener (Pacheco *et al.*, 2015). Antony *et al.* (2003) delimit the idea that the individual philosophies of Lean and Six Sigma's improvement capabilities had reached the optimal point or ceiling and that an integration would provide the organization with process acceleration and responsiveness to customer, operate at lower cost of poor quality, strive for perfection through "six" sigma capability and provide greater flexibility throughout the business. Pacheco *et al.* (2015) in comparing the complementarity and implications of Lean and Six Sigma provided encapsulating benefits from the synergy of both concepts. Albliwi *et al.* (2015) however provided the top ten benefits experienced from the implementation of Lean Six Sigma as follows:

(1) increased profits and financial savings;
(2) increased customer satisfaction;
(3) reduced cost;
(4) reduced cycle time;
(5) improved key performance metrics;
(6) reduced defects;
(7) reduction in machine breakdown time;
(8) reduced inventory;
(9) improved quality; and
(10) increased production capacity.

The fusion provides enhanced capability that enables each limitation within the individual concepts to be offset, therefore surpassing capabilities beyond any single methodology.

3. Summary of existing literature reviews on Lean Six Sigma

As Yadav and Desai (2016) clarified, literature reviews on Lean Six Sigma are scantily available as compared to the isolated model of Lean or Six Sigma. A few had however attempted the review of Lean Six Sigma related literatures.

Lande *et al.* (2016) did a systematic literature review on critical success factors (CSFs) in both manufacturing and services industry in India between 2000 and 2015 with 143 journal articles. Aware on the rampant focus in healthcare settings, Deblois and Lepanto (2016) narrowed the focus to acute care settings in their systematic review of literatures between 1999 and January 2015 on continuous improvement approaches of Lean and Six Sigma. There were high overlaps in relative efficacy between Lean and Six Sigma. Prasanna and Vinodh (2013) provided a refined Lean Six Sigma framework with improved Lean anchorage for small and medium enterprises (SMEs) application. Through the literature survey, they found that Lean improvement could be done through waste categorization and merging Quality Function Deployment with Value Stream Mapping. The proposed model is known as Lean anchored Six Sigma DMAIC (LADMAIC). The authors argue that Lean and Six Sigma tools need to be used concurrently to attain common goal. Abu Bakar *et al.* (2015) attempted a renewal of literature review on the CSFs of the hybrid model of Lean Six Sigma since 2010 which highlights on the readiness factor prior to implementation of the program. Albliwi *et al.* (2015) made a review of literatures to identify important themes within Lean Six Sigma application. The systematic literature review of 37 papers from 2000 to 2013 from various top journals portrayed a noticeable increase in popularity and deployment of Lean Six Sigma, especially in countries such as the USA, UK, The Netherlands and India. Albliwi *et al.* (2014) also did a systematic literature review of 56 papers between 1995 and 2013 which revealed a total of 34 critical failure factors (CFFs) in deployment of Lean Six Sigma program. In this paper, 19 case studies were critically underlined to reflect the relevant factors that highlighted exploration for future research areas.

Mason *et al.* (2015) reviewed Lean Six Sigma publications and utilization in the surgical process. Using top medical databases, they collated a total of 124 published materials from which six common aims on the purpose of Lean Six Sigma application were defined. The aims were to optimize outpatient efficiency, to improve operating theatre efficiency, to decrease operative complications, to reduce ward-based harms, to reduce mortality and to limit unnecessary cost and length of stay. Zhang *et al.* (2012) took on a review of published articles on Lean Six Sigma from 2000 to December 2011 in top databases such as EBSCO host, Emerald, Google Scholar and Science Direct which yielded them 116 published papers. The review shows Lean Six Sigma research is on an elementary stage. Most research was discovered in 2011 (33 publications). Lean Six Sigma is beneficial for manufacturing and services alike and even large and small firms. The latest systematic literature on Lean Six Sigma is by Yadav and Desai (2016) which spanned a total of 14 years from 2001 to 2014. They shortlisted 189 articles from 58 peer-reviewed journals. The dimensions analysed in the literatures are publication years and journals, countries, research design, research type and application sector within industries.

4. Research methodology

In scrutinizing a field of study or the state of knowledge in a subject, Li and Cavusgil (1995) informed three ways of accomplishing it, a Delphi method, meta-analysis and content analysis. The final method, content analysis, is a technique to manifest the content of literature in a systematic, qualitative and quantitative fashion. As per Harwood and Garry (2003), it was first used in analysing hymns, newspaper and magazine articles, advertisements and political speeches in the nineteenth century. This

study will take on a content analysis approach in reviewing what has been studied thus far in the field of Lean Six Sigma and the research gaps extant which could be propagated and researched on. According to Ibrahim *et al.* (2015), there are three main steps in conducting content analysis:

(1) analysis of articles;
(2) content definition within category; and
(3) identification of literature review gaps.

A detailed step of enduring the process of content analysis for this study is portrayed in Figure 1 below.

The first step in moving about the research was to search for articles related to Lean Six Sigma, subject to only academic journals. To capitalize as much details and materials as possible, no starting date or year of the search was stipulated; however, the cut-off point was set to be June 2016. However, the review of the literatures showed articles published between 2000 and 2016 matching the cut-off year. "Lean Six Sigma" was used as the search term which resulted in inclusion of keywords and articles of "Lean" and "Six Sigma" discretely as well. The search is focused on Lean Six Sigma as a hybrid model with the objective of narrowing the scarcity in the literature. The result of the search still contained some unconnected articles on either concept of Lean and Six Sigma, individually. However, to ensure the goodness of the search, those unconnected articles were not discarded, as they fell under the search term of "Lean Six Sigma", and they were used for the analysis, as the contents of those articles contained some articulation on the fusion model of Lean Six Sigma as well. The search for the articles took place in an extensive manner to congregate as many articles as possible ranging from various databases which include ABI/INFORM Complete ProQuest, Emerald, ScienceDirect, Business Source Elite @ EBSCOhost, SpringerLink and Wiley Online Library, as these databanks contain most reputable journals in the field of operations, quality and industrial management. A latest review on Lean Six Sigma literature by Yadav and Desai (2016) also mentioned a similar list of database that prompted the choice of these outlets in addition to suggestions from past studies. It has to be mentioned that this research discarded articles that were not included or not published in the abovementioned databases. It also excluded short surveys, book chapters, conference reviews, prefaces, book reviews, editorial notes, master's theses, doctoral dissertations and textbooks. To classify the search as exhaustive may be debatable; nevertheless, the articles reviewed from the selection of journals and databases which are cited by many authors in this field of study are reasonably representative and comprehensive to the body of research related to Lean Six Sigma.

The articles were classified and reviewed based on 11 main dimensions deemed to be significant which are purpose or focus of study, years of publication, journal published, methodologies, theory used, country of study, industry, active authors, CSFs, barriers and challenges for implementation and contribution by universities. These dimensions were analysed in the 261 shortlisted articles from a total of 102 published journals.

5. Results of the content analysis

As the study intends to understand the progress or development of Lean Six Sigma in the field of scholarly research, the 261 articles are clustered and classified into Lean, Six Sigma, Lean and Six Sigma, Lean Six Sigma and others. The reason for such variation is owing to the fact, as we already know, Lean Six Sigma is the latest hybrid model of process

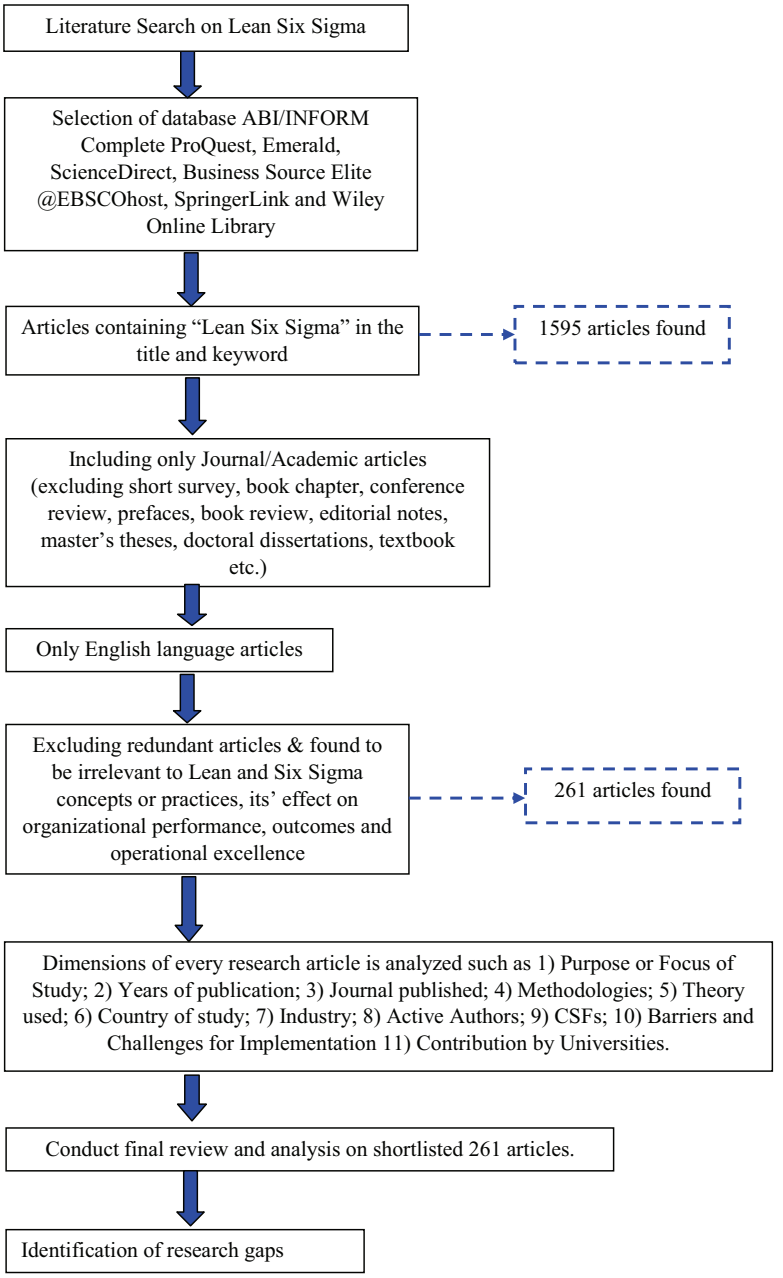


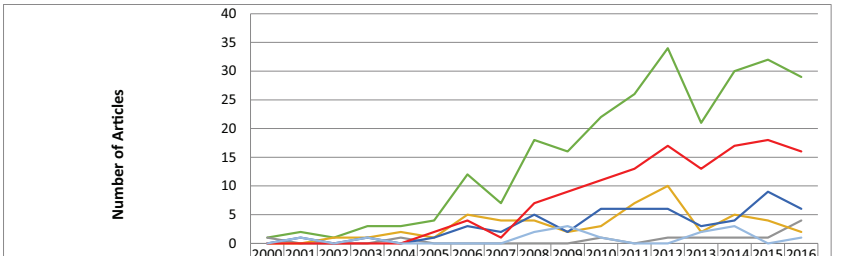
Figure 1.
Research methodology of the study

improvement which arose through the fusion of Lean and Six Sigma. The search for the article did also capture the isolated or individual concept of Lean and Six Sigma in the keywords, additionally with other concepts that were studied together with it such as total quality management (TQM), just in time (JIT), business process re-engineering (BPR), quality management and continuous improvement in general. Therefore, this classification would enable us to view in contrast the conceptual pattern of the studies throughout the years.

5.1 Analysis of articles

The overall movement of the study in the field of Lean Six Sigma had in fact been on a growth pattern. The study of the hybrid model of Lean Six Sigma accounts for 49.04 per cent. The research of the combination of Lean and Six Sigma is 21.07 per cent of the total amount, whereas Six Sigma and Lean standing independently sums up at 20.31 and 4.21 per cent, respectively, while the rest are other combinations. Thus, it can be concluded that Lean Six Sigma is a study increasing in focus in the field of process improvement. For a closer and chronological analysis of this lengthy period of research, the period of investigation are segregated into four-year intervals: from 2000 to 2003, 2004 to 2007, 2008 to 2011 and 2012 onwards. The summarized table for the timelines recorded are shown in the Figure A1 (Figure 2).

As shown in the table, the number of articles had risen dramatically after the 2004-2007 period. It can be said that the attention in the fused model of Lean Six Sigma began to attract scholars after this period. Prior to that, it can be seen in the illustration that the discrete studies of Lean and Six Sigma were given emphasis, marked by the pattern on the trend lying above that of Lean Six Sigma's. However, right after the stipulated period from 2004 to 2007, the study in the latter's field had actually begun to take off quite vividly above the isolated approaches. Number of articles in 2000-2003 and 2004-2007 were donned mainly by the discrete model of Lean and Six Sigma with five and 19 (combination of Lean, Six Sigma and Lean and Six Sigma articles) articles, respectively, compared with seven of Lean Six Sigma in total. After that, Lean Six Sigma articles took the centre stage with 40 and 81 articles registered in 2008-2011 and 2012 onwards over and above the combined articles of 36 and 59 for the discrete articles in that period. The jump in Lean Six Sigma articles represents a 471.43 per cent rise in the 2008-2011 period from the preceding period and 102.5 per cent increase from 2012 onwards. This is an immense disparity as compared to the



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of Articles Published	1	2	1	3	3	4	12	7	18	16	22	26	34	21	30	32	29
Lean	1	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1	4
Six Sigma	0	0	1	1	2	1	5	4	4	2	3	7	10	2	5	4	2
Lean and Six Sigma	0	1	0	1	0	1	3	2	5	2	6	6	6	3	4	9	6
Lean Six Sigma	0	0	0	0	0	2	4	1	7	9	11	13	17	13	17	18	16
Others	0	1	0	1	0	0	0	0	2	3	1	0	0	2	3	0	1

Figure 2.
Number of journal articles reviewed on lean Six Sigma

proportion of Lean, Six Sigma and Lean and Six Sigma combined where the percentage of increase in 2008-2011 period is only 89.47 per cent and subsequently endured a slowdown to 63.89 per cent. This justifies the movement of the trend towards the Lean Six Sigma hybrid paradigm.

Some regard the George Group were the first to use the combination of Lean and Six Sigma interactively since 1986 and popularly coined the term "Lean Six Sigma" (Salah *et al.*, 2010). But as many quote, the hybrid model did not come to much attention after the new millennium (Byrne *et al.*, 2007; Sheridan, 2000). This explains the slow pick up even by academicians as well, as noticeable in the diagram. The 2008 economic recession is an important agenda that may have caused a shift in the attention where many businesses worldwide suffered a setback and were in dire need of trimming, savings, efficiencies, cost reduction and significant improvement. Following the limitations reported in the isolated concepts and the growing attention of industries to scour for an innovative approach parallel to the evolving nature of the business environment, the hybrid model soon began to pick up in thoughts. Mader (2009) is one of the first few to articulate on the diversity of the Lean Six Sigma model along with the likes of Näslund (2008), Pepper and Spedding (2010), Salah *et al.* (2010), Maleyeff *et al.* (2012), Hilton and Sohal (2012) which are among the important ones. An important feature to be noted here is the year the articles were published which ranged after 2000s and most importantly after 2008 wherein the Lean Six Sigma model became evidently popular among academicians and industrialists alike. This justifies the take off in the pattern of the graph of Lean Six Sigma studies.

5.2 Analysis of publication outlets

As shown in Table AI, the primary publication outlet for research in Lean Six Sigma are *International Journal of Lean Six Sigma, International Journal of Operations and Production Management, International Journal of Productivity and Performance Management, International Journal of Quality and Reliability Management, International Journal of Six Sigma and Competitive Advantage, Journal of Operations Management, The Quality Management Journal, The TQM Journal, The TQM magazine*, and *Total Quality Management and Business Excellence*. As evident, Lean Six Sigma has a dedicated journal which accounts for the majority of the published articles (16.09 per cent), the *International Journal of Lean Six Sigma*. *Journal of Operations Management* stands second with 4.98 per cent, whereas *International Journal of Productivity and Performance Management* comes at third with 4.60 per cent. *International Journal of Quality and Reliability Management, The Quality Management Journal* and *Total Quality Management and Business Excellence* are next closest contributors with 4.21 per cent each. *The TQM Journal* which used to be called as *The TQM Magazine* (Yadav and Desai, 2016) is also a significant contributor with a combination of 4.21 per cent of the total articles. *International Journal of Operations and Production Management* and *International Journal of Six Sigma and Competitive Advantage* accounts for 3.83 and 3.07 per cent of publications, respectively. As mentioned by Yadav and Desai (2016), the nature of research in the field of Lean Six Sigma is diverse; thus, it would be hard to merge the literature under any discipline which explains the vast number of journals that have registered the interest in the subject. Nevertheless, the rest of the journals are not as significant contributors as those highlighted above.

5.3 Analysis of methodologies

Technically on a broad-based perspective, a study approach can be divided into quantitative or qualitative. Malhotra and Grover (1998) scrutinized the field-based empirical methodologies in the production and operations management which shed light on the types

of methodologies that can be dissected. They explained there are six main methodologies: descriptive, conceptual, perspective, empirical, exploratory cross-sectional and exploratory. The descriptive methodology describes, formulates and makes or modifies models of the Lean Six Sigma concepts. Conceptual methodology explains the basic and fundamental concepts of Lean Six Sigma. Empirical modelling refers to the methodology of data or empirical evidence taken from the existing surveys, case studies, literature reviews and the likes which are translated into mathematical or statistical modelling that are usually subject to equation scrutiny. Exploratory cross-sectional is a methodology wherein the data or information is collected through a survey at one or a particular point in time. Exploratory longitudinal refers to data collection through a prolonged period of time, two or more points in time within a same organization or case subject. Given the extent of the study, two more methodologies were included for detailed analysis. These were review, which are articles based on literature reviews and case study, those articles that are based on cases.

Such a variation in the methodologies used in various studies will allow for a detailed inspection on how the studies are being carried out or which type of methodology seems appropriate and given importance in the subject of the study. Similar implementation was adopted by Ibrahim *et al.* (2015), who also stands as a reference point as the motive of this analysis is in synchronization with the said study, which is to learn the pattern and trend of the subject matter and identify literature gaps (Table I and Figure 3).

The 261 articles were reviewed and analysed based on the eight types of methodologies as stipulated and displayed, as per the table above. As depicted in general, case study-based research on Lean Six Sigma stands atop at 22.71 per cent followed by perspectives and empirical investigation through surveys or questionnaires at 18.32 per cent. Typically, case studies would be used to analyse the real-life situation or occurrence before putting it to empirical test. The evidence above suggests that the study in Lean Six Sigma is largely on a case study basis which is marginally greater than empirical studies. However, it has to be noted that this would be an overall statement. Given the division of the studies, it can be seen that the hybrid model of Lean Six Sigma is pretty much still on an exploratory stage with case studies reporting 38 researches in total while empirical research is still lacking. Most empirical-based studies are reported by Six Sigma alone with 23 studies. Besides case studies, scholars are also increasingly interested in providing perspective on the subject matter, describe the underlying concepts, and they provide customized models of Lean Six

Table I. Distribution of research methodologies

	Number of papers						
Methodologies	Lean	Six Sigma	Lean and Six Sigma	Lean Six Sigma	Others	Total number of papers	(%)
Review	1	3	6	15	2	27	9.89
Perspective		*8*	*15*	*24*	*3*	*50*	*18.32*
Conceptual	1	2	8	18	1	30	10.99
Descriptive	1	8	2	29	2	42	15.38
Empirical (Survey/exploratory cross-sectional)	*5*	*23*	*6*	*13*	*3*	*50*	*18.32*
Explanatory (Longitudinal)		3	1	3	2	9	3.30
Exploratory (Case study)	*3*	*4*	*16*	*38*	*1*	*62*	*22.71*
Empirical (Modelling)			2	1		3	1.10
Total	11	51	56	141	14	273	100.00

Notes: 12 articles had mixed-mode methodology; items in italic represent the most applied research methodologies in Lean Six Sigma studies

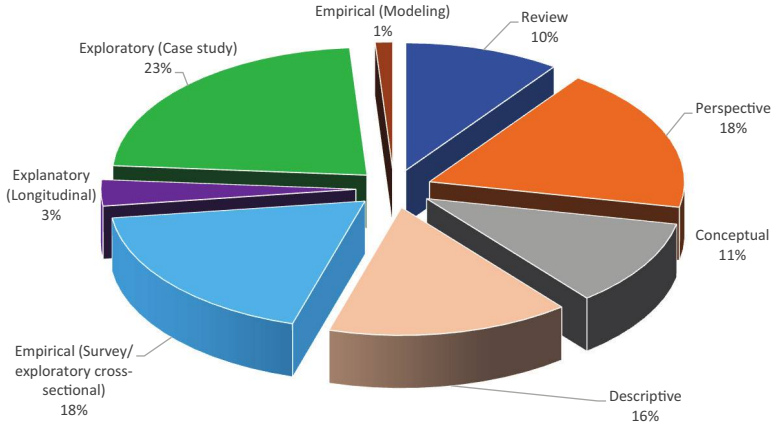


Figure 3.
Distribution of methodologies

Sigma which also ranked top or above from empirical studies (13 papers), perspective (24 papers), conceptual (18 papers) and descriptive (29 papers) based investigation. These findings are in line with Yadav and Desai (2016) who found a similar pattern. Empirical or mathematical modelling and longitudinal-based studies are very rare as reported in the articles reviewed with just over 1 and 3 per cent, respectively. Reviews in this study are also moderately available (9.89 per cent), although much of it is concentrated in Lean Six Sigma purview with 15 papers compared to others.

5.4 Analysis of theories

Linderman *et al.* (2003) articulates on the lack of theoretical underpinning for Six Sigma which only offers best practice studies as a basis for research investigation. In deliberation of understanding Six Sigma through goal theoretic perspective, they argued for the formulation and recognition of useful theories that could explain the phenomenon. In search of an underlying theory of Six Sigma in addition to provide an indorsed definition for Six Sigma, Zhang *et al.* (2008) used a grounded theory approach to understand the Six Sigma phenomenon. Explaining on contingency theory basis they put forth the idea of Six Sigma promoting ambidexterity, in which control theory submits on structural control of the concept, whereas boundary spanning roles and communication relates to exploration of structure. Javier Lloréns–Montes and Molina (2006) examined the prescription of Six Sigma to that of several management theories in relation to leadership, customer satisfaction, human resource practices and change and organizational learning and how it connects to the improvement of organizational effectiveness. Sin *et al.* (2015) demonstrated the connection of Six Sigma phenomenon through the organizational knowledge creation theory (Nonaka and Takeuchi, 1995) under the cloak of knowledge-based view of the firm theory (Grant, 1996; Kogut and Zander, 1996) wherein knowledge is the central tendency of resources and competitive advantage.

On Lean in the other hand, Rossiter Hofer *et al.* (2011) compared the implications of Lean implementation by comparing China and the USA. Using the institutional theory, they inspected economic, socio-cultural and regulative forces that shed light on China's case whereby the latter two seem to be in hindrance. Using core competence theory, Parry *et al.* (2010) developed a methodology for Lean implementation based on four fundamental facets which are market analysis, the visible value stream, customer value analysis and financial

modelling. Ram Matawale *et al.* (2014) analysed a way to identify the extent of Leanness in industrial practice using the grey system theory. Hozak and Olsen (2015) described the notion of Lean psychology that were built on the basis of psychological theories that terms System 1 and System 2 thinking that reflects the mechanics of Lean functioning between practice and thinking.

The study also examined the use of theories in line to the concept of Lean Six Sigma. As displayed in Table II below, studies in Lean Six Sigma generally lacks in theoretical justification which accounts for 207 articles and 79.31 per cent of the total. This supports the proclamation by Zhang *et al.* (2008) that this line of research lacks theoretical guidance. However, there are indications on attempts on theoretical-based studies in the domain of absorptive capacity, organizational learning, goal-setting theory, dynamic capability, resource-based view of firm (RBV), organizational knowledge creation, socio-technical systems theory and knowledge management. Not many studies among these drilled deep

	Number of papers					
Theories	Lean	Six Sigma	Lean and Six Sigma	Lean Six Sigma	Others	Total number of papers
None specified	6	25	45	125	6	207
Absorptive capacity		4	1	1	2	8
Organizational learning		6	1	1	1	9
Goal setting theory		5	2		1	8
Dynamic capability	1	3	2	1	2	9
RBV	1	3	2			6
Knowledge-based View of Firm	1					1
Organizational knowledge creation	2	3			1	6
Socio-technical systems theory	1	1			2	4
Knowledge management		3				3
Rational choice theory				1		1
Efficient market hypothesis				1		1
Capital asset pricing model				1		1
Modern portfolio theory				1		1
Organization ambidexterity			1			1
Diffusion of innovation				1		1
Systems thinking			1			1
Expectancy theory of motivation		1				1
Fit theory					1	1
Regulatory fit theory		1				1
Concept of fit					1	1
Institutional theory		1				1
Signalling theory					1	1
Stakeholder theory				1		1
Stretch strategy		1				1
System of profound knowledge			1			1
Theory of realistic evaluation (RE)				1		1
Contextual theory					1	1
Complementarity theory			1			1

Table II.
Analysis of theories

Note: There were 15 articles that used more than one theory

into the theoretical underpinnings of the study, as mostly were done based on the context of the research and acted as a supporting mechanism to justify findings.

All the reported theories have some parts to play in the implementation or embracement of Lean and Six Sigma concepts. Nonetheless, a couple of them are crucial in justifying the functioning mechanism of the concept. The RBV could be regarded as a theory describing the resource nature of Lean Six Sigma implementation particularly explaining the sustainability on competitive advantage. Absorptive capacity relates several other theories notably organizational learning and knowledge management given that the fundamentals of absorptive capacity are much attributed to gaining and exploiting knowledge. Another theory that is of significance is dynamic capability. Dynamic capability refers to firms' ability to systematically generate and modify operational routines to continuously improve organizational efficacy which consequently enhances firms' competitive advantage (Teece *et al.*, 1997; Zollo and Winter, 2002). Other noteworthy theories include goal setting theory that's very much attached to Six Sigma's underlying principles more than Lean. The eminence of Six Sigma is the greatest when it comes to adhering to targets and hard metrics. The organizational knowledge creation theory of which Sin *et al.* (2015) used to explain the process of knowledge generation individually and collectively through the DMAIC phases of Six Sigma is another prominent principle that underlies Six Sigma's project functions. The resulting analysis on this aspect demonstrated that most articles rarely used any theoretical framework. It is highly conceivable through this fact as to why many of the authors in the articles reviewed had encouraged the use of theories and examine the underlying theories surrounding the concept of Lean Six Sigma in future research.

5.5 Analysis of industry sectors

Both Lean and Six Sigma was born in the manufacturing constituency which then found its way in just about any process regardless of industries and tasks which made it a universal improvement method. Table AII shows that the manufacturing industry was the focus of attention irrespective of the clusters be it Lean, Six Sigma, Lean and Six Sigma or Lean Six Sigma. The concentration is at 15.36 per cent. Next to it is the surprise focus of healthcare industry which had an 11.11 per cent contribution to the research, most of which is an emphasis of the hybrid model with a total of 18 papers, which is equivalent to that of manufacturing. This could also be substantiated with the hospital subsector which also falls within this category which marks at 3.27 per cent. The medical line and healthcare are in need of more quality and focused improvement consistent with growing population and even ageing in some countries. Besides the demographic concern, the healthcare industry has substantial objectives that associate human lives. Thus, medical errors are a cause for concern which the USA mainly have found evidence of quite a considerable loss of lives. And with the complexity of organization and job structure, the healthcare needs improved, robust and flexible apparatus such as the Lean Six Sigma to tackle its complexities. Most papers in this arena focused on case studies. The other paralleled focus industry is the service industry at 3.92 per cent. George and George (2003) advocated the necessity of using Lean Six Sigma in service industries wherein they emphasized the sluggishness service process may possess. This is mainly owing to the fact that services outcome are intangible, it is invisible to the eye and measurable only through satisfaction of the customers. So for one that could not see the processes they're going through, it is relatively hard to improve the process which is where the use of data, process mapping, statistical tools from the Lean Six Sigma approach would assists. As notified in the table, of late there is an increasing trend to the studies that focuses in the services industry. Besides service in general, finance, banking,

IT, business process outsourcing, shared services, call centres have also registered interest in the concept. Interestingly government operations and the military are also rising in attentiveness in the use of the concept especially in the USA, comprising 1.96 per cent in this research. It is surprising how Lean Six Sigma can be innovatively used for instances such as logistical battles as described by Hook (2016). Another thriving area for Lean Six Sigma research is in the higher educational institutions. There has been an increasing focus on the need to embed Lean Six Sigma in the educational institutions (Sunder, 2016a; Svensson *et al.*, 2015; Antony *et al.*, 2012) for administrative and education (Shokri and Nabhani, 2015; Kanigolla *et al.*, 2014; Ellis *et al.*, 2014; Pavlovic *et al.*, 2014) betterment or innovation.

5.6 Analysis of geographic distribution

Lean, through the TPS in Japan and Six Sigma from Motorola at the USA, did not take long to cross boundaries and permeate into every corner of the globe given the stature of its success that lured many around the world to explore the opportunity it offers. Figure 4 associates the top ten geographic distribution in the articles reviewed. Parallel to its stature in the world economy, US ranked in most where the studies had taken place with 12.85 per cent of the total articles reviewed. India is considered a fast-growing nation in this area which raked up the second spot with globally studied articles at around 5.21 per cent. The UK leads next followed by global coverage with 4.86 per cent and 4.51 per cent, respectively. Europe and The Netherlands ranked fifth spot jointly at 3.47 per cent trailed by Malaysia which stands at the subsequent spot with a 2.08 per cent contribution. It needs to be highlighted the studies in Malaysia of Lean Six Sigma are comparably low. Of the three articles, two of them studied CSFs of Lean Six Sigma implementation (Habidin and Yusof, 2012; Jeyaraman and Kee Teo; 2010) and the other being a conceptual framework of Lean Six Sigma's interaction with green concept and its effect on financial performance (Zamri *et al.*, 2013). Although efforted, the studies on the hybrid model are substantially low and are in

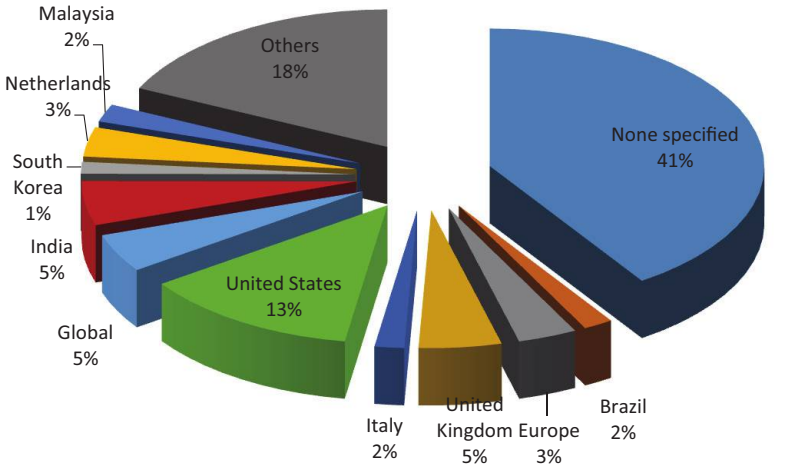


Figure 4.
Geographic distribution of articles

Notes: None Specified – Country not specified; others – Other countries as stated in table (refer appendix)

need of further academic contribution of its phenomena in the country. Brazil, South Korea and Italy are subsequent countries within the top ten list of Lean Six Sigma related studies.

5.7 Analysis of active authors in Lean Six Sigma

Research in Lean Six Sigma had been on the rise and did not fail to get the attention of researchers worldwide. A total of 680 authors, inclusive of authors and co-authors contributed to the 261 articles found in this research. Table AIV shows the top 33 authors who have been active in the field of Lean Six Sigma thus far. Jiju Antony recorded the most article published in the field with 20 articles in total, a finding synonymous to Yadav and Desai (2016). Kevin Linderman takes second spot with 11 articles followed by Ronald J.M.M. Does, Roger G. Schroeder and Maneesh Kumar with nine, eight, and seven articles, respectively. Adrian S. Choo and Weiyong Zhang share the sixth highest publication in Lean Six Sigma with six articles each preceding Henk de Koning who has five articles registered under his name. The rest of the authors had a contribution of four and three articles as per depicted in the table.

5.8 Critical success factors of Lean Six Sigma

CSFs are substantial elements that need to be considered in the implementation of a program such as Lean Six Sigma. The adherence and effects on the CSFs is a key determinant to the success and failure of a program or initiative. CSFs are technically essential elements that must be accomplished to garner competitive advantage (Brotherton and Shaw, 1996). Boynton and Zmud (1984) explain that CSFs are critical aspects that need to be healthy and function well to ensure and sustain optimistic outcome and success. Antony *et al.* (2012) suggested CSFs are important aspects that need to be defined, understood and tracked in implementing a Lean Six Sigma project in an organization, as they serve as vital indicators on the achievement of the initiative. Although not many, several authors had touched on the subject of CSFs in Lean Six Sigma. Jeyaraman and Kee Teo (2010) studied and identified ten CSFs in the electronic manufacturing service (EMS) industries in Malaysia and other global sites. They also proposed a theoretical framework on the CSFs affecting operational and organizational performance moderated by organizational belief and culture. Näslund (2013) provided a differential view from the usual CSFs by emphasizing the importance of strategic alignment, project management and training. Fadly Habidin and Mohd Yusof (2013) identified seven CSFs from a sample of 252 Malaysian automotive organizations which they expected to provide a guideline in the implementation of Lean Six Sigma in the automotive industry. Lande *et al.* (2016) explored the CSFs in the Indian experience with respect to SMEs from both manufacturing and services industry.

Table AV provides a compilation of the top 14 CSFs congregated from the articles in this study. As per the table, the conceptual definition of the CSFs are described in the first column, whereas the second column provides the key and frequent terms used in literatures. Meanwhile, the final column provides the references that documented similar CSFs. Almost unequivocally the most leading CSF found to be consistent in almost every relevant article was support, dedication and commitment of top management. strong customer emphasis, amicable culture, effective training for implementing Lean Six Sigma, selection of strategic projects and good leadership follows suit in importance. Nevertheless, the 14 CSFs should be viewed as a set of vital factors that are equal in importance given the recurrence in many articles. Other factors that does not fall into the list and found to be non-repeating include competency of master black belt or black belt, company financial capability, established Lean Six Sigma dashboard (Jeyaraman and Kee Teo, 2010), organizational infrastructure,

change management, team emphasis, IT support, accountability, result or bottom line (Lertwattanapongchai and William Swierczek, 2014), link towards product design, quality measurement system or data quality, benchmarking, role of quality department, inventory control (Lande *et al.*, 2016), prior implementation of other quality improvement program, availability of cross-functional team (Abu Bakar *et al.*, 2015), developing organizational readiness (Antony *et al.*, 2012), supportive performance management and IT systems (Psychogios *et al.*, 2012) and clear improvement goals, sufficient and clearly allocated resources (Manville *et al.*, 2012).

5.9 Critical barriers and challenges in Lean Six Sigma implementation

While the research in CSFs of Lean Six Sigma are fairly increasing in number the barriers, challenges and failure factors had also caught the attention of scholars along the line. Barriers, challenges and failures of implementation of an initiative could be directly relational with the success factors. In other words, the opposite impact on the CSFs would express the failures of an initiative. However, an analysis is still required to justify the reality. There are several authors who have explored this facet in the field of Lean Six Sigma. Albliwi *et al.* (2014) had provided one of the most extensive study on CFFs in the implementation of Lean Six Sigma from renowned database in the field between 1995 and 2013. They underlined 34 CFFs cited in literatures and identified top five factors which are lack of top management attitude, commitment and involvement, lack of training and education, poor project selection, weak link towards strategic objective and lack of resources. In explaining the synergy between Lean and Six Sigma, Sunder (2013) analysed the top barriers in deploying Lean Six Sigma. A Pareto analysis pertaining the reason for failure displayed top four factors which include lack of top management involvement, wrong selection of projects, narrow perspectives on projects and lack of ownership on the deployment. Antony *et al.* (2012) studied the challenges and barriers of the use of Lean Six Sigma in Higher Education Institutions (HEIs) in which they found twelve items that may retard the success of the initiative.

Table AVI displays the top ten critical barriers and challenges in the implementation of Lean Six Sigma identified by analysing the articles found in this study. Similar to the most sought-after aspect in the deployment of Lean Six Sigma, top management support is critical in this aspect too. Failure or a lack of support from this part of the organization may severely impact the implementation of the program. Causes for concern from a managerial viewpoint include lack of proper training, cultural breakdown and resistance, weak link between lean six sigma implementation and organization objectives, lack of awareness on Lean Six Sigma, lack of employee engagement and lack of resources. Whereas technical aspects that may impede the progress of Lean Six Sigma deployment include poor project selection, lack of expertise support and impatience towards change.

Other critical factors not included in the list consist of unclear strategy, lack of communication at various levels, lack of process thinking, absence of an adequate reward system, corruption, government regulation, no metrics-based environment, lack of motivation, lack of consideration of the human factors, lack of awareness of the benefits of lean or six sigma, high implementation cost, ineffective project management, poor selection of candidates for belts training, lack of an effective model or roadmap to guide the implementation, threat of redundancy, time consuming, replicating another organisation's Lean/Six Sigma strategy and lack of application of statistical theory (Albliwi *et al.*, 2014; Chakravorty, 2009; Psychogios *et al.*, 2012; Antony *et al.*, 2012; Jeyaraman and Kee Teo, 2010; Kwak and Anbari, 2006; Snee, 2010; Pepper and Spedding, 2010; Gamal Aboelmaged,

2010; Gurumurthy and Kodali, 2011; Thomas *et al.*, 2008; Svensson *et al.*, 2015; Sunder, 2013).

5.10 Contribution of Lean Six Sigma articles by university

It would be a noteworthy point to analyse the universities or education institutions that have been active in the contribution of Lean Six Sigma articles thus far. Table AVII exhibits the list of universities and education institutions that have contributed to this field. The universities and education institutions compiled from the articles consist of main and co-authors' institutes. Nevertheless, out of the 261 articles, 58 are without any indication of education institutions. This is because of them being authored by industry practitioners such as consultants, medical practitioners, bankers and the likes. A total of 107 universities have been identified from 203 articles. The records show universities from the UK and USA had been the most active with 24.14 per cent and 22.17 per cent of contribution, respectively, followed by India (14.78 per cent), The Netherlands (10.34 per cent) and Australia (6.40 per cent). University of Strathclyde, Heriot–Watt University and Cardiff University of the UK seems to be the most active universities of all, regardless of countries. Northern Illinois University, University of Kentucky and University of Arizona is the most active in the USA. The National Institute of Technology in both India and The Netherlands recorded the highest contributor of Lean Six Sigma articles indicating the importance of the subject in technically oriented education institutions.

6. Discussion

A central and decisive step in the initial process of an academic research is the literature review. It is a time-consuming and extensive process, as one is required to scour about the field of study to gain as much as insight into defining the purposefulness of the research. There are several important functions and purposes of this process. According to Sekaran and Bougie (2003), the role of literature review is to position the research relative to existing knowledge and build on it; elude the risk of re-inventing the wheel; revisit the backgrounds and viewpoint of problems at multiple angles; frame one's thinking for insights on research; provide significant and researchable ideas and guidance on conceptual and theoretical frameworks. Adding to this, Hart (1998) also specified literature review serves to identify relationship between ideas and practice; ideas and theories; understanding structure of the subject; identify main methodologies and research techniques; identify what has been done and what needs to be done; extend a research interest; analyse the strengths and weaknesses of a topic and displaying a historical context on the development of a study.

Although it could be contentious to be claimed as exhaustive, in this study, a total of 261 articles have been identified and reviewed from 102 scientific publications which were a good representation of Lean Six Sigma literature base, as it sheds some lights on the gaps in the extant literatures. The findings of our content analysis can be classified, namely, into five areas; the evolution of Lean Six Sigma, theories, methodologies, industry focuses and concerns and regions.

First, we conclude that this study showed that scholarly works or research in the field of Lean Six Sigma has begun to grow since the new millennium or after 2000s but more significantly after the 2004-2007 and 2008 periods. It can be argued that standalone models of Lean and Six Sigma are well-researched compared to Lean Six Sigma. Also it can be considered that the field is relatively new and could use much focus in future research endeavours.

Second, the change in pattern was very notable for the hybrid model studies of Lean Six Sigma, which implies that more scholars and practitioners are focusing on the merging of

Lean and Six Sigma. Arnheiter and Maleyeff (2005) mentioned organizations should be able to capitalize on the strengths of Lean and Six Sigma practices. This may be a reflection on the industry level, as there happen to be buzzwords where firms who were initially using either Six Sigma or Lean practice are contemplating to add the other half for the hybrid model to surpass the "low hanging fruit scenario". But aspects that maybe stopping them are the lack of a methodology for a proper implementation. This explains the large proportion of perspective, conceptual and descriptive-based studies as exemplified. These studies were in suggestion on the best possible ways and manner of implementing Lean Six Sigma and most case studies depicts organization's unique way of handling the concept.

Third, another contemplation on embracing the dual approach may be the lack of empirical validity on the fusion of Lean and Six Sigma. As depicted in Figure 3, Lean Six Sigma articles focus mainly on case studies, descriptive, perspective and conceptual methodologies topping the categories with 26.95, 20.57, 17.02 and 12.77 per cent, respectively. Empirical distributions are fairly low with only 9.22 per cent. It was found in the review that almost all the articles on the integration of Lean and Six Sigma in the build up to the hybrid model are anecdotal and qualitative-based explicating the incremental effects they could have. Thus far, based on the review on the articles in this study, there has not been any empirical validation that explains the enhanced effectiveness the fusion model could bring, more precisely on the interaction terms of both concepts had not been studied. Supplementing that is the lack of theories explaining this incremental phenomenon.

Fourth, this study enlightens the suggestion to the lack of theoretical understanding that enterprises behind the philosophy which could very well explain the purpose of using them and highlight on how it could be handled more efficiently. Linderman *et al.* (2003) highlighted there is no basis for research in the area on Six Sigma other than best practice studies given the lacklustre of theories that explains the phenomenon. Zhang *et al.* (2008) went to the same extent in defining this scenario as was the case with many subsequent scholars. To date, there seems to be a lackluster in tackling this issue, as shown in the analysis 79.31 per cent are without a theoretical basis. This calls for more emphasis in this area which would be useful to industry managers to justify on the importance of using process improvement philosophies within their organizations.

Fifth, as process improvement is applicable almost universally as explained in the review, the dimensions in which it could permeate are wide-ranging. Accordingly, many theories could be used to define its existence. It was found notable theories used thus far were absorptive capacity, organizational learning, goal-setting theory, dynamic capability, RBV, organizational knowledge creation, socio-technical systems theory and knowledge management. Lean Six Sigma or process improvement activities are knowledge-based in general, thus it shows the prevalence of knowledge-oriented theories as stated. However, as mentioned before, this study articulates that some of the theories could be placed as the underpinnings that explain the Lean Six Sigma phenomenon such as absorptive capacity, dynamic capability and RBV. It has to be mentioned that the theory of absorptive capacity, especially as re-conceptualized by Zahra and George (2002), who advocated that the construct is multidimensional, has not been examined in greater depth although the literatures concerning this theory had mentioned about this multidimensional aspect. However, it failed to examine how they are related unto providing an impact. The theory of dynamic capability is valuable in explaining the concepts of Lean and Six Sigma either discreetly or fused. The definition of the theory itself is self-explanatory and with the latest hybrid model it can as well explain the interaction dynamics of two concepts that complement each other, dynamically enabling firms to surpass capability boundaries. In addition to it, as McAdam and Hazlett (2010) claim the link between theory and practice on methodology such as Six Sigma had been inconsistently scrutinized.

Sixth, many articles observed had placed much focus on examining the performance outcome of using Lean, Six Sigma or Lean Six Sigma. This is a natural response, given the philosophies enables process excellence and enhance performance outcomes. There is also a considerable amount of studies that assessed the competitive advantage these approaches could bring which were elucidated by the eminence of those firms that succeeded in using them. However, there is a lack of studies that actually justifies the sustainability of competitive advantage attained in using the approach, especially when it is being submitted that Lean Six Sigma is a much enhanced approach surpassing the isolated models, as it could advance the envelope of firms' ability.

Seventh, there is a debate between exploration and exploitation in process management literatures that process management activities largely focuses on exploitative manners alone without considering exploration thereby stunting certain aspects of innovation (Benner and Tushman, 2003). However, some argued that this may not be the case, as process improvement activities such as Lean Six Sigma could instead promote both types of innovation radical and incremental (Antony *et al.*, 2016, Azis and Osada, 2010; Hoerl and Gardner, 2010).

Eighth, there is evidence of organizations muddled in a dilemma between which strategy to use to tackle problems, Lean, Six Sigma or Lean Six Sigma (Antony *et al.*, 2003; Antony *et al.*, 2016; Snee and Hoerl, 2007).

Ninth, country wise, it is evident that most studies took place in the developed part of the world being USA and UK. But concentration in developing countries such as in India has been growing as many countries are in the effort to lead itself for more development. Malaysia stands in one of them; however, efforts to enhance the knowledge base are inviting especially robust ones.

Tenth, this article identified 14 CSFs that are pivotal in the implementation of Lean Six Sigma. These 14 factors are to be viewed as a cohesive unit in which every aspect would render an impact towards the success of the initiative. Eleventh, one should not undermine the barriers and challenges, as reported here, the top ten most causative effect that could stall the implementation of the initiative. CSFs and barriers or challenges often at times work hand in hand. The ability of an organization to understand and identify the relevant success factors, challenges and barriers prior to the implementation may have huge influential impact on the progress of Lean Six Sigma deployment in the organization. However, it is also important to note that not all the factors stated in this findings may be inherent and identical across organizations, as it is simply a case to case basis where some organization may find certain aspects to be overriding than others.

7. Conclusion and limitations

This study's purpose is to scrutinize Lean Six Sigma literatures through content analysis and reviewing its past and present trends that revealed noteworthy gaps. The search term "Lean Six Sigma" was used to amass a total of 261 articles from reputable scientific journals that are representative in the field of study. The articles were reviewed and categorized as per Malhotra and Grover (1998) classification scheme. The study result was based on an extrapolation over a 17-year time frame from 2000 to 2016. Given the emergence of the hybrid concept beginning in 2000s, research or scholarly works in the field was also analogous with this timeline, especially since 2008. The scrutiny revealed that players within the industry place some concern on the lack of implementation methodology on the hybrid model given the fluid nature of its practice and the debate about innovative contribution and performance outcomes. Besides that there is also a dilemma and contemplation in merging or integration of Lean and Six Sigma by those

who had initial exposure with either concept. The lack of theoretical emphasis linking Lean Six Sigma is also one source of concern matching this quandary, as the analysis showed the majority of study eluding this line of research wherein it could divulge significant findings to the body of knowledge in addition to offering guidance to practitioners. The study also discovered a lack of empirical work as compared to case studies, descriptive, perspective and conceptual-based research. The concept which evolved through the manufacturing industry is now largely sought after in the services industry which is gaining exponential attention, as shown in this study such as healthcare and education among the most. Country wise, although the practice is prevalent in developed countries, developing ones are seemingly on the thrust pedal likewise given the global competitive conundrum.

Given the profundity of the research, it should be said that our research comprises some limitations. The articles reviewed are those containing the keyword "Lean Six Sigma"; nevertheless, it should be conceded that there might be articles which focus on Lean Six Sigma but never included it as a keyword in the title. There is a likelihood that some related or relevant articles might have used different terms in describing the synonymous notion. Hence, owing to the inclusion–exclusion conditions certain articles may have been left out. The study is based on key databases which contained the cited 102 journal publications. Besides that, accessibility of certain journals and articles also posed a quandary that precluded a proper consolidation of articles and had to be foregone. There are of course other journals that are not part of this database that still embrace studies in this field. Nevertheless, it can be said that although not exhaustive, this study is comprehensive and stands representative of those scientific journals that hosts this field of study. This study has made an attempt to classify the content of Lean Six Sigma studies that has never before attempted given the complexity and diversity inherent. Therefore, the study can stand as a basis for future endeavours in an attempt to ameliorate the classification and contents in ways that best describe the researches in the field of Lean Six Sigma.

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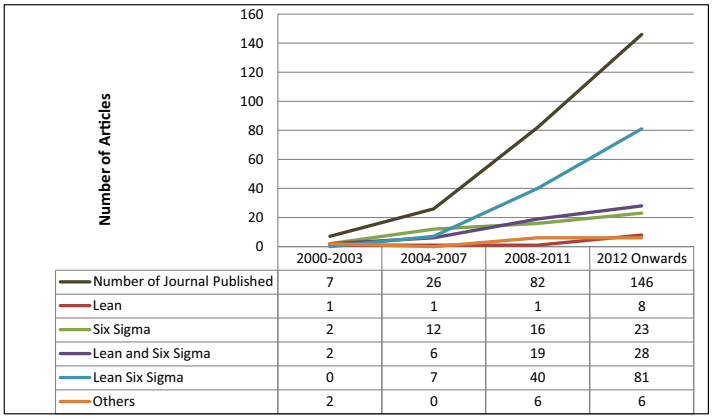
Appendix



	2000-2003	2004-2007	2008-2011	2012 Onwards
Number of Journal Published	7	26	82	146
Lean	1	1	1	8
Six Sigma	2	12	16	23
Lean and Six Sigma	2	6	19	28
Lean Six Sigma	0	7	40	81
Others	2	0	6	6

Figure A1.
Summarized table for Lean Six Sigma studies timeline

No.	Journal published	2000-2003	2004-2007	2008-2011	2012 Onwards	Total
1	*Academy of Business Journal*			1		1
2	*Academy of Information and Management Sciences Journal*			1		1
3	*Academy of management review*	1				1
4	*Aircraft Engineering and Aerospace Technology*	1				1
5	*American Journal of Business*				1	1
6	*Amfiteatru Economic*				1	1
7	*Armed Forces Comptroller*		1	4		5
8	*Asian Journal on Quality*	1	2			3
9	*BMC health services research*				1	1
10	*Business Management and Strategy*				1	1
11	*Business Performance Management*			1		1
12	*Business Performance Management Magazine*			1		1
13	*Business Process Management Journal*			1	2	3
14	*Cardiovascular Revascularization Medicine*				1	1
15	*Decision Sciences*			1		1
16	*Decision Sciences Journal of Innovative Education*				1	1
17	*Drug discovery today*			2		2
18	*Economic and Organization*		1			1
19	*European Journal of Operational Research*				1	1
20	*Global Business and Organizational Excellence*			2		2
21	*IEEE Transactions On Engineering Management*			1		1
22	*IFAC Proceedings Volumes*				1	1
23	*In Healthcare Management Forum*				1	1
24	*Industrial Engineer: IE*				2	2
25	*Industrial Management and Data Systems*				1	1
26	*Interdisciplinary Journal of Contemporary research in business*				1	1
27	*International Journal of Automotive Technology*				1	1
28	*International Journal of Business and Management*				1	1
29	*International Journal of Business Research and Development*				1	1
30	*International Journal of Emerging Sciences*			1		1
31	*International journal of health care quality assurance*				4	4
32	*International Journal of Innovation Science*				1	1

Table AI.
Journal published related to lean six sigma

(*continued*)

No.	Journal published	2000-2003	2004-2007	2008-2011	2012 Onwards	Total
33	*International Journal of Innovation, Management and Technology*			*1*		*1*
34	*International Journal of Lean Six Sigma*			*14*	*28*	*42*
35	*International Journal of Operations and Production Management*	1	1	2	6	10
36	*International Journal of Pediatrics and Adolescent Medicine*				1	1
37	*International Journal of Production Economics*				2	2
38	*International Journal of Production Research*			2	3	5
39	*International Journal of Productivity and Performance Management*		*1*	*4*	*7*	*12*
40	*International Journal of Project Management*			1		1
41	*International Journal of Quality and Reliability Management*			*2*	*9*	*11*
42	*International Journal of Quality and Service Sciences*				2	2
43	*International Journal of Scientific And Research Publications*				1	1
44	*International Journal of Six Sigma and Competitive Advantage*		*2*	*3*	*3*	*8*
45	*International Statistical Review*			1		1
46	*Investment Management and Financial Innovations*			1		1
47	*IOSR Journal of Business and Management*				1	1
48	*IUP Journal of Operations Management*			1	1	2
49	*IUP Journal of Supply Chain Management*				1	1
50	*Journal for Healthcare Quality*			4		4
51	*Journal of advances in Management Research*			1		1
52	*Journal of Business Case Studies*			1		1
53	*Journal of Business Strategy*			1		1
54	*Journal of Chemical Health and Safety*				1	1
55	*Journal of Computer Information Systems*				1	1
56	*Journal of digital imaging*				1	1
57	*Journal of Engineering, Design and Technology*				1	1
58	*Journal of evaluation in clinical practice*				2	2
59	*Journal of Facilities Management*				1	1
60	*Journal of Management and Engineering Integration*			1		1

(*continued*)

Table AI.

No.	Journal published	2000-2003	2004-2007	2008-2011	2012 Onwards	Total
61	*Journal of Manufacturing Technology Management*			3	1	4
62	*Journal of Operations Management*	*2*	*2*	*5*	*4*	*13*
63	*Journal of Technology Studies*				1	1
64	*Journal of the Operational Research Society*				1	1
65	*Leadership in Health Services*				1	1
66	*Learned Publishing*			1		1
67	*Management Science*		1			1
68	*Operations Management Research*			2		2
69	*Organization Development Journal*		1			1
70	*Physician Exec*			2		2
71	*Physics Procedia*				1	1
72	*Procedia Computer Science*				1	1
73	*Procedia Engineering*				1	1
74	*Procedia Manufacturing*				2	2
75	*Procedia-Social and Behavioural Sciences*				5	5
76	*Quality and quantity*				1	1
77	*Quality and Reliability Engineering International*	1				1
78	*Quality control and applied statistics.*			1		1
79	*Quality Engineering*			2	1	3
80	*Quality Innovation Prosperity*				1	1
81	*Quality Progress*		1			1
82	*R&D Management*			1		1
83	*Serbian Journal of Management*				1	1
84	*South East Asian Journal of Management*				1	1
85	*Strategic HR Review*				1	1
86	*Strategy and Leadership*		1			1
87	*Supply Chain Management: An International Journal*		1			1
88	*Technology Innovation Management Review*				2	2
89	*Technovation*			1		1
90	*The American Statistician*			1		1
91	*The Annals of the University of Oradea, Economic Sciences series*			1		1
92	*The International Journal of Advanced Manufacturing Technology*		1			1
93	*The International Journal of Human Resource Management*				3	3
94	*The Journal of Applied Business and Economics*			1		1
95	*The Journal of high technology management research*		1			1
96	*The Quality Management Journal*			*4*	*7*	*11*
97	*The Romanian Economic Journal*			1		1

Table AI. (*continued*)

No.	Journal published	2000-2003	2004-2007	2008-2011	2012 Onwards	Total
98	*The Surgeon*				1	1
99	*The TQM Journal*				*6*	*6*
100	*The TQM magazine*		*5*			*5*
101	*Total Quality Management and Business Excellence*		*3*		*8*	*11*
102	*Transfusion*			1		1
	Grand Total	7	25	83	146	261

Notes: The TQM Journal used to be known as The TQM Magazine; journals in italic shows the primary publication outlets for Lean Six Sigma studies

Table AI.

Table AII.
Classification of industry sectors

No.	Industry Sub-Sectors	Number of papers					Total frequency of industries in the papers	(%)
		Lean	Six Sigma	Lean and Six Sigma	Lean Six Sigma	Others		
1	None specified	5	32	17	24	7	85	27.78
2	Aerospace			4	2		6	1.96
3	Airline				4		4	1.31
4	Airport			1			1	0.33
5	Automotive		1		5		6	1.96
6	Banking			1	3		4	1.31
7	Business process outsourcing (BPO)			1	1		2	0.65
8	Call centre				1		1	0.33
9	Chemical				1		1	0.33
10	Construction of large machinery				1		1	0.33
11	Construction industry				3		3	0.98
12	Consultancy			3	3		6	1.96
13	Courier service				1		1	0.33
14	Direct selling service			1			1	0.33
15	Education			1	2		3	0.98
16	Electronics				3	1	4	1.31
17	Engineering/engineering design			1	1		2	0.65
18	Entrepreneurial firms					1	1	0.33
19	*Finance*			*3*	*4*		*7*	*2.29*
20	Food and beverages				1		1	0.33
21	Food industry			1	2		3	0.98
22	Government/government operations			2	1		3	0.98
23	*Health care*	*1*	*3*	*9*	*18*	*3*	*34*	*11.11*
24	HEIs			1	4		5	1.63
25	High-tech engineering		1				1	0.33
26	*Hospitals*		*1*	*2*	*7*		*10*	*3.27*
27	Human resource				2		2	0.65
28	Insurance				2		2	0.65
29	Investment				1		1	0.33
30	IT		1	1	5		7	2.29
31	Local government					1	1	0.33

(*continued*)

No.	Industry Sub-Sectors	Number of papers					Total frequency of industries in the papers	(%)
		Lean	Six Sigma	Lean and Six Sigma	Lean Six Sigma	Others		
32	Logistics			1			1	0.33
33	Machinery and transportation parts industry					1	1	0.33
34	Maintenance			1	3		4	1.31
35	*Manufacturing industry*	*4*	*12*	*10*	*18*	*3*	*47*	*15.36*
36	Manufacturing R&D				1		1	0.33
37	Maritime Operations				1		1	0.33
38	Military				6		6	1.96
39	Multinational corporation		1		1		2	0.65
40	Non-profit organizations (NPO)				1		1	0.33
41	Oil and gas and energy			1	1		2	0.65
42	Pharmaceutical				4		4	1.31
43	Publishing				2		2	0.65
44	Recycling industry				1		1	0.33
45	Semiconductor		1				1	0.33
46	*Services industry*	*2*	*3*	*2*	*3*	*2*	*12*	*3.92*
47	Shared services			1			1	0.33
48	SMEs				3		3	0.98
49	Telecommunication			2	3		5	1.63
50	Universities				2		2	0.65
Grand Total		12	56	67	152	19	306	100.00

Note: Items in italic refers to the top industry sub-sectors in which Lean Six Sigma studies were carried out

Table AII.

No.	Geographic distribution	Number of papers: Lean	Six Sigma	Lean and Six Sigma	Lean Six Sigma	Others	Total frequency papers	(%)
1	None specified	4	27	26	54	6	117	40.63
2	Algeria				1		1	0.35
3	Australia			1	2		3	1.04
4	*Brazil*	*1*		*1*	*3*		*5*	*1.74*
5	Canada			1		1	2	0.69
6	China		1				1	0.35
7	Denmark			1			1	0.35
8	*Europe*		*5*	*1*	*3*	*1*	*10*	*3.47*
9	France	1		1			2	0.69
10	Sweden			2	1		3	1.04
11	*UK*	*2*		*4*	*7*	*1*	*14*	*4.86*
12	Belgium	1					1	0.35
13	Germany				1	1	2	0.69
14	*Italy*	*1*			*3*	*1*	*5*	*1.74*
15	Japan					1	1	0.35
16	*USA*	*2*	*6*	*8*	*18*	*3*	*37*	*12.85*
17	*Global*		*4*	*1*	*8*		*13*	*4.51*
18	*India*		*1*	*4*	*10*		*15*	*5.21*
19	Indonesia				1		1	0.35
20	Iraq		1				1	0.35
21	Ireland			2	1		3	1.04
22	Kenya				2		2	0.69
23	Uganda				1		1	0.35
24	Tanzania				1		1	0.35
25	Rwanda				1		1	0.35
26	*South Korea*		*3*	*1*			*4*	*1.39*
27	Spain					2	2	0.69
28	Taiwan			1	2		3	1.04
29	Thailand				1		1	0.35
30	Turkey				1		1	0.35
31	*The Netherlands*			*2*	*8*		*10*	*3.47*
32	Lithuania	1					1	0.35
33	*Malaysia*		*3*		*3*		*6*	*2.08*
34	Mexico			1			1	0.35
35	New Zealand				1		1	0.35
36	North America					1	1	0.35
37	Portugal			1	1		2	0.69
38	Saudi Arabia				1		1	0.35
39	Scandinavia			1			1	0.35
40	Scotland			1			1	0.35
41	Serbia				1		1	0.35
42	Finland			1			1	0.35
43	Singapore			3			3	1.04
44	Hong Kong			1			1	0.35
45	Philippines			1			1	0.35
46	Sri Lanka			1			1	0.35
47	Pakistan			1			1	0.35
Grand Total		13	51	69	137	18	288	100.00

Note: Items in italic refers to the countries which has the highest publication on Lean Six Sigma studies

Table AIII.
Geographic distribution of articles

No.	Author	Articles	References
1	Jiju Antony	20	Arumugam *et al.* (2016), Antony *et al.* (2016), He *et al.* (2015), Svensson *et al.* (2015), Albliwi *et al.* (2015), Arumugam *et al.* (2014), Albliwi *et al.* (2014), Kirkham *et al.* (2014), Arumugam *et al.* (2013), Laureani *et al.* (2013), Antony *et al.* (2012), Arumugam *et al.* (2012), Timans *et al.* (2012), Antony and Kumar (2012), Laureani and Antony (2011), Antony (2011), Laureani and Antony (2010), Laureani *et al.* (2010), Antony (2004), Antony *et al.* (2007)
2	Kevin Linderman	11	Linderman *et al.* (2010), Schroeder *et al.* (2008), Zhang *et al.* (2008), Shah *et al.* (2008), Choo *et al.* (2007b, 2007a), Linderman *et al.* (2003), Linderman *et al.* (2006), Arumugam *et al.* (2014), Jacobs *et al.* (2015), Arumugam *et al.* (2016)
3	Ronald J.M.M. Does	9	Lameijer *et al.* (2016), Kuiper *et al.* (2014), Niemeijer *et al.* (2013), de Koning *et al.* (2008a), Erdmann *et al.* (2010), de Koning *et al.* (2008a, 2006), Van den Heuvel *et al.* (2006), de Koning *et al.* (2010, 2008b)
4	Roger G. Schroeder	8	Linderman *et al.* (2006), Schroeder *et al.* (2008), Linderman *et al.* (2003), Cua *et al.* (2001), Zhang *et al.* (2008), Choo *et al.* (2007b, 2007a), Linderman *et al.* (2010)
5	Maneesh Kumar	7	Arumugam *et al.* (2013), Antony *et al.* (2012), Antony and Kumar (2012), Kumar *et al.* (2011), Antony *et al.* (2007), Kumar *et al.* (2008), Antony *et al.* (2005)
6	Adrian S. Choo	6	Linderman *et al.* (2006), Schroeder *et al.* (2008), Linderman *et al.* (2003), Choo *et al.* (2007b, 2007a), Choo (2011)
7	Weiyong Zhang	6	Zhang *et al.* (2011), Hill *et al.* (2011), Zhang and Xu (2008), Zhang *et al.* (2008), Zhang and Xu (2016), Zhang *et al.* (2006)
8	Henk de Koning	5	Koning *et al.* (2006, 2008b), Van den Heuvel *et al.* (2006), de Koning *et al.* (2010, 2008a)
9	V.Arumugam	4	Arumugam *et al.* (2012), Arumugam *et al.* (2014), Arumugam *et al.* (2013), Arumugam *et al.* (2016)
10	Alexander Douglas	4	Arumugam *et al.* (2012), Laureani *et al.* (2010), Douglas *et al.* (2015a, 2015b)
11	Howard Gitlow	4	Martinez and Gitlow (2011), Pranckevicius *et al.* (2008), Gitlow and Gitlow (2013), Johnson *et al.* (2006)
12	Charles R. Gowen III	4	McFadden *et al.* (2014), McFadden *et al.* (2015), Gowen and Tallon (2005), Gowen *et al.* (2012)
13	Alessandro Laureani	4	Laureani and Antony (2011), Laureani and Antony (2010), Laureani *et al.* (2010), Laureani *et al.* (2013)
14	Kathleen L. McFadden	4	McFadden *et al.* (2014), McFadden *et al.* (2015), Dobrzykowski *et al.* (2016), Gowen *et al.* (2012)
15	Ronald D. Snee	4	Snee (2005), Snee (2008b, 2010, 2008a)
16	Vijaya Sunder M	4	Sunder (2013), Sunder (2016a, 2016b), Vijaya Sunder (2015)
17	Ashish Agarwal	3	Chaurasia *et al.* (2016), BR *et al.* (2015), Agarwal *et al.* (2016)
18	Saja Ahmed Albliwi	3	Albliwi *et al.* (2015), Svensson *et al.* (2015), Albliwi *et al.* (2014)
19	Shreeranga Bhat	3	Bhat *et al.* (2016), Bhat and Jnanesh (2013), Bhat *et al.* (2014)
20	Jens J. Dahlgaard	3	Antony *et al.* (2016), Dahlgaard and Dahlgaard-Park (2006), Setijono and Dahlgaard (2007)
21	Jeroen De Mast	3	De Mast (2006), Lameijer *et al.* (2016), de Koning *et al.* (2008a)
22	Draghici Mihai	3	Petcu *et al.* (2010), Pamfilie *et al.* (2012), Petcu *et al.* (2011)
23	Leopoldo Gutierrez–Gutierrez	3	Gutiérrez *et al.* (2012), Gutierrez Gutierrez *et al.* (2016a, 2016b)

(*continued*)

Table AIV. List of active authors in the field of Lean Six Sigma

No.	Author	Articles	References
24	Nurul Fadly Habidin	3	Habidin and Yusof (2012), Fadly Habidin and Mohd Yusof (2013), Habidin *et al.* (2016)
25	N.A. Jnanesh	3	Bhat *et al.* (2016), Bhat and Jnanesh (2013), Bhat *et al.* (2014)
26	John Maleyeff	3	Peteros and Maleyeff (2015), Arnheiter and Maleyeff (2005), Maleyeff *et al.* (2012)
27	Petcu Andreea Jenica	3	Petcu *et al.* (2010), Petcu *et al.* (2011), Pamfilie *et al.* (2012)
28	Alexandros G. Psychogios	3	Psychogios and Tsironis (2012), Tsironis *et al.* (2016), Psychogios *et al.* (2012)
29	Janet H. Sanders	3	Sanders and Karr (2015), Sanders and Pagliari (2011), Sanders (2013)
30	Andrew Thomas	3	Thomas *et al.* (2008b, 2014, 2008a)
31	Loukas K. Tsironis	3	Psychogios and Tsironis (2012), Tsironis *et al.* (2016), Psychogios *et al.* (2012)
32	S. Vinodh	3	Vinodh and Swarnakar (2015), Prasanna and Vinodh (2013), Swarnakar *et al.* (2016)
33	Xingxing Zu	3	Zu *et al.* (2008), Zu and Fredendall (2009), He *et al.* (2015)

Table AIV.

No.	Critical success factors	Key terms used	Literatures
1	Support, dedication and commitment of top management	Management engagement and commitment, management commitment and leadership, uncompromising top management support and commitment, top management involvement and support, senior management commitment, management's commitment, management involvement and commitment, top management support	Jeyaraman and Kee Teo (2010), Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Abu Bakar *et al.* (2015), Antony *et al.* (2012), Psychogios *et al.* (2012), Manville *et al.* (2012), Näslund (2013), Andersson *et al.* (2014), Besseris (2014), Chakravorty and Shah (2012), Chiarini (2011), Hilton and Sohal (2012)
2	Effective training for implementing Lean Six Sigma	Employee training, quality-driven training, training and education, effective Lean Six Sigma training program, resources and skills to facilitate implementation	Lande *et al.* (2016), Psychogios *et al.* (2012), Abu Bakar *et al.* (2015), Manville *et al.* (2012), Näslund (2013), Jeyaraman and Kee Teo (2010), Lertwattanapongchai and William Swierczek (2014), Clegg *et al.* (2010), Fadly Habidin and Mohd Yusof (2013)
3	Selection of strategic projects	Effective project selection, top-down and bottom-up project selection, project selection/initiation, project prioritization and selection, project selection and prioritisation, project prioritization, selection, reviews and tracking	Psychogios*et al.* (2012), Laureani and Antony (2012), Näslund (2013), Lande *et al.* (2016), Abu Bakar *et al.* (2015), Manville *et al.* (2012), Jeyaraman and Kee Teo (2010), Psychogios *et al.* (2012)
4	Strong customer emphasis	Customer satisfaction, linking Lean Six Sigma to customer, customer focus	Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Abu Bakar *et al.* (2015), Manville *et al.* (2012), Psychogios *et al.* (2012), Lande *et al.* (2016), Laureani and Antony (2012)
5	Good leadership	Strategic and visionary leadership, leadership champion, project leadership/team and approach, management leadership	Antony *et al.* (2012), Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Abu Bakar *et al.* (2015), Näslund (2013), Arnheiter and Maleyeff (2005), Assarlind *et al.* (2013), Fadly Habidin and Mohd Yusof (2013), Jeyaraman and Kee Teo (2010)
6	Amicable culture	Organizational culture, cultural change, organizational belief and culture, quality-driven corporate culture	Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Manville *et al.* (2012), Jeyaraman and Kee Teo (2010), Psychogios *et al.* (2012), Chakravorty and Shah (2012), Thomas *et al.* (2014), de Koning *et al.* (2008a), Kumar and Antony (2008)

(*continued*)

Table AV.
CSFs of Lean Six Sigma

Table AV.

No.	Critical success factors	Key terms used	Literatures
7	Effective project management	Project management, project management skills, project monitoring and measurements, project success stories, best practices sharing and benchmarking, organisational infrastructure and project management, project management and implementation, process management	Näslund (2013), Jeyaraman and Kee Teo (2010), Lertwattanapongchai and William Swierczek (2014), Abu Bakar *et al.* (2015), Lande *et al.* (2016), Manville *et al.* (2012)
8	Rewards and recognition plan	Reward and recognition system, linking Lean Six Sigma to reward and recognition, employee reward	Jeyaraman and Kee Teo (2010), Chakravorty and Shah (2012), Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Abu Bakar *et al.* (2015), Manville *et al.* (2012), Fadly Habidin and Mohd Yusof (2013)
9	Effective and transparent communication flow/plan	Effective communication at all levels vertically and horizontally, communication of information, frequent communication and assessment on Lean Six Sigma results, an effective communication plan	Antony *et al.* (2012), Arumugam *et al.* (2012), Manville *et al.* (2012), Jeyaraman and Kee Teo (2010), Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Andersson *et al.* (2014
10	Strategic orientation in implementation of Lean Six Sigma	Strategic quality planning, strategic direction and planning, strategic alignment	Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Antony *et al.* (2012), Näslund (2013)
11	Involving and engaging employees in Lean Six Sigma implementation	Employee involvement, employee engagement, commitment of executive employee, employee satisfaction, linking Lean Six Sigma to employees, employee relation/ empowerment	Jeyaraman and Kee Teo (2010), Lertwattanapongchai and William Swierczek (2014), Lande *et al.* (2016), Manville *et al.* (2012), Näslund (2013), Assarlind *et al.* (2013)
12	Strong link between Lean Six Sigma implementation and business strategy	Linking Lean Six Sigma to business strategy	Lande *et al.* (2016), Abu Bakar *et al.* (2015), Manville *et al.* (2012), Assarlind *et al.* (2013), Fadly Habidin and Mohd Yusof (2013)
13	Supplier involvement	Supplier relationship, linking Lean Six Sigma to suppliers	Lande *et al.* (2016), Näslund (2013), Abu Bakar *et al.* (2015), Manville *et al.* (2012)
14	Genuine understanding of Lean Six Sigma	Understanding the tools and techniques, understand Lean Six Sigma methodology	Lande *et al.* (2016), Manville *et al.* (2012)

Table AVI. Critical barriers and challenges in Lean Six Sigma implementation

No.	Barriers and challenges to Lean Six Sigma implementation	Key terms used	Literatures
1	Lack of top management support	Lack of top management attitude, commitment and involvement, lack of top management involvement, lack of management support, weak change management, management resistance, inside events or factors derail the change, lack of visionary leadership	Albliwi *et al.* (2014), Sunder (2013), Shokri *et al.* (2016), Antony *et al.* (2007), Antony and Kumar (2012), Kwak and Anbari (2006), Arumugam *et al.* (2013), Jeyaraman and Kee Teo (2010), Pepper and Spedding (2010), Snee (2010), Chiarini (2011), Gamal Aboelmaged (2011), Bhasin (2012), Chakravorty (2009)
2	Lack of proper training	Poor training and coaching, lack of training and education, inadequate training, lack of appropriate training and knowledge	Albliwi *et al.* (2014), Chakravorty (2009), Antony and Kumar (2012), Antony *et al.* (2007), Svensson *et al.* (2015), Shokri *et al.* (2016), Kwak and Anbari (2006), Bhasin (2012)
3	Poor project selection	Poor Lean Six Sigma project selection and prioritisation, poor project execution, wrong selection of projects, wrong selection of Lean or Six Sigma tools, narrow project-only perspective	Sunder (2013), Albliwi *et al.* (2014), Gamal Aboelmaged (2011), Antony and Kumar (2012), Antony *et al.* (2007), Nonthaleerak and Hendry (2008), Chakravorty (2009)
4	Weak Link between Lean Six Sigma Implementation and Organization Objectives	A weak link between the CI projects and the strategic objectives of the organization	Antony *et al.* (2012), Albliwi *et al.* (2014), Chiarini (2011), Psychogios *et al.* (2012), Bhasin and Burcher (2006)
5	Lack of resources	Lack of right skilled resources, lack of resources, securing sufficient resources, availability of resources, budget and time, lack of financial support, lack of human resources	Sunder (2013), Antony *et al.* (2012), Svensson *et al.* (2015), Antony and Kumar (2012), Gamal Aboelmaged (2011), Antony and Desai (2009)
6	Lack of employee engagement	Poor adaptation of employees expected to change their behaviour, no employee engagement, low employee morale and job satisfaction, lack of team autonomy	Lertwattanapongchai and William Swierczek (2014), Jeyaraman and Kee Teo (2010), Sunder (2013), Svensson *et al.* (2015), McAdam and Lafferty (2004)

(*continued*)

Table AVI.

No.	Barriers and challenges to Lean Six Sigma implementation	Key terms used	Literatures
7	Cultural breakdown and resistance	Culture and resistance to change, organisational culture issues, resistance of culture change, a culture that lacks in openness, trust and acceptance, resistance to change	Svensson *et al.* (2015), Antony *et al.* (2012), Albliwi *et al.* (2014), Antony and Kumar (2012), Chiarini (2011), Kwak and Anbari (2006)
8	Impatience towards change	Improve a process in isolation, hastened towards solution, quick-fix mindset, impatient solution implementation	Antony *et al.* (2012), Sunder (2013), Albliwi *et al.* (2014)
9	Lack of expertise support	Lack of leadership, lack of right skilled resources, lack of motivation to lead improvement, lack of ownership, lack of process thinking and process ownership, the person leading the change was ineffective, no support from experts, malpractice	Svensson *et al.* (2015), Lertwattanapongchai and William Swierczek (2014), Gurumurthy and Kodali (2011), Antony *et al.* (2012), Albliwi *et al.* (2014), Sunder (2013), Jeyaraman and Kee Teo (2010)
10	Lack of awareness on Lean Six Sigma	Lack of appropriate awareness, the change addressed the wrong problem, failed to address the problem, lack of readiness, problem understanding terminologies, unclear strategy and lack of awareness, lack of understanding about the different types of customers	Lertwattanapongchai and William Swierczek (2014), Psychogios *et al.* (2012), Antony *et al.* (2012), Pamfilie *et al.* (2012), Shokri *et al.* (2016), , Antony and Kumar (2012), Gurumurthy and Kodali (2011)

Universities	Country	Article contribution
University of Strathclyde	UK	12
Heriot–Watt University		9
Cardiff University		5
Newcastle University		4
Northumbria University		4
School of Science and Engineering		3
Liverpool John Moores University		2
Kingston University		1
University of Derby		1
Strathclyde University		1
Newport Business School		1
Bristol University		1
University of Cardiff		1
University of South Wales		1
University of Southampton		1
Coventry University		1
University of Wales Newport		1
Northern Illinois University	USA	5
University of Kentucky		4
University of Arizona		4
University of Nebraska Medical Center		2
Central Michigan University		3
Temple University		3
Arizona State University		3
Oklahoma State University Center for Health Sciences		3
University of Miami		2
Wayne State University Detroit		2
The University of Toledo		1
Kaplan University		1
Rensselaer Polytechnic Institute		1
Purdue University Calumet		1
Central Connecticut State University		1
Quinnipiac University		1
University of Central Florida		1
Brenau University		1
Bowling Green State University		1
University of Central Missouri		1
Indiana State University		1
Ohio State University		1
The University of Tennessee		1
The University of Michigan		1
National Institute of Technology	India	6
Indian Institute of Technology – Madras		4
S.V. National Institute of Technology		4
Priyadarshini College of Engineering		4
Engineering of National Institute of Technology		3
Yeshwantrao Chavan College of Engineering		1
College of Engineering		1
PSG College of Technology		1

(*continued*)

Table AVII. Contribution of Lean Six Sigma articles by university

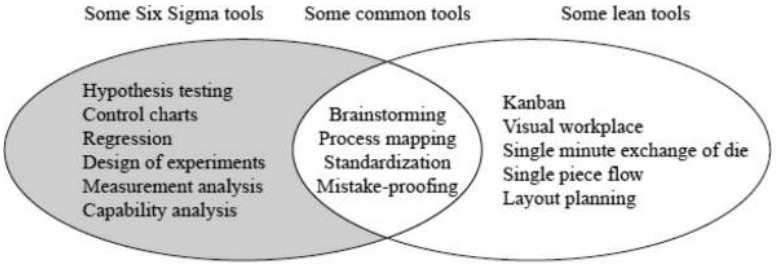
Universities	Country	Article contribution
Darshan Institute of Engineering and Technology		1
St Joseph Engineering College		1
Indian Statistical Institute		1
K.V.G. College of Engineering		1
ABV – Indian Institute of Information Technology and Management		1
St. Joseph Engineering College		1
University of Amsterdam	The Netherlands	8
University of Groningen		4
Rotterdam School of Management		2
University of Twente		2
Delft University of Technology		2
Stenden University of Applied Science		1
Erasmus University Rotterdam		1
Tilburg University		1
Monash University	Australia	4
RMIT University		2
La Trobe University		2
Victoria University		2
The University of Queensland		1
University of Newcastle		1
University of Wollongong		1
University of Macedonia	Greece	3
Technological and Educational Institution of Piraeus		1
University of Sheffield		1
Technical University of Crete		1
University of Rome Tor Vergata	Italy	4
University of Messina		1
University of Ferrara		1
Tunghai University	Taiwan	1
National Tsing Hua University		1
Ming Hsin University of Science and Technology		1
National Chiao Tung University		1
Pontifical Catholic University of Parana	Brazil	1
FAE University Center		1
Federal University of Technology – Parana		1
Federal University of Santa Catarina		1
The Bucharest Academy of Economic Studies	Romania	2
West University of Timisoara		1
University of New Brunswick	Canada	3
Concordia University		1
Brock University		1
Universiti Sains Malaysia	Malaysia	1
Universiti Kuala Lumpur		1
Universiti Pendidikan Sultan Idris		1
Chalmers University of Technology	Sweden	1
University of Technology		1
Dublin City University	Ireland	1
Waterford Institute of Technology		1
University of Africa	Kenya	1

Table AVII. (*continued*)

Universities	Country	Article contribution
Kenya Institute of Management		1
University of Otago	New Zealand	1
Victoria University of Wellington		1
Institut Teknologi Bandung	Indonesia	1
Universitas Islam Indonesia		1
Qatar University	Qatar	1
King Abdullah University of Science and Technology	Saudi Arabia	1
Norwegian University of Science and Technology	Norway	1
New University of Lisbon	Portugal	1

Note: 58 articles are either not registered under any university or authored by industry practitioners

Table AVII.



Source: Salah *et al.* (2010)

Figure A2.
An example of Six Sigma and lean common tools

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