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## Quantitative analysis of Six Sigma, Lean and Lean Six Sigma research publications in last two decades

**Purpose** – This research study intends to extend previous studies to a hybrid analysis of three business improvement practices of Lean, Six Sigma and Lean Six Sigma (LSS) within last two decades and identify the research gaps and focuses in more comprehensive and robust classification framework.

**Design/methodology/approach** - A secondary data collection and literature review was conducted to collect information about peer reviewed journal articles under six dimensions of a tested classification framework. The frequency and distribution analysis was conducted followed by the Pearson's Chi Squared test to analyse any relationship between dimensions of framework in order to identify the gap.

**Finding** –Despite a relatively great deal of regular research outputs about Six Sigma, Lean and LSS, academic journal articles have been found mainly limited to a few industries, themes and countries. “General manufacturing”, “healthcare”, “automotive” and “electronic industries” as sectors; and “tools and techniques”, “benefits” and “success factors” as key themes have been mostly approached by LSS, Six Sigma and Lean management articles. It was also found that there is still a great disparity amongst researchers and journals to publish about these three business improvement practices.

**Research Implications** – The research publications for LSS, Six Sigma and Lean management should have wider approach towards various manufacturing and service sectors, countries and journal publications. A greater level of research/enterprise activities has been found in relation to LSS and Six Sigma articles compared to Lean management articles.

**Originality/Value-** This research aims to identify the gaps in research publications during last two decades about three major business improvement practices in one package and through more comprehensive robust classification framework and also through comparative analysis.

**Key Words** – Lean Six Sigma, Six Sigma, lean Management, Research Publications

### Introduction

The last two decades have witnessed a clear boom in the widespread management and improvement of quality in the international context. This was as the result of increased pressure from customers to promote continuous implementation of quality management practices (Antony, 2014; and Calvo-Mora et al, 2014). Many of these quality management

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3 practices are road maps or toolboxes of the Total Quality Management (TQM) philosophy  
4 that address the critical success factors (CSFs) and principles of TQM (Calvo-Mora et al,  
5 2014; and Dahlgard and Dahlgard – Park, 2006). TQM philosophy is an integrated  
6 organisational – wide philosophy aimed towards continuous improvement of both product  
7 and service processes in order to exceed customer satisfaction (Baird et al, 2011). Lean and  
8 Six Sigma are two popular contemporary process improvement practices or methodologies  
9 developed from TQM philosophy to drive organisations towards efficiency and excellence  
10 (Assarlind et al, 2013). However, during last few years, both practitioners and researchers  
11 obliged to integrate these two business improvement methodologies and develop Lean Six  
12 Sigma (LSS) to achieve better and more effective results for both cost efficiency and  
13 customer satisfaction (Reosekar et al, 2014; Assarlind et al, 2013; Atmaca and Girenes, 2013;  
14 Wang and Chen, 2012; Choi et al, 2012; Hilton and Sohal, 2012; Lee et al, 2011; Delgado et  
15 al, 2010; Dahlgard and Dahlgard - Park, 2006; and McAdam and Lafferty, 2004).

26 From a research perspective there are a number of peer reviewed academic journal articles  
27 that have been published about lean, Six Sigma and LSS within last two decades. However, it  
28 seems the research studies and publications for these business improvement practices focuses  
29 on limited areas, and the research gap in relation to different aspects was not clearly  
30 structured for researchers who are interested to work in this field. Aboelmaged (2010) has  
31 clearly developed a structured framework identifying the major themes, research types and  
32 application sectors for Six Sigma during almost sixteen years and up to 2010. Karthi et al  
33 (2012) has also developed a literature review to identify key areas of application in Six  
34 Sigma. But, these research publications were limited to the Six Sigma and few classification  
35 criteria. Likewise, Martinez-Jurado and Moyano-Fuentes (2014) have developed a literature  
36 review analysis of links between Lean and supply chain management (SCM) and  
37 sustainability. But, this piece of work was limited to the specific theoretical and conceptual  
38 research area. Their research has developed after a literature review conducted by Stone  
39 (2012) who only categorised lean literature in four phases during four decades. In relation to  
40 LSS, Zhang et al (2012) has developed a LSS literature review, which was only limited to  
41 investigate the industry, theory and country integration amongst the publications between  
42 2000 and 2011. This research study intends to extend these previous studies to a hybrid  
43 analysis of three business improvement practices of Lean, Six Sigma and LSS within two  
44 decades and identify the research gaps in more comprehensive and robust classification  
45 framework. The aim of this article is to have a quantitative comparative analysis of the  
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3 existing literature, and therefore the name of authors for analysed articles do not appear in  
4 findings and analysis, instead they appear on reference list and also appendix. As the result,  
5 the key published research focus and gap of these three business improvement practices  
6 within a classification framework will be recommended and discussed in conclusion remarks.  
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11 The remaining of the paper is divided into four sections. The first section is the description of  
12 the research methodology, which has been used in this study. Then, the classification  
13 framework that constructs the analysis will be presented. This is followed by the result and  
14 analysis, which demonstrates the finding from each classification under each of the three  
15 business improvement practices separately. The final section covers the conclusion remarks  
16 and the research implications of the study.  
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### 22 23 **Research methodology**

24 The main data collection method was the secondary data collection in which the data can be  
25 obtained from published sources and can be further analysed to provide additional or  
26 different knowledge, interpretations or conclusions (Saunders et al, 2012). This research  
27 targeted English peer-reviewed journal articles as main source of rigorous research  
28 publications and primary source of obtaining information by academics and researchers.  
29 Therefore, papers with other languages, the conference proceedings, textbooks, news reports,  
30 masters and doctoral dissertations and unpublished working papers have not been considered.  
31 The research also concentrates on articles with main focus on Six Sigma, lean and LSS in  
32 their topic. It was not possible to conduct the research under specific literature or discipline  
33 due to the nature of these three process improvement practices. As a result, various online  
34 sources and databases were searched as the source of data collection.  
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44 The primary research data bases included Emerald, Science Direct (Elsevier), Business  
45 Premier, Interscience, Inderscience, Willey on-line, IEEE-Xplore and Google Scholar. These  
46 databases facilitated the access to the on-line full text of the articles. The compiling data  
47 collection has been conducted for the period of Nine months through extensive database  
48 review of hundreds articles from 1992 up to the 2013. Some of the articles could consider  
49 more than one of these three business improvement practices. Some of the studied articles  
50 that were only analysed as part of data collection have been appeared in Appendix. The  
51 published articles up to 2013 that appeared in the reference list could also be part of the  
52 analysis. However, it was not possible to guarantee covering all relevant articles through this  
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3 search. Then, the collected information under each classification was exported to the Excel  
4 spreadsheet for review, and frequency and distribution analysis. This was further extended to  
5 more detailed inter-relationship analysis between different classification dimensions through  
6 Pearson's Chi-square test to analyse any relationship between categorical data (Field, 2013).  
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8 The result would be presented through Cross-tabulation or Contingency tables by SPSS,  
9 recognised as sophisticated data analysis software.  
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### 13 14 15 **Classification framework**

16 The classification framework was developed based on the literature review and also the work  
17 of Aboelmaged, 2010 who has developed his classification framework as the result of  
18 previous studies (Nonthaleerak and Hendry, 2006; and Brady and Allan, 2006). This will  
19 develop a flow of research activities with the purpose of updating the existing knowledge.  
20 The peer reviewed academic articles were analysed for Six Sigma, Lean and LSS under these  
21 dimensions:  
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- 26 (1) Year of the publication
  - 27 (2) Research Method
  - 28 (3) Major theme and focus
  - 29 (4) Industry and Sector
  - 30 (5) Journal
  - 31 (6) Country where the research was conducted
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35 This classification framework will provide guidelines for more rigorous investigation of the  
36 research focus, research gap, main research challenges and the trend of the research activities  
37 in relation to the field of Six Sigma, Lean and LSS.  
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### 41 **Results and analysis of the classification**

42 It was decided to analyse each quality improvement practice separately to identify key areas  
43 of gap and the trend for each practice individually. This will be followed by cross-  
44 comparison analysis in the conclusion and implication section.  
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### 49 ***Six Sigma***

50 Six Sigma programme was launched by Motorola and then developed by GE in Mid-1980's  
51 as a business improvement methodology to identify and eliminate the opportunities of defect  
52 and variation (Drohomeretski et al, 2014; and Karthi et al, 2012). It is recognised as a means  
53 of managing global competitiveness through continuous improvement and business  
54 excellence (Shokri et al, 2014). Six Sigma fosters a strategic and systematic alignment of  
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3 quality and statistical thinking and project management (Miguel, 2014). It is described as a  
4 business excellence strategy (Antony et al., 2007) and as being a customer-driven (Nakhaie  
5 and Neves, 2009; De-Koning and De-Mast, 2006), a project-driven (Assarlan et al, 2012;  
6 Kwak and Anbari, 2006) or a business-driven (Savolainen and Haikonen, 2007)  
7 methodology. It focusses on decision-making based on quantitative data (Shokri et al, 2014;  
8 and De-Koning and De-Mast, 2006) and statistical and non-statistical tools (Manville et al,  
9 2012), to lead towards improving the organisation's product, process and service (Savolainen  
10 and Haikonen, 2007), financial performance (Nakhaie and Neves, 2009) or general business  
11 strategy (Savolainen and Haikonen, 2007). Benefits of the Six Sigma have also been  
12 promoted by Soti et al (2010) as the elimination of subjective decision making through  
13 consistent and reliable data collection and analysis.  
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23 Improvement via Six Sigma will be achieved through a decentralised and incremental  
24 improvement strategy in both manufacturing and service sectors (Holmes et al, 2015; Antony  
25 et al, 2012a; and Antony, 2014) and in any organisation with any size (Antony et al, 2005).  
26 The current research studies have acknowledged the need for integration of six sigma  
27 methodology with other management practices in both philosophical and practical aspects  
28 (Reosekar et al, 2014). This has even been extended to an integrated framework of Six Sigma  
29 and SCM to improve the supply chain network (Mishra and Sharma, 2014).  
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36 Foundational (e.g. management commitment and leadership), operational (e.g. road map and  
37 tools) and sustainability (e.g. link to strategy, customers and suppliers) factors build the key  
38 enablers for Six Sigma success (Brun, 2011, Soti et al, 2010; and Antony and Desai, 2009).  
39 In fact, the Six Sigma road map is in the heart of the practical utilisation of the Six Sigma  
40 towards improvement. DMAIC (Define, Measure, Analysis, Improve, Control) is the most  
41 common road map that could be used as the practical Six Sigma methodology to improve the  
42 process (Arumugam et al, 2013; Cheng, 2013; Goh, 2013; Antony et al, 2012a; and Kaushik  
43 and Khanduja, 2009). The key barriers of implementing Six Sigma have been recommended  
44 as lack of resources, internal resistance and poor project selections (Antony and Desai, 2009).  
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### 53 *Distribution by the year of publication*

54 Figure 1 shows the distribution of 591 Six Sigma articles published over the period from  
55 1992 to 2013. It is not completely evident in this study that all 2013 Six Sigma papers have  
56 been targeted. After a period of booming publications up to 2006, it is clear that Six Sigma  
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publication have plummeted slightly or remained almost the same up to 2013. The reason for this could be revealed in next sections. The result of Pearson's Chi-Square test analysis indicates the increasing number of service – related publications since 2009. The result also revealed that after a plummeting trend between 2009 and 2011, the level of case study papers increased in 2012 and 2013.

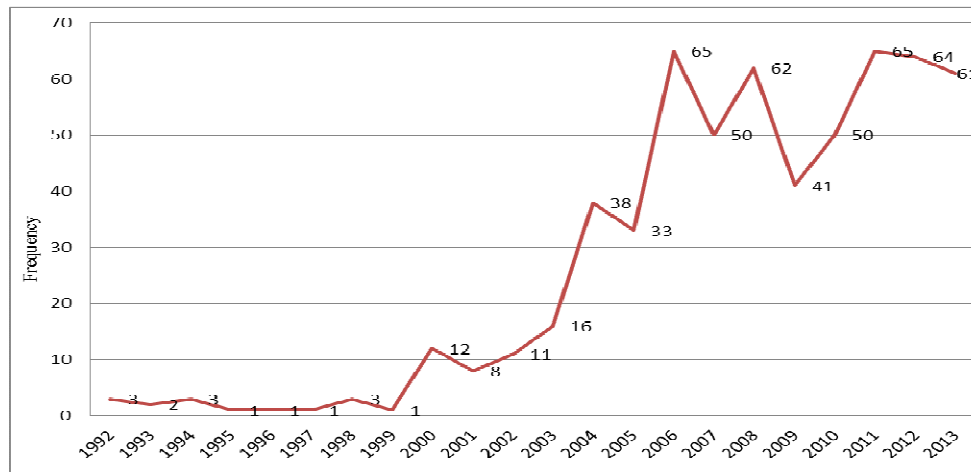


Figure 1 – Distribution of Six Sigma articles by year (1992-2013)

#### *Distribution by the research method*

It was revealed that 297 articles have been developed through case study as the action research methodology, whilst 294 of the articles have been developed through preliminary research approach such as qualitative and quantitative data collection. As the result of Pearson's Chi-Square test analysis, it was clear that the case study – related publications have had greater share in last two years. This would have also increased the thematic focus of these papers on DMAIC and Six Sigma tools and techniques due to the nature of the case study papers.

#### *Distribution by the major themes and focus*

It is unavoidable to have articles that are relevant to more than one theme, so listing an article under more than one theme or focus was considered in this analysis. For example, many articles that had the theme of Six Sigma tools and techniques have also been focused on DMAIC. There have also been some articles that focused on both benefits and key success factors (KSFs). Having reviewed the literature extensively, a total of 15 themes were identified in Six Sigma articles as the most common themes. The result of this analysis was depicted in figure 2. It was evident that Six Sigma tools and techniques (132 articles) and also

DMAIC methodology (101 articles) have kept their position as top two themes since previous studies (Abolmaged, 2010). However, it was clear that there has been increase in publications about “success factors” (63 articles) and “benefits from implementation” (40 articles) during 2010 and 2013.

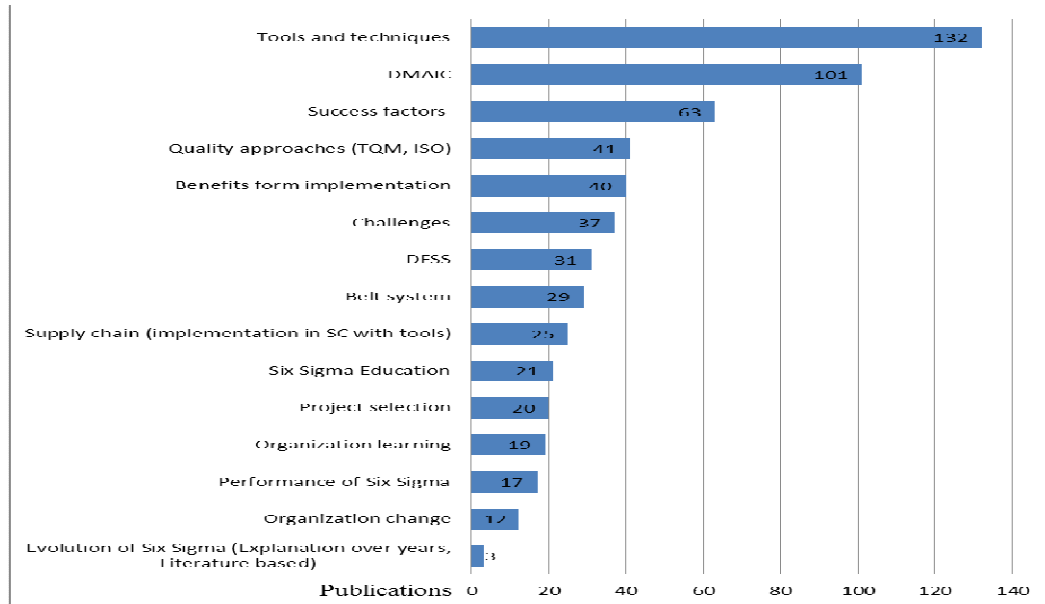


Figure 2 – Distribution of Six Sigma articles by focus or theme

It was revealed from Pearson’s Chi-Square test analysis that 64% of the articles with the theme of “tools and techniques” and “DMAIC methodology” have been published in USA (85 articles), India (36 articles) and UK (27 articles). It was also revealed that articles with the theme of “KSFs”, “DMAIC” and “tools and techniques” have been mainly focusing on manufacturing sector with 103 articles against 79 articles in service sector, whilst articles with the theme of “Six Sigma challenges” have been mainly focusing on service sector with 10 articles against 3 articles in manufacturing sector.

#### *Distribution by industry and sector*

It was revealed that 393 articles (66%) of the total 591 Six Sigma – related reviewed articles have been focusing on a particular industry or sector. The Six Sigma research gap between some specific industries and others has been clearly evident. Figure 3 represents that Health Care, General manufacturing, Electronics and Automotive industries have been in the focus of nearly 50% of the Six Sigma articles. It seems there are still may other sectors that have not been approached by Six Sigma research and publications recently.



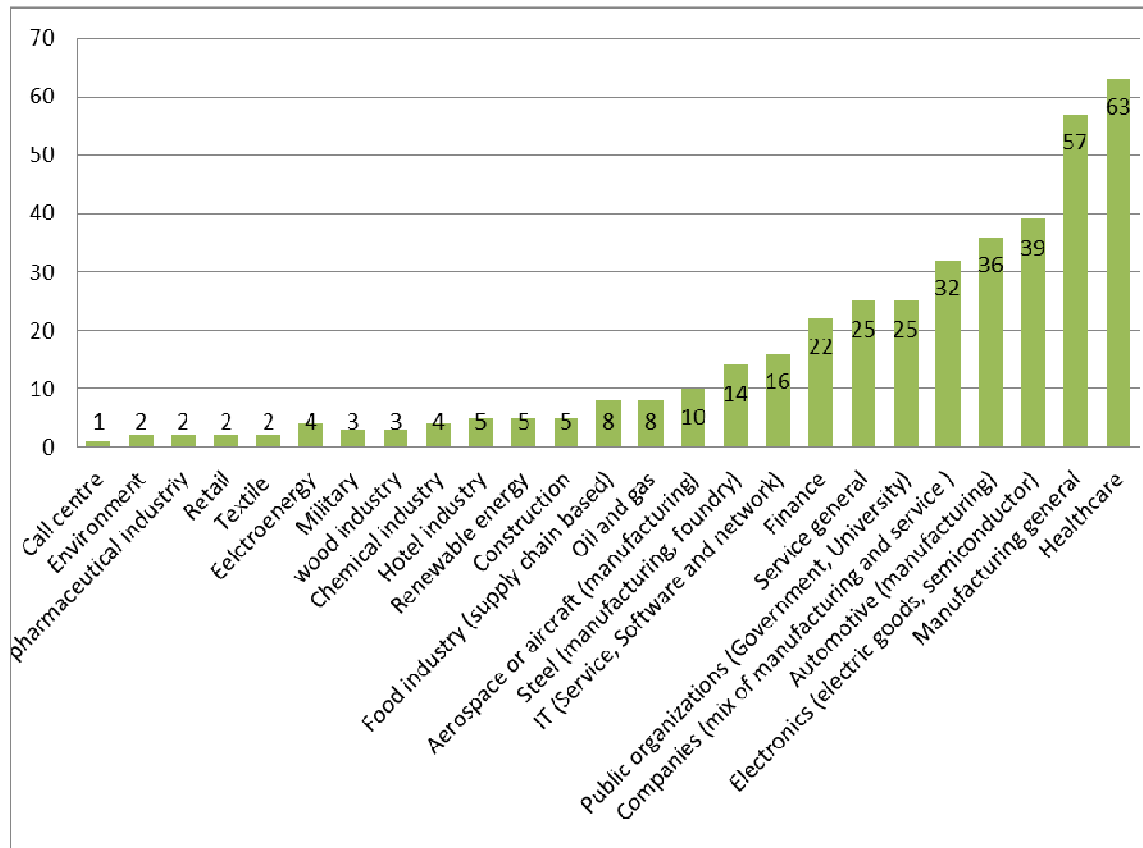


Figure 3 – Distribution of Six Sigma articles by Sector/Industry

The result of Pearson's Chi-Square test analysis revealed that there has been some level of increasing trend in Six Sigma publications in general service, steel and renewable energy sectors after 2010. It was also interesting to note that 40 DMAIC-related articles (nearly 47% of total DMAIC-related articles) have been focusing on health care, general manufacturing and automotive sector. This was unlike some other articles about sectors such as General Service and Finance industries that had almost the equal frequency of various Six Sigma themes in their research.

#### *Distribution by peer reviewed academic Journal*

The proportion of publications in various Journals has been presented in table 1. It was decided to include any Journal with less than 8 Six Sigma publications during last two decades as the "others". There are clearly some specific Journals that had more Six Sigma publications during last 20 years. Furthermore, Journals such as "International Journal of Lean Six Sigma" and "International Journal of Six Sigma and Competitive Advantage" are

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3 Six –Sigma oriented Journals, which have been created few years ago and mainly publish Six  
4 Sigma and lean – focused articles. The result of the Pearson’s Chi-Square test analysis  
5 revealed that the intensity of themes such as Six Sigma DMAIC, Six Sigma tools and  
6 techniques and KSFs is higher in these two Journals. The declining number of Six Sigma –  
7 related publications in Journals since 2008 is also clear, which could be due to more interest  
8 of doing research about LSS.  
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14 **Table 1 appears here**  
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20 *Distribution by the country where the research was conducted*

21 It was evident from the result of analysis that there are some countries where have more  
22 active Six Sigma researchers. The proportion of publications in various countries has been  
23 presented in table 2. This would recognise the base country of the first author as the  
24 corresponding author. It was also decided to include any country where 10 or less than 10 Six  
25 Sigma research publications have been identified during last two decades as the “others”. The  
26 result revealed the significant amount of overall six Sigma research publications in USA.  
27 This could be due to the significant high level of professional and research Six Sigma  
28 activities in this country.  
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38 **Table 2 appears here**  
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43 The result of Pearson’s Chi-Square test analysis revealed the declining of Six Sigma  
44 publications in USA and UK within last few years. This could also be due to increasing  
45 number of LSS publications in these countries. However, it seems researchers in India and  
46 Iran have still increased number of Six Sigma – related publications. It was also revealed that  
47 USA – based researchers had more interest to publish Six Sigma articles in Healthcare sector  
48 than others. General manufacturing sector has been targeted by UK – based researchers more  
49 than other countries, whilst automotive sector was in the centre of attention by India – based  
50 Six Sigma researchers to publish more than other countries.  
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### *Lean Management*

Lean originated in the Japanese automotive sector and then developed in service and other manufacturing industries (Bateman et al, 2014; Bhasin, and Burcher, 2006; and Bendell, 2006). Lean management is widely considered as business process improvement strategy, which is beneficial to a range of companies dealing with the increased threat of cost competition (Thomas et al, 2014; and Herzog, and Tonchia, 2014). It was described as “the systematic removal of waste by all members of the organisation from all areas of the values stream” (Khataie and Bulgak, 2013; Keyser and Sawhney, 2013; and Naslund, 2008). The academic literature offers numerous examples of firms that have achieved significant performance improvement and reducing disruption as the result of implementing Lean management (Khataie and Bulgak, 2013; and Marley and Ward, 2013). It was also broadly used in public sector including healthcare, where it was analysed in interaction with agility principles (Stanton et al, 2014; Bateman et al, 2014; and Aronsson et al, 2011).

Lean Management is one of the few management practices that would be considered as both philosophy and tool (Herzog, and Tonchia, 2014). The Lean Philosophy or Lean Thinking has been deciphered as paradigm from jargon to a commonly-shared language (Stone, 2012). Lean Thinking is a critical concept in which the value generation and waste reduction would have inter-relationship. The concept of the waste reduction recognises Lean Management as another road map of TQM (Dahlgard and Dahlgard-Park, 2006). This has been acknowledged by some research activities in different sectors such as construction (Salvatierra-Garrido and Pasquire, 2011). Value generation has been defined as the fulfilment of customer requirements through understanding the requirements, mapping the process, promoting flow of value from and to stakeholders, pulling value from customer and moving towards perfection (Bateman et al, 2014; Drohomerski et al, 2014; and Salvatierra-Garrido and Pasquire, 2011). This has been approached differently by Magenheimer et al (2014) as a three-phased methodology, in which a holistic view of customer-oriented process will be modelled in first stage, followed by identifying and evaluating the waste as next stages.

Literature has provided many benefits of Lean application including reducing work-in-process, cycle time and inventory and therefore increasing competitive advantage, and improving product and business performance (Agus and Hajinoor, 2012; and Andersson et al, 2006). Later, the role of Lean implementation on problem solving skills has also been acknowledged (Worley and Doolen, 2015). However, it was also criticised due to promoting

less flexibility and reliability in processes, reliance on Just-In-Time (JIT) delivery in supply chain and impact on environmental sustainability (Keyser and Sawhney, 2013; and Andersson et al, 2006). In fact, one of the biggest challenges of Lean application has been introduced as great level of trade-off to promote a lean, global and green supply chain (Martinez-Jurado and Moyano-Fuentes, 2014; and Mollenkopf et al, 2010). This has emerged more current research interest on interrelationships between lean management, Supply Chain management and sustainability (Martinez-Jurado and Moyano-Fuentes, 2014; and Agus and Hajinoor, 2012).

#### *Distribution by the year of publication*

Figure 4 shows the distribution of 287 lean management articles published over the period from 1992 to 2013. It is not completely evident in this study that all 2013 lean management papers have been targeted. The analysis revealed an increasing trend of lean management publications from 2007 to 2011. Then, there has been a big jump on number of published papers in 2013 after a sharp decline in 2012. The Pearson's Chi-Square test analysis indicates increased publication of lean management about automotive manufacturing in 2013 after a plummeting period between 2003 and 2012. The analysis has also revealed the increased interest on research articles and themes such as challenges, implementation and also integration with other quality management initiatives during last few years.

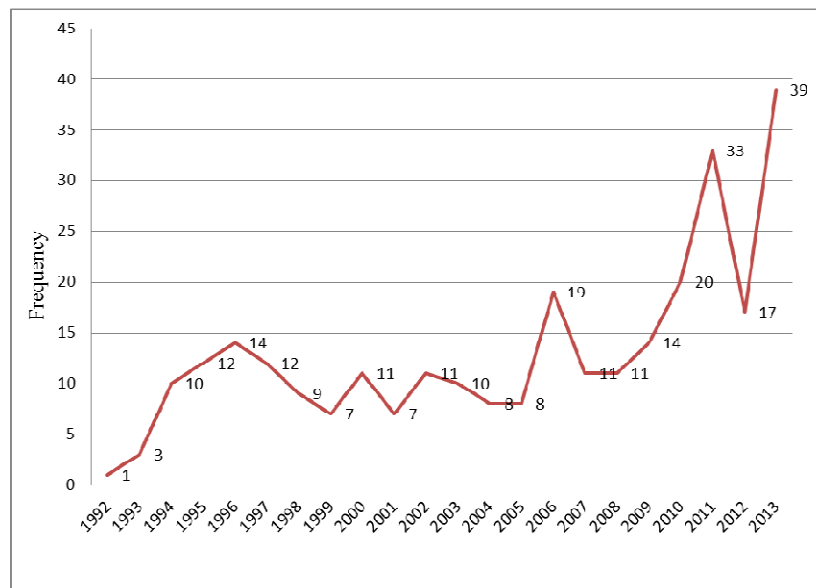


Figure 4 – Distribution of lean Management articles by year (1992-2013)

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3 *Distribution by the research method*

4 It was revealed that 90 articles have been developed through case study as the action research  
5 methodology, whilst 197 articles have been developed through preliminary research approach  
6 such as qualitative and quantitative data collection. The Pearson's Chi-Square test analysis  
7 has suggested increasing average number of preliminary research articles since 2006. This  
8 would have also increased the thematic focus of these papers on studying lean  
9 implementation challenges and also lean integration with other quality management practices  
10 and other management initiatives such as Supply Chain Management (SCM) and  
11 sustainability. The distribution of preliminary research articles was reported significantly  
12 higher than case study approached papers in the UK and USA unlike India.  
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21 *Distribution by the major themes and focus*

22 There could be some articles that are relevant to more than one lean theme, so listing an  
23 article under more than one theme or focus was considered in this analysis. For example,  
24 many articles that had the theme of lean application could also be considering some lean tools  
25 and techniques. There could also be some articles that focused on lean analysis and therefore  
26 reviewing the benefits and challenges. Having reviewed the literature extensively, a total of  
27 16 themes were identified in lean management articles as the most common themes.  
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34 The result of this analysis was depicted in figure 5. It is clear from analysis that more than  
35 half of the lean – related articles (152 articles) focused on lean implementation, lean  
36 integration with quality management practices and supply chain management, and also lean  
37 challenges that have been mostly published by researchers in the UK and USA. In fact, the  
38 result of Pearson's Chi-Square test has revealed that increased focus on lean integration with  
39 other quality management practices and also challenges to implement lean has mainly  
40 happened during post - 2010 period. It was also evident from this result that 39 articles about  
41 implementation (80% of total) were related to a specific sector, where general manufacturing,  
42 automotive and healthcare sectors (24 articles out of 39 articles) had the biggest share.  
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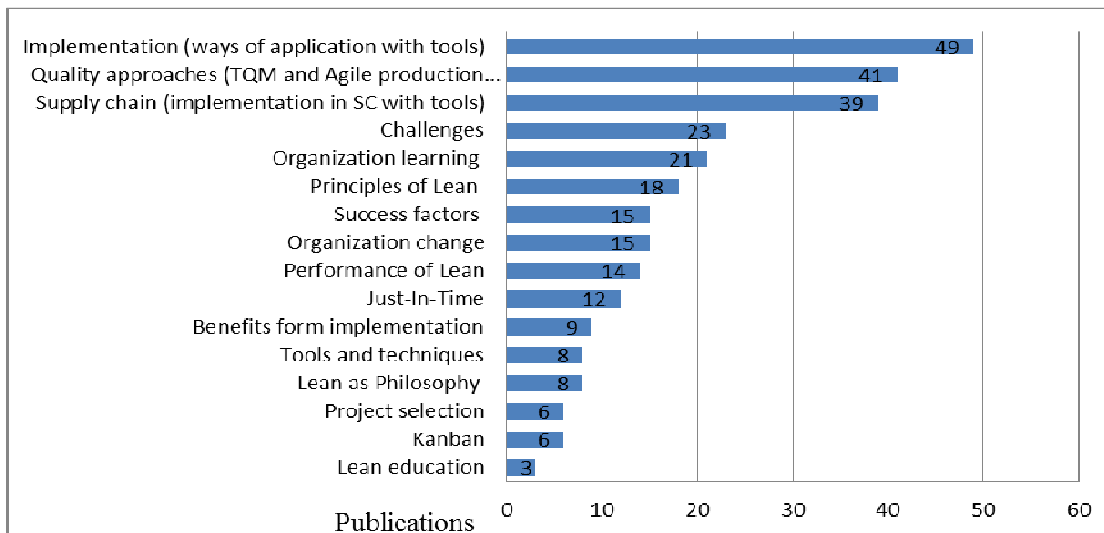


Figure 5 – Distribution of Lean Management articles by focus or theme

*Distribution by industry and sector*

It was revealed that 198 articles of the total 287 lean management – related reviewed articles (69%) have been focusing on a specific industry or sector. It was depicted in figure 6 that 124 articles specifically focused on general manufacturing, automotive and healthcare. It seems there are still many other sectors, especially service sectors that have not been approached by lean management research and publications recently.

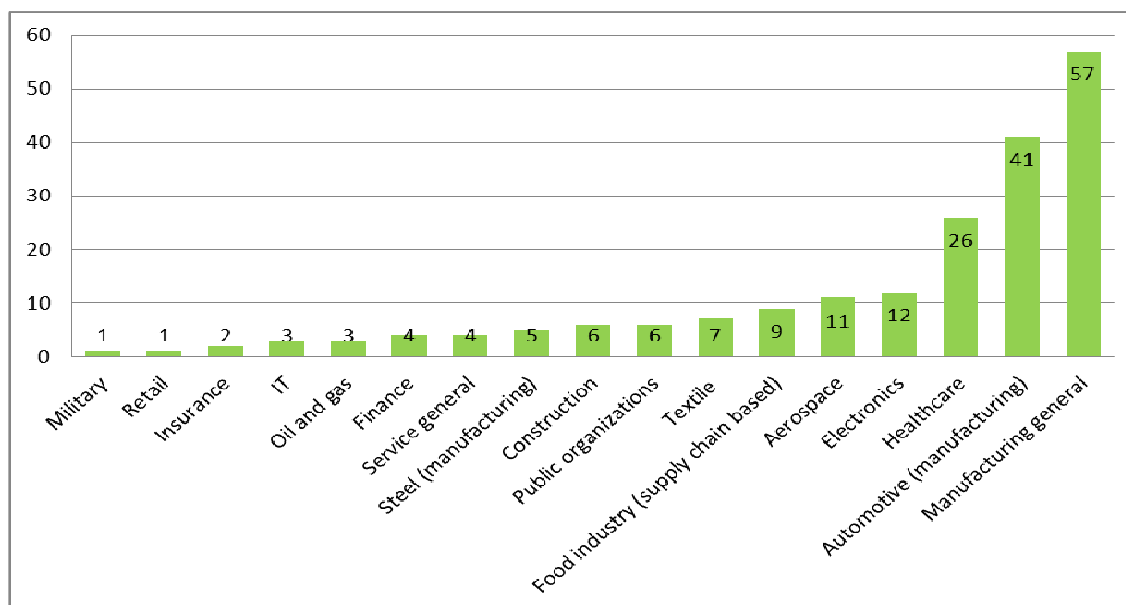


Figure 6 – Distribution of Lean Management articles by Sector/Industry

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3 The result of Pearson's Chi-Square test analysis revealed that lean management publications  
4 in automotive manufacturing started to decline from 2003, but there has been evidence of  
5 increased publication in 2013. Nevertheless, the average number of lean management  
6 publications in healthcare and general manufacturing has increased since 2009. The same  
7 analysis revealed that more than 50% of the lean publications about general manufacturing  
8 and automotive had case study research approach, whilst there has been a similar share of  
9 preliminary research and case study approach articles in healthcare publications.  
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#### 16 *Distribution by peer reviewed academic Journal*

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18 The proportion of publications in various Journals has been presented in table 3. It was  
19 decided to include any Journal with less than 8 lean management publications during last two  
20 decades as the "others". There are clearly some specific Journals that had Lean Management  
21 publications more than other journals during last 20 years. It was interesting to note that 87 of  
22 these articles, which construct about 30% of total analysed articles were published by three  
23 journals as "International Journal of Operations and Production Management" (IJOPM),  
24 "Journal of Manufacturing Technology Management (JMTM)" and "International Journal of  
25 Lean Six Sigma (IJLSS)". Majority of the lean – related articles published in IJLSS focused  
26 on lean implementation and integration with quality management practices (11 articles).  
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33 Further more, 32 articles out of 46 lean – related articles published in IJOPM focused on lean  
34 implementation, and integration with other quality management practices, Just-In-Time (JIT),  
35 Kanban and challenges. The analysis also revealed that 64% of lean – related articles in all  
36 these three journals had preliminary research methodology.  
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43 **Table 3 appears here**

#### 44 45 46 47 *Distribution by the country where the research was conducted*

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49 It was evident from the result of analysis that there are some countries where have more  
50 active lean management researchers. The proportion of publications in various countries has  
51 been presented in table 4. This would recognise the base country of the first author as the  
52 corresponding author. It was also decided to include any country where 7 or less than 7 lean  
53 management research publications have been identified during last two decades as the  
54 "others". The result revealed the significant amount of lean management research  
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3 publications developed in USA and UK. This is followed by Sweden and Italy as two EU  
4 countries and also India.  
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8 **Table 4 appears here**  
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12 The result of Pearson's Chi-Square test analysis has revealed no significant trend variation of  
13 publications in USA and UK during last two decades. However, there has been significant  
14 increase in average lean management publication by Indian researchers during last few years.  
15 The same analysis has already indicated UK – based lean research publications were mostly  
16 related to automotive, general manufacturing, healthcare and food sectors. The USA-based  
17 lean research publications were mostly related to general manufacturing, automotive,  
18 electronics and aerospace sectors.  
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26 ***Lean Six Sigma (LSS)***  
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28 LSS is now regarded as one of the most effective business transformation initiatives that has  
29 evolved through the combination of Lean and Six Sigma, both recognised as leading TQM  
30 tools for performance improvement (Brianvand and Khasseh, 2013; Assarlind et al, 2013;  
31 Wang and Chen, 2012; Choi et al, 2012; Hilton and Sohal, 2012; Atmaca and Girenes, 2013;  
32 Lee et al, 2011; Delgado et al, 2010; Dahlgarrd and Dahlggaard - Park, 2006; and McAdam  
33 and Lafferty, 2004). Snee (2010) cited by Albliwi et al (2014) and Zhang et al (2012) has  
34 defined LSS as “a business strategy and methodology that increases process performance  
35 resulting in enhanced customer satisfaction and improved bottom line results. It was first  
36 introduced into literature around 2000 (Albliwi et al, 2014; and Antony et al, 2012b).  
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44 From a research perspective there are a number of studies that have investigated different  
45 aspects of LSS within organisations with different sizes (Goh, 2013; Assarlind et al, 2013;  
46 Desai et al., 2012; Choi et al., 2012; Jayaraman et al., 2012; and Lee et al., 2011). The  
47 research studies of LSS have also been extended to different sectors and case studies in  
48 manufacturing (Ismail et al, 2014; Gijo, 2014; Akbulut-Bailey et al, 2012; and Thomas et al,  
49 2009) and service sectors (Isa and Usmen, 2015, Bhat et al, 2014, Algasem et al, 2014; and  
50 Delgado et al, 2010). Notwithstanding, implementing LSS in service industry has been  
51 recognised more challenging compared to the manufacturing sector (Antony et al, 2012b).  
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3 The literature review by Zhang et al (2012) has revealed increasing number of LSS research  
4 activities in health and general manufacturing sectors within last few years.  
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8 The goal of LSS similar to Six Sigma is to eliminate waste factors known as defects by  
9 accomplishing a near perfect quality level through the systematic removal of variability and  
10 causes of the defect (Choi et al, 2012; and Thomas et al, 2009). The waste factors could be  
11 considered in all forms including material, time, movement, transport, process, energy and  
12 environment (Maleyeff et al, 2012). LSS has a benefit of an incorporating focus on cost and  
13 process cycle time reduction from lean perspective and sustainable process improvement and  
14 profitability from Six Sigma perspective (Atmaca and Girenes, 2013, Sarkar et al, 2013;  
15 Salah et al, 2011; and Pepper and Spedding, 2010). It could also be recognised as an  
16 environmental waste reduction and therefore green methodology (Maleyeff et al, 2012). This  
17 combination of lean and six sigma has also been criticised by Bendell (2006) cited in Pepper  
18 and Spedding (2010), who recognised LSS as combination of two ill-defined and non-  
19 compatible tools.  
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30 By utilising the LSS five-phased systematic methodology of DMAIC as a project  
31 management improvement model, which in principle is similar to Six Sigma methodology,  
32 organisations can tackle their own specific problems (Tenera and Pinto, 2014; and Gupta et  
33 al, 2012). Nevertheless, the literature has acknowledged that LSS methodology application in  
34 service sector has not been as wide as manufacturing (Bhat et al, 2014). The KSFs and  
35 critical failure factors for LSS application has been reported by literature similar to Six Sigma  
36 (Albliwi et al, 2014).  
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#### 43 *Distribution by the year of publication*

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45 Figure 7 shows the distribution of 155 LSS articles published over the period from 2003 to  
46 2013. It is not completely evident in this study that all 2013 LSS papers have been targeted. It  
47 is obvious that LSS publications have started to emerge from early 21<sup>st</sup> century, since the  
48 researchers started studying on this integrated tool from early 2000's. It is clear from figure 7  
49 that there has been a sharp increase in LSS publications since 2008, which could be due to  
50 more research interest in this area. The Pearson's Chi-Square test analysis revealed increased  
51 publication of LSS in healthcare since 2010, general manufacturing since 2011, and  
52 electronics sector during 2013. This result also revealed that benefits, success factors and  
53 tools and techniques of LSS alongside investigating the integration of Lean and Six Sigma  
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have been popular publication themes since 2010. It also seems from this analysis that case study approached research publications have outweighed the survey – approached articles since 2010.

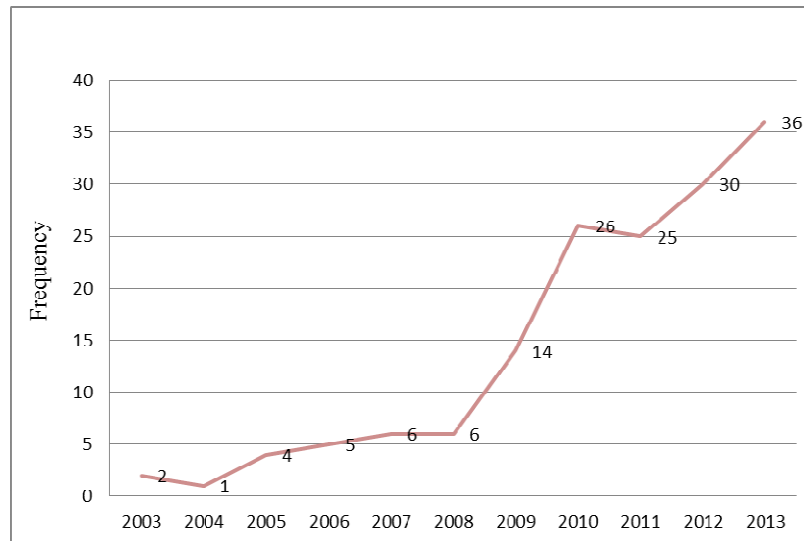


Figure 7– Distribution of LSS articles by year (2003-2013)

#### *Distribution by the research method*

It was revealed that 92 articles have been developed through case study as the research methodology, whilst 63 articles have been developed through preliminary research approach such as qualitative and quantitative data collection. It was revealed from the Pearson's Chi-Square test analysis that more than 50% of the LSS case study-approached papers were related to health care and general manufacturing sectors. It was also clear from this result that most of the case study-approached LSS articles focused on tools and techniques, DMAIC methodology and benefits of implementation, whilst more than 50% of preliminary research-approached papers focused on integration of Lean and Six Sigma, benefits, success factors and tools and techniques of LSS.

#### *Distribution by the major themes and focus*

It is unavoidable to have articles that are relevant to more than one theme, so listing an article under more than one theme or focus was considered in this analysis. For example, many articles that had the theme of LSS tools and techniques have also been focused on DMAIC. There have also been some articles that focused on both benefits and key success factors (KSFs). Similar to Six Sigma, a total of 15 themes were identified in LSS articles as the most common themes. The review of articles has revealed in figure 8 that benefits from

implementation with 30 articles, tools and techniques with 26 articles, and integration with other business improvement practices and also DMAIC methodology each with 19 articles have been the most popular LSS research themes.

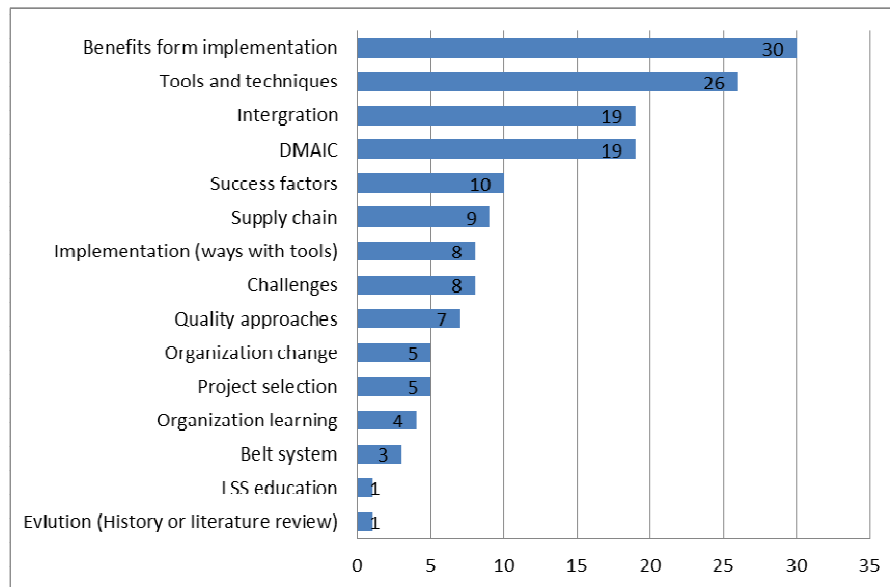


Figure 8 – Distribution of LSS articles by focus or theme

The result of Pearson's Chi-Square test analysis revealed that 36% of articles with the theme of "Benefits from Implementation" were related to the healthcare sector. This sector has also been targeted by almost 50% of papers with the themes of "DMAIC Methodology" and "Tools and Techniques". It was also indicated that nearly 50% of papers with these two popular themes were published in the USA, while this rate was 58% for the theme of "Benefits from Implementation".

#### *Distribution by industry and sector*

It was revealed that 74% of reviewed LSS – related articles have been focusing on a particular industry or sector. The LSS research gap between some specific industries and others has clearly been evident. Figure 9 represents that health care and general manufacturing industries have been in the focus of nearly 50% of the LSS articles. It seems there are still many other sectors that have not been approached by LSS research and publications recently. It was clearly evident from the result of Pearson's Chi-Square test analysis that there has been an increasing trend of popularity of LSS articles in healthcare and general manufacturing and automotive sectors since 2012. Nevertheless, there seems to be more healthcare LSS publications during 2010 - 2011 than 2012 - 2013. It was also revealed

that the proportion of LSS articles in large and small manufacturing organisations was similar. The clear gap of number of healthcare related LSS articles in the USA with other countries was also evident from this analysis.

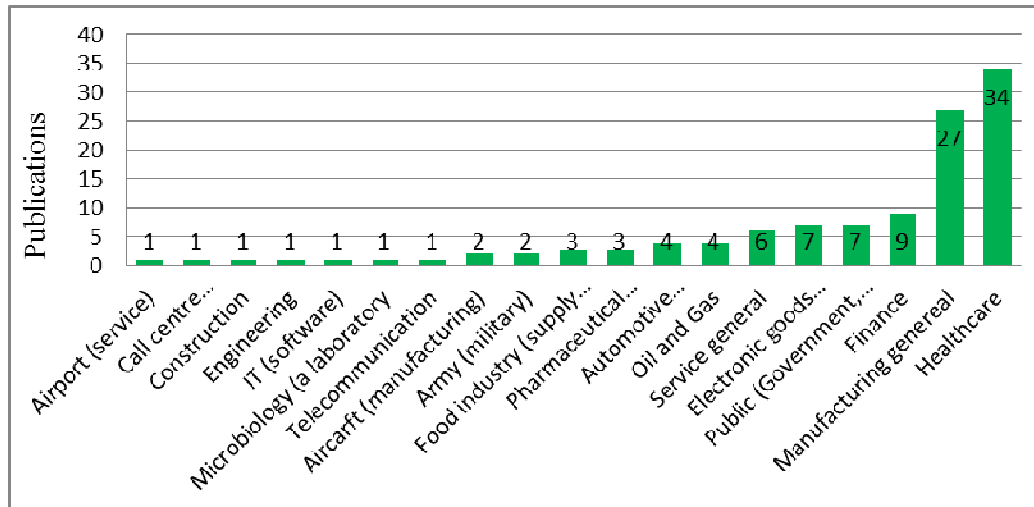


Figure 9 – Distribution of LSS articles by Sector/Industry

#### *Distribution by peer reviewed academic Journal*

The proportion of publications in various Journals has been presented in table 5. It was decided to include any Journal with less than 6 LSS publications during last decade as the “others”. A greater level of disparity has been found in relation to the approached journals in comparison with Six Sigma and Lean. It was clearly observed that there are few journals that have been approached by LSS research authors more than others. For instance, the “IJLSS” is a peer reviewed journal that has been created by Emerald publishers since 2011 with the key focus on LSS, Six Sigma and Lean – related articles. As overall, it seems that LSS research authors would find journals with the quality theme more suitable to publish their papers.

**Table 5 appears here**

The result of Pearson’s Chi-Square test analysis revealed no specific differences between journals in relation to the theme or focus of the LSS article. However, it was evident that most of the LSS articles about the healthcare have been published by other journals such as

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3 health – related journals. It was also revealed that 83% of LSS related papers that published  
4 in “IJLSS” were published in the USA and UK.  
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#### 8 *Distribution by the country where the research was conducted*

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10 It was evident from the result of analysis that there are some countries where have more  
11 active LSS researchers. The proportion of publications in various countries has been  
12 presented in table 6. This would recognise the base country of the first author as the  
13 corresponding author. It was also decided to include any country where 5 or less than 5 LSS  
14 research publications have been identified during last decade as the “others”. USA by far has  
15 been clearly recognised as the top country base for the LSS researchers who publish articles  
16 followed by the UK and India.  
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#### 22 **Table 6 appears here**

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26 The result of Pearson’s Chi-Square test analysis has revealed that the rapid augmentation of  
27 publications by LSS researchers in the USA has started since 2009, whilst this has started just  
28 in 2013 in the UK and India. It was evident that nearly 50% of the publications by USA–  
29 based researchers have been focused on the healthcare sector with “benefits of application”  
30 and “tools and techniques” themes and case study approach. UK and Indian – based  
31 researchers had almost the equal share in general service and manufacturing and also finance  
32 sectors, but with the similar themes to Americans as “benefits of application” and “tools and  
33 techniques”.  
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#### 41 **Conclusion remarks and research implications**

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43 This research study was the extension of some previous studies to develop a hybrid  
44 quantitative analysis of three business improvement practices of Lean, Six Sigma and LSS  
45 within two decades. The key aim of this research was to identify the research gaps through  
46 more comprehensive classification framework and also comparative analysis. It was decided  
47 to provide the conclusion and research implications under each classification dimension to  
48 enable providing a better and clearer comparison amongst three business improvement  
49 practices. Despite a relatively great deal of regular research outputs about Six Sigma, Lean  
50 and LSS, academic journal articles have been found mainly limited to a few industries,  
51 themes and countries.  
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3 It was concluded that the average LSS publications have increased since 2008, whilst the Six  
4 Sigma publications reduced. This will indicate the change of research focus from Six Sigma  
5 to LSS during last few years. It was also clear that there has been relatively more interest on  
6 case study approach during last few years for Six Sigma and LSS publications. In fact, the  
7 increased case study approach of these two tools with practical aspects of the DMAIC  
8 methodology would possibly reflect more research and enterprise integration. There will be  
9 an expectation that researchers somehow work with businesses more closely and broadly to  
10 develop the application of these tools in the future. This was unlike the Lean publications,  
11 which had more primary research approach analysing the challenges and integration with  
12 other business management practices. This would possibly reflect the existence of more  
13 challenges of the publication of action research in Lean Management compared to the LSS  
14 and Six Sigma.  
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24 It is evident that organisational and educational themes have not been in the centre of  
25 attention as much as “tools and techniques”, “DMAIC Methodology” and “success factors”  
26 themes for both Six Sigma and LSS research publications. It is clear that themes such as  
27 benefits of implementation and integration with other management practices have been  
28 approached by LSS articles rather than Six Sigma articles. Interestingly, many researchers  
29 who published in Lean Management topic have had great interest of research publications  
30 about integration with other quality management practices and SCM in implementation  
31 perspective. However, Lean research publications had much lower interest on tools and  
32 techniques compared to Six Sigma and LSS.  
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41 A relative strong link has been found between industry and research publications, since  
42 majority of the published articles would have some link to a specific sector/industry.  
43 However, some industries attracted more researchers compared to others. General  
44 manufacturing, healthcare, automotive and electronic industries were amongst most popular  
45 sectors that have been approached by all papers. It seems the research publications for all  
46 three business improvement practices should have wider approach to also include all service  
47 industries and also aerospace and construction industries. LSS articles had better approach  
48 towards some service sectors such as public, finance and service general sectors compared to  
49 six sigma and lean articles.  
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3 The journal publication frequency seems to be dramatically limited to the operations  
4 Management – related journals for all three business improvement practices. There has been  
5 plenty variation amongst other journals with minimum tendency. USA has been introduced as  
6 the country with the highest level of research publications, which could include researchers  
7 from academia and industry sector. Researchers based in the UK and India have had greater  
8 interest to publish academic articles about Six Sigma, Lean and LSS outside USA. A great  
9 gap between USA and other countries especially in relation to some specific sectors has still  
10 been evidence. This could be as the result of more extensive research/enterprise and also  
11 professional training and project development in American organisations. This has been a key  
12 issue in mid- 1990's and is still a distinctive element for USA compared to other countries in  
13 relation to these publications, despite of publication growth in the UK and some few other  
14 countries.  
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24 It seems a greater deal of cross- disciplinary approach of these publications towards themes  
25 and sectors is required to be considered in the future research works. This would emphasise a  
26 need for more collaborative academia/enterprise approach in wider perspective to publish  
27 research activities in these fields. The current LSS, Six Sigma and Lean researchers would  
28 perhaps need to come out of their comfort zone and expand their research activities to more  
29 innovative areas especially in relation to sectors. This would possibly make the research  
30 publications more interesting and beneficial especially after a greater deal of research outputs  
31 with integrated focus on different fields.  
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39 The main focus of this research was to develop a quantitative - built framework that would  
40 recommend the focus and key gaps of research publications towards Six Sigma, Lean and  
41 LSS. Therefore, it was decided to represent the analysis with numbers and include as many  
42 articles as possible in sampling. However, there could be still many other research articles in  
43 the same fields that had not been considered due to being in different databases. The  
44 qualitative approach to have deeper analysis of the published research gap could also be  
45 considered as the tail of this work, in which authors would be approached through more  
46 interactive data collection method.  
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<b>Peer Reviewed Journal</b>	<b>Quantity</b>
Journal of Manufacturing Technology Management	8
International Journal of Production Research	8
Journal of Operations Management	10
International Journal of Productivity and Performance Management	12
The TQM Journal	13
Quality and Reliability Engineering International	17
The TQM Magazine	20
Quality Engineering	21
International Journal of Quality & Reliability Management	25
International Journal of Lean Six Sigma	25
Total Quality Management & Business Excellence	41
International Journal of Six Sigma and Competitive Advantage	46
Other Journals	345

Table 1 – Distribution of Six Sigma papers by Journal

<b>Country of research conduct</b>	<b>Quantity</b>
USA	215
Others	149
UK	65
India	60
Taiwan	42
Singapore	14
Netherlands	13
China	11
Iran	11
Turkey	11

Table 2 – Distribution of Six Sigma papers by country, where the research was conducted

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<b>Peered Reviewed Jornal</b>	<b>Quantity</b>
International Journal of Lean Six Sigma	8
Journal of Operations Management	8
Supply Chain Management: An International Journal	9
International Journal of Productivity and Performance Management	14
International Journal of Production Economis	17
Journal of Manufacturing Technology Management	20
International Journal of Lean Six Sigma	21
International Journal of Operations and Production Management	46
Other journals	144

Table 3 – Distribution of Lean Management papers by Journal

<b>Country of research Conduct</b>	<b>Quantity</b>
USA	90
UK	72
Others	54
Sweden	15
Italy	12
India	11
Australia	9
Spain	8
Netherlands	8
Denmark	8

Table 4 - Distribution of Lean papers by country, where the research was conducted



Peered Reviewed Journal	Quantity
International Journal of Quality & Reliability Management	6
Quality Management in Health Care	6
The TQM Journal	6
The TQM Magazine	6
Total Quality Management & Business Excellence	7
International Journal of Six Sigma and Competitive Advantage	7
International Journal of Productivity and Performance Management	7
International Journal of Lean Six Sigma (IJLSS)	12
Other Journals	98

Table 5 – Distribution of Lean Management papers by Journal

Country of research	Quantity
USA	79
UK	26
Others	24
India	13
Netherlands	7
Taiwan	6

Table 6 - Distribution of LSS papers by country, where the research was conducted