A critical perspective on the changing patterns of Lean Six Sigma research

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Abstract

Purpose – The purpose of this paper is to utilise the research patterns of the most prolific contributors to Lean and Six Sigma methodologies over a 15-year period to inform the discussion on whether the methodologies should be or are being integrated.
Design/methodology/approach – Structured searches using keywords were carried out using a single database (SCOPUS) to identify the most prolific contributors to research articles in the areas of Lean, Six Sigma and Lean Six Sigma, and thereafter patterns were analysed in five-year periods between 2000 and 2015.
Findings – This research demonstrates clear changing and evolving patterns of research activity. Not only is there a clear emergence of research focussed on Lean Six Sigma rather than a single methodology, there are also indications that researchers publish work using different methodologies in response to different challenges.
Research limitations/implications – The research is restricted to a single database and includes only the 21 most prolific contributors in each five-year period. The analysis is based on the focus of each peer-reviewed paper contributed to.
Practical implications – This research is intended to support and inform organisations which are developing or running business process improvement approaches by demonstrating the flexibility of Lean and Sigma, and evidencing that researchers work across different approaches and combine them when appropriate.
Originality/value – This paper provides a unique perspective on the debate for the integration of Lean and Six Sigma by looking at the patterns of work of researchers themselves to identify whether the focus of research has in fact moved on from exclusively lean or Six Sigma to more integrated approaches as has been argued in individual pieces of research.

Keywords Six Sigma, Integration, Lean
Paper type Viewpoint

Introduction

The genesis of both Lean and Six Sigma has been well established in literature. Lean's origins in the Toyota Production System and focus on waste in process and Six Sigma's roots within Motorola and focus on reducing variation in process to improve efficiency and quality (Antony *et al.*, 2016). Ever since the integrated term Lean Six Sigma has been coined (George, 2002), there has been an ongoing debate about whether or how the approaches should be integrated (Cherrafi *et al.*, 2016).

The motivation for this paper is to step back from the technical arguments and detail over approaches, tools or methodologies regarding the evolution Lean and Six Sigma integration and review whether or not the research contributions of individuals reflect the evolution and whether patterns of publications by individuals reflect the academic discussion over the integration of Lean Six Sigma. In other words, the contributions of the most active individuals in this field have evolved in terms of subject matter. Is a researcher who historically focussed on Lean now contributing to Lean Six Sigma research or do they remain focussed on Lean, for example, and what does this inform us regarding the Lean Six Sigma journey?

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The intention is to explore whether the partnership between Lean and Six Sigma has grown closer and whether research have changed their focus between the methodologies to add to the body of knowledge on the appropriate deployment of business improvement methodologies.

Literature review

This review and analysis was prompted by the progress of the discussion around whether Lean and Six Sigma are complementary or rival methodologies and whether organisations need to choose a singular approach to complement their business improvement strategies. The origins of both methodologies have been well written about, with Lean having its roots in the Toyota Production System and Six Sigma rooted in total quality management and its development within Motorola (Antony *et al.*, 2016).

The use of the term Lean Six Sigma can be traced back to 2001 in the book *Leaning Into Six Sigma: The Path to integration of Lean Enterprise and Six Sigma* (Wheat *et al.*, 2001) and was additionally adopted by Michael George (2002) shortly thereafter. It is also noted that the term "Lean Sigma" (Sheridan, 2000) was also used to describe how Six Sigma Black Belts would assist in Kaizen workshops within BAE systems, in circumstances where data-driven problems were identified.

Arnheiter and Maleyeff (2005) published an article within *The TQM Magazine* entitled "The integration of lean management and Six Sigma". Their stated intention was to dispel myths about both methodologies and to discuss "[…] what lean organisations can gain from Six Sigma and what Six Sigma organisations can gain from lean management". In their paper, Arnheiter and Maleyeff, argue that organisations which utilise Six Sigma should make more use of data in their decision making and Lean organisations should utilise tools that eliminate waste as part of their process improvement methodology. They argue that each system prioritises distinct aspects of organisational performance and that implementation of only one approach might mean that the full potential is not realised, benefits are not optimised and improvements are difficult to sustain.

It has additionally been argued that Lean can be seen as a precursor to Six Sigma (Shah *et al.*, 2008) with the adoption of a wider set of lean tools and techniques leading to an increased likelihood of adopting a Six Sigma approach.

Although the term Lean Six Sigma was coined around 2001, it was still argued that by 2006, there remained a research gap in terms of the maturity of academic research around Lean Six Sigma (Bendell, 2006). Bendall comments that the arguments around the non-compatibility are vociferous and, in his words, can approach a "near-religious argument about the professed compatibility of approaches". Bendall goes on to give examples of how Lean and Six Sigma can however practically negatively impact on each other. The emerging arguments for the benefits of utilising both Lean and Six Sigma have also been summarised as "targeting every type of opportunity available within an organisation" (Pepper and Spedding, 2010).

The development of this discussion is exampled through the work of Salah *et al.* (2010), in their article "The integration of Six Sigma and lean management" in the *International Journal of Lean Six Sigma*. The focus of this paper has clearly shifted from a discussion about whether Lean and Six Sigma are complementary to describing how they should be integrated. This focus implies that the debate has moved on and integration of the methodologies is commonly accepted. In this paper, the authors describe how the DMAIC structure, which is a key element of a Six Sigma approach, can integrate Lean tools into each phase.

This debate is far from concluded however and while there is recognised common ground between the methodologies there are also differences (Antony, 2011). The varying interpretations of the two methodologies and their differences and commonalities are evidenced in the opinions of academics and practitioners quoted in the paper and can help inform appropriate or targeted usage of each approach.

There are many additional references which demonstrate the work of researchers; however, the brief literature review presented is intended to only give a flavour or the timeline for the debate, from initial work on combining Lean and Six Sigma in the early 2000s, to examining the strengths and weaknesses of each and whether they are complementary in 2005 through to how they should best be integrated in 2010. This timeline has been used as a basis for this research and as an alternative method of exploring the journey by looking at whether the patterns of contributions by researchers have changed over the period 2000–2015.

Methodology

Given that the aim of this work was to explore the contributions made by researchers over a fixed period, several different databases were assessed for use. The use of searches across multiple databases was ruled out as not all supported the presentation of search results in a way in which the frequency of contributors could be recognised. The key factors considered in identifying an appropriate database was the ability to format search results ranked by the number of contributions made by researchers as well as the size and scale of the database to maximise the number of results.

The "SCOPUS" database was selected for use as it supported identification of contributions per individual researcher and it analyses over 21,000 titles from more than 5,000 publishers across the world (Elsevier, 2017) and across multiple disciplines. The searches were limited to articles rather than books or conferences papers to focus on the timescales relevant to this review. Beyond this, the knowledge that articles in this research have all been peer reviewed adds to the confidence level on quality. The search terms used within the SCOPUS database were "lean production", "lean thinking", "lean manufacturing", "Lean Six Sigma" and "Six Sigma".

The search term "Lean" alone was avoided to minimise any overlap to terminologies used in medical publications not related to process improvement methodologies and, in turn, support the identification of contributions which were relevant to this research.

The searches were thereafter carried out across the periods 2000–2004, 2005–2009 and 2010–2014. Groups of years were chosen rather than single years in recognition that articles could be researched, submitted and published over more than a one-year period and so publication patterns and frequencies could be smoothed. Additionally, the time periods are intended to support comparison to the literature over the period which discusses integration of Lean and Six Sigma and later methods by which this can be achieved.

The analysis of the results has been categorised through the abstract and the keywords used in the articles as a means of ensuring the main focus of each article is included. The term Lean and Six Sigma is used to identify articles where both Lean and Six Sigma are referenced but not as an integrated approach as with Lean Six Sigma. Most commonly articles classified as Lean and Six Sigma are those which discuss, compare, critique or otherwise analyse Lean and Six Sigma without presenting them as an integrated approach.

Findings

The search findings are presented in the three temporal groupings with some observational commentary, and this is thereafter summarised and an overall analysis is presented at the end of this section.

2000–2004

The output from the searches made during this period identified that the 21 most prolific contributors made a total of 76 contributions to articles, and these have been broken down by the area of focus, as shown in Figure 1.

As can be seen from the figure, Researcher "*A*" published the most number of identified contributions to published articles with nine, and the smallest number of contributions were made by researchers "*R*", "*S*" and "*T*" with two each.

Figure 2 breaks down the countries in which the 21 contributors were active during the period 2000–2004.

It can clearly be seen that the UK and USA dominate as the countries where the most prolific contributors are active. There is also a strong presence of industry-type journals rather than academic journals and this is seen strongly in the UK with contributions to automotive industry journals being a frequent source of output. Of the nine most prolific contributors from the UK, three have made their contributions exclusively to industry-type journals over a relatively brief period within the five-year span of this group of searches. In the USA, the contributors published in journals more focussed on engineering or quality in general.

The results of the searches shown initially in Figure 1 demonstrate that 17 of the researchers published contributions in one area of focus only, either Lean or Six Sigma. The researcher's activeness in only one area of focus demonstrates that, while not exclusively so, there is a dominant focus on Six Sigma in the USA and Lean in the UK amongst the 21 most prolific contributors of this period.

The remaining four contributors did explore more than one area. Researchers "*A*" and "*N*" focussed on Six Sigma but also contributed to articles which explored elements of Lean and Six Sigma together. Researchers "*A*" and "*N*" were both UK-based researchers at this time. From a Lean perspective, researcher "*M*" has shown a focus on Lean but has contributed to an article on Lean and Six Sigma.

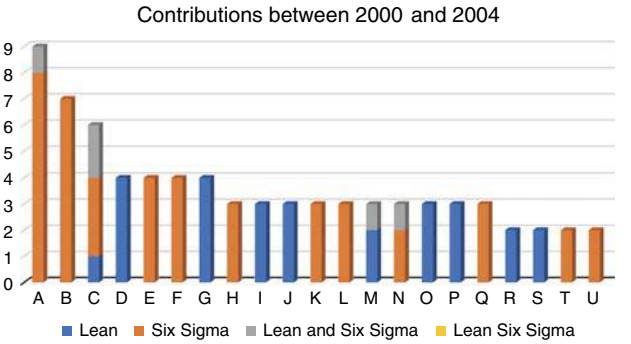

Figure 1.
Summary of contributions made between 2000 and 2004 shown by the area of focus

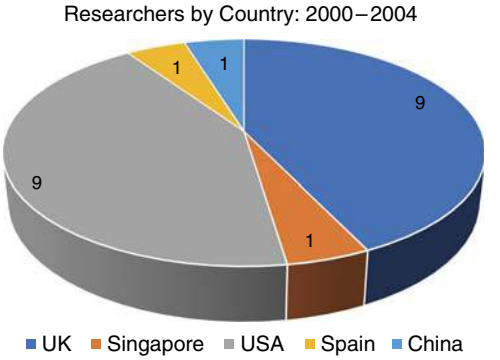

Figure 2.
Most prolific researchers by country between 2000 and 2004

One researcher ("*C*") has contributed to articles on "Lean", "Six Sigma" and "Lean and Six Sigma" during this period and is the only contributor shown to be active across three of the categories of this research. "*C*" was a UK-based researcher at this time and all of the contributions made were within an Automotive Industry trade magazine with five of the six contributions all being within the same issue.

Given the focus of this paper on the journey of the debate and integration of Lean and Six Sigma, it is noted that none of the 21 researchers identified in Figure 1 has contributed to articles on Lean Six Sigma at this time, but 4 of the researchers have clearly started to consider both Lean and Six Sigma as part of their research output. Of these, three researchers were UK based and the fourth was US based.

2005–2009

The second five-year period has been presented in the same format using the same search criteria and is summarised in Figure 3.

The searches relating to the second five-year period show that the 21 most prolific researchers published a total number of 159 contributions to articles in related subjects. Researcher "*A*" is the only researcher who appears in both Figure 1, 2000–2004, and Figure 3, 2005–2009; this researcher has made the most number of contributions in both periods with 9 between 2000 and 2004, rising to 28 between 2005 and 2009. The fewest number of contributions is now shown as four by researchers "NN" and "OO". This does show the increasing numbers of contributions being made during this second period of the research.

As with the period 2000–2004, the researchers have been broken down into the country of activity, and this is shown in Figure 4.

It can be seen from Figure 4 that the 21 most prolific contributors are now active in nine countries rather than the five represented in the period 2000–2004. Researchers in the USA remain particularly active but the number of UK-based contributors in the most prolific 21 has dropped from nine to three. Researchers in Europe make up 11 of the 21 researchers identified during this period. Particularly, the emergence of India as a base for researchers very active in this area is also noted. Another identified factor during this period is that less of the contributions were made to industry-type journals and the articles were almost exclusively within academic journals.

During this second five-year period, nine of the most prolific researchers shown in Figure 3 are shown as focussing on only one area, either "Lean" or Six Sigma". This has reduced from 17 of the 21 researchers identified during 2000–2004. Of the nine researchers contributing to articles exclusively on either Lean or Six Sigma, two were based in India, one in Canada, one in Germany, one in China, one in Taiwan and three in the USA. Many of these researchers represent countries which did not appear in the search results from the first period.

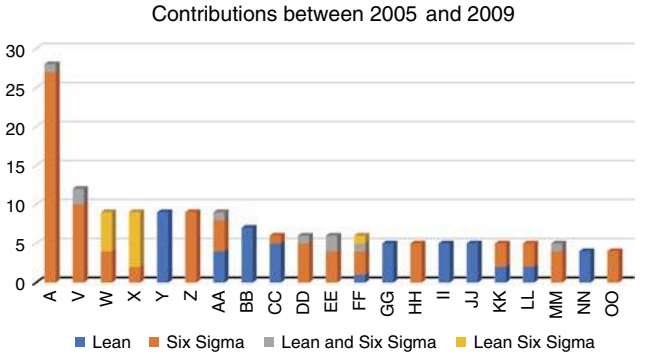

Figure 3.
Summary of contributions made between 2005 and 2009 shown by the area of focus

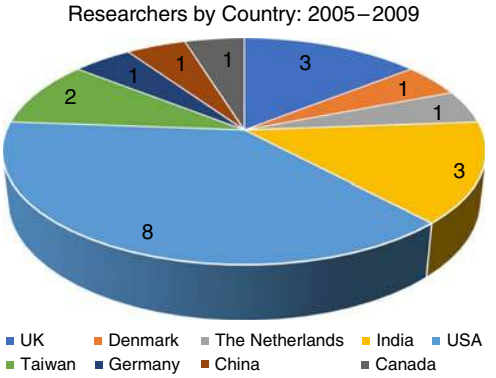

Figure 4.
Most prolific researchers by country between 2000 and 2004

This would tend to suggest that there is a pattern between 2000 and 2009 of researchers becoming active in the field through an initial focus on either Lean or Six Sigma exclusively.

In the period 2005–2009, the number of researchers' activeness across more than one area of focus has risen to 11 from 4 in the previous five-year period. Breaking the contributions down by country of activity demonstrates the growth of contributions exploring Lean and Six Sigma in the same article during the period 2005–2009. This is particularly evident in the UK and USA, which were heavily featured in the contributions of those focussing exclusively on only Lean or Six Sigma during the first period.

This second period surfaces the first contributions which are focussed on "Lean Six Sigma" with researchers "*W*" and "*X*" making contributions to articles which focus on both Six Sigma and Lean Six Sigma. Both researchers are from European countries, and neither they nor their country featured among the results for 2000–2004. For both these researchers, the greatest number of their contributions is for articles focussed on integrated Lean Six Sigma. Researcher "FF" is the only researcher to have made contributions across all four areas of focus in this study and was based in Taiwan at the time of the contributions.

Figure 3 also demonstrates that five of the researchers ("AA", "CC", "FF", "KK" and "LL") have made contributions to papers which focus on either "Lean" or "Six Sigma", which perhaps also challenges the concept that researchers only work in one or other area of business improvement methodology. The countries in which these researchers are based show a broad spread as well, being India, USA, Taiwan, UK and USA, respectively. From the research results, there are no clear links as to why these researchers have made contributions in both Lean only and Six Sigma only articles.

2010–2014

Figure 3 represents the summary of the results for the 21 most prolific contributors during the period 2010–2014 (Figure 5).

By this period, the 21 most prolific researchers identified are shown to have made 232 contributions to articles in the area of focus. Those researchers contributing in only a single area of focus are eight (albeit it can be seen that researcher "AAA" contributed to articles only relating to Lean Six Sigma).

The breakdown of researchers by country in which they are based is shown in Figure 6.

The 21 most prolific contributors were based in five countries in 2000–2004, in nine countries in 2005–2009 and across ten countries in 2010–2014. During the first period of this research, contributors in the USA and UK dominated the list of 21 researchers. As well as the growth of the number of countries represented by these contributors, there is also a shift in the clusters of researchers. Only 4 of the 21 researchers are UK based, and only 3 were US based.

The increase in the number of researchers from India (5) is noted but it is also noted that no researchers from African countries have appeared in the searches nor from Middle Eastern countries. It also appears that Asian countries are under-represented considering the scale and populations of these countries. It may be that the next five-year period reflects the further proliferation of Lean Six Sigma in these countries.

During the period 2010–2014, 13 of the researchers made contributions to papers focussed on more than one methodologym and eight of those were contributing to papers on three or more of the areas of focus of this research. By this period, one researchers' contributions, from the USA, are exclusively focussed on Lean Six Sigma, and only seven of the most prolific contributors are focussed on either Lean or Six Sigma exclusively. Of these, two contributors, one each from India and Taiwan, have contributed only to Six Sigma articles. The remaining five researchers have contributed exclusively to articles on Lean. These researchers are based in Germany (two), UK, USA and Romania.

For the third period in succession, researcher "*A*" has been the most prolific with the number of contributions now rising to 31. Additionally, however, this period sees a rise in the number of researchers who have shown across more than one period with researchers "*X*", "*V*", "*Z*", "II" and "HH" appearing in the 2005–2009 summary as well as the current one. Given that the researchers who appear across more than one single time period provide the most direct evidence of any changing patterns of research by individuals, they are explored in more detail through the summary and analysis of the results.

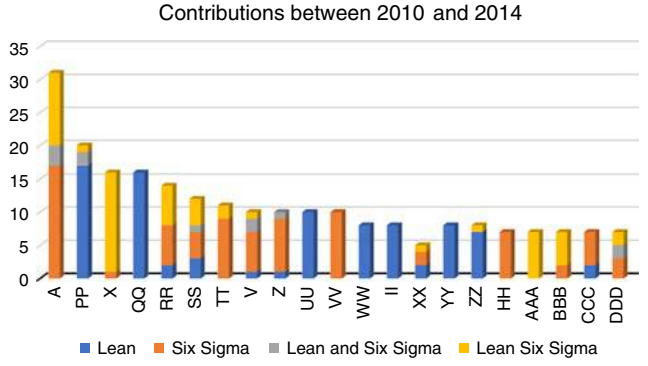

Figure 5.
Summary of contributions made between 2010 and 2014 shown by the area of focus

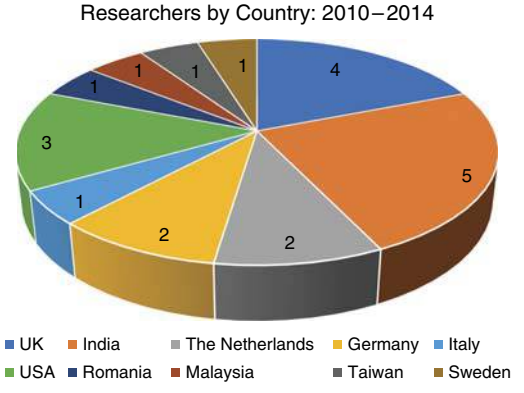

Figure 6.
Most prolific researchers by country between 2010 and 2014

Summary and analysis of results

One of the initial considerations was whether there was any evidence that researchers were shifting focus from exclusively researching either "Lean" or "Six Sigma" to integrated methodologies such as Lean Six Sigma or Lean Sigma, and whether they were researching exclusively in one methodology or another.

The pattern of researchers' contributions focussed exclusively on Lean or Six Sigma

Over the period of the review, the 21 most prolific contributors in each five-year period whose contributions have only looked at either "Lean" or "Six Sigma" has reduced. In terms of "Lean" alone, the number of researchers has reduced from eight to six to five, and those looking at "Six Sigma" alone has reduced from nine to three to two. It is clear that each five-year period has seen a decline in the number of researchers whose contributions to articles are purely in relation to Lean or Six Sigma alone (from 17 to 9 to 7).

It should of course be noted that the overall number of contributions has increased from 76 in the first period to 232 in the third period. When examined, it can also be seen that the number of researchers who have focussed their output on Six Sigma alone has decreased at a far quicker rate than those who have focussed on Lean alone. This would appear to infer that Lean has been more readily integrated with Six Sigma by those who may have previously researched Six Sigma alone than the reverse scenario where Lean researchers have been less quick to include Six Sigma in any transition. This of course raises the consideration that there may be some aspects of Six Sigma which discourage Lean practitioners and researchers from expanding their research to include both methodologies.

It is possible that Six Sigma is seen as more technical and less easy to implement or that the use of some statistical tools is off-putting? Certainly, one difficulty encountered by the authors in deploying Lean Six Sigma is the frequent non-availability of suitable data within organisations.

The pattern of researcher contributions which include both Lean and Six Sigma

When considering the researchers whose outputs include contributions to articles about both Lean and Six Sigma or the more integrated Lean Six Sigma the change in focus over the 15-year period is represented in Table I.

The evolving focus of contributions which include discussion or argument which examine both Lean and Six Sigma in individual articles can be seen to by the number of researchers involved over each period and through the timeline, the consequent decrease from contributions about Lean and Six Sigma and the increase in contributions about Lean Six Sigma. This would also seem to support the discussion within the literature review around the question of whether the methodologies should be integrated through to how best to integrate the methodologies. The number of contributions which explore Lean and Six Sigma have been published in the first and second periods, and the second and third periods, has seen an increase in integrated Lean Six Sigma articles. This appears to suggest that the integration of Lean and Six Sigma has been successful through the pattern of publications by researchers, albeit it is noted that there remain researchers who work exclusively in Lean or Six Sigma.

Beyond the initial considerations in this research of exploring whether researcher contributions were changing over time, and whether there was a shift from research on

Table I. Summary of researchers contributing to articles on Lean and Six Sigma or Lean Six Sigma

Period	Lean and Six Sigma	Lean Six Sigma	Both	Total
2000–2004	4	0	0	4
2005–2009	6	2	1	9
2010–2014	1	7	5	13

single methodologies towards a more integrated outlook, it was noted that several researchers were additionally contributing to research focussed on lean as well as Six Sigma in addition to the integrated Lean Six Sigma approach. This may indicate an approach by researchers of matching, tools, approaches or methodologies to tackle specific issues or problems rather than simply endorsing one single approach to improvement.

In the period 2010–2014, 5 of the 21 most prolific contributors were involved in research focussed on Lean, Six Sigma and Lean Six Sigma or Lean and Six Sigma outputs. In the period 2005–2009, five of the researchers also contributed to outputs focussed on Lean alone and Six Sigma alone, although only two of the five also contributed to output on Lean and Six Sigma or Lean Six Sigma. There was only one researcher in the period 2000–2004 who contributed to articles focussed on Lean and separately to articles focussed on Six Sigma.

This would appear to suggest that researchers are utilising tools from Six Sigma or lean or integrating lean and Six Sigma depending on the issue or problem they are exploring and shows an increasing flexibility and interchangeability. It has been a previous criticism of approach around to not apply the right tools to the right problems and the need for flexibility around when Lean and Six Sigma tools should be applied proportionately (Antony, 2013).

The changing pattern of research contributions across multiple time periods

As part of this paper, consideration was given to the countries in which the 21 most prolific contributors were based and it has been seen that the number of countries in which the researchers are based has increased in each period and in particular broadening out from the USA and UK, whose researchers dominated the first period shown.

This analysis of the 21 most prolific contributors in Lean and/or Six Sigma over the 15-year period also considered the longevity of researcher's contributions across the three periods, each of five years, and where contributors were identified as appearing in more than one period, whether their research focusses had changed or evolved. There were a total of 6 researchers identified whose work appeared amongst the most prolific 21 researchers. The nature and number of their contributions is shown in Figure 7.

The figure shows that only one researcher (A) appears in the 21 most prolific contributors in each of the time periods researched and, in fact, is the most prolific contributor in each of the three periods with 8, 28 and then 31 contributions. Their main focus across the 15-year period has been Six Sigma, but in each of the three periods, they have contributed to articles which have explored both Lean and Six Sigma, and in the third period, they have become more involved in Lean Six Sigma research. This researcher is UK based and initially focussed on manufacturing, but their contributions have broadened out to all sectors of business, both public and private.

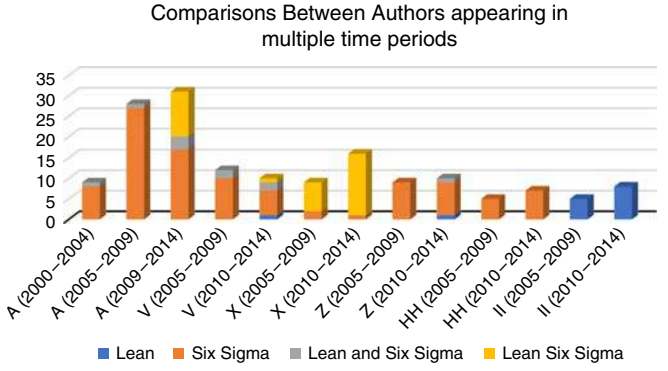

Figure 7.
Summary of contributions made by researchers across more than one period shown by the area of focus

Another five researchers were identified as being active over the periods 2005–2009 and 2010–2014, two of the researchers (HH and II) have focussed exclusively on Six Sigma and Lean respectively. Researcher HH is Taiwan based and has again published across a number of different sectors including leisure and retail but mainly in regard to manufacturing. Researcher II is Germany based and has contributed exclusively in Lean and exclusively in manufacturing.

The remaining three researchers have made contributions in more than one area. Researcher "*X*" is noticeable as the only contributor who has predominantly contributed to Lean Six Sigma outputs over more than one period. This researcher is the Netherlands based and their contributions have primarily focussed on health areas but have also extended to other public-sector areas. Researchers "*V*" and "*Z*" have contributed to articles focussed on both Lean and Six Sigma as well as both methodologies together. Researcher "*V*" is UK based and their contributions have focussed on small and medium enterprises. Researcher "*Z*" is US based and their contributions are primarily health based but also include the manufacturing sector.

The six researchers identified as operating in the 21 most prolific contributors over more than one time period can be seen to be from a range of countries and operating across a number of business sectors with an element of commonality in manufacturing and health.

Comparing the six researchers referenced across Figure 4 with the spread of contributors presented in the figures across each of the three periods of time, it does suggest that researchers who have focussed on Lean alone have been the least likely to sustain their output, albeit this is a very small and limited sample. The figure does show that four of the six researchers have broadened their research focus between time periods to include the discussion of Lean and Six Sigma or Lean Six Sigma as part of a more integrated approach or at least discussion and consideration of the advantages and disadvantages of each methodology.

Limitations/future research

As identified in the methodology, this research was conducted using only one database and has only taken the 21 most prolific researchers rather than every researcher active in the field. It has been intended as a first step towards assessing whether the integration of Lean and Six Sigma can be evidenced through the work of researchers rather than through individual contents of journal articles. It is intended to broaden the inclusion criteria and the number of databases searched in order to further test some of the patterns of behaviours identified from the analysis in this paper.

Additionally, the more specific content of each contribution has not been analysed to consider the nature of the debate, research or argument and the specific deployments of Lean and/or Six Sigma. There may be further patterns of research which could be drawn from a deeper analysis rather than solely focussing on the methodology focussed on in the paper.

This research was intended to identify whether or not the research focus of contributors in this area changed over time and it is considered that future research is possible to further explore what has motivated or informed the changes or evolution in research direction.

Conclusion

This research and analysis has contributed to the evidence which shows the changing pattern of research in Lean and Six Sigma from the analysis of contributions of the researchers. While it is recognised that this analysis is carried out utilising only the 21 most prolific contributors over a 15-year period, there are clear patterns over the changing focus of peer-reviewed journal articles in this field from Lean or Six Sigma, through Lean and Six Sigma and most recently emerging as Lean Six Sigma.

The analysis does give some indications that proponents of Six Sigma have more readily identified the benefits from incorporating Lean into their work and that Lean proponents have been less quick to do so. The rationale for this has not been explored as part of this paper.

The analysis of this research supports the arguments for integrating Lean and Six Sigma by demonstrating that this journey is reflected in the contributions of researchers in this field. There are some indications of researchers contributing to articles across methodologies, including articles that focus exclusively on Lean or Six Sigma. This would tentatively suggest the recognition that tools and techniques should be applied to individual problems and the contributions are the recognition of this.

Perhaps in the future researchers will identify less with being subject matter experts in Lean or Six Sigma alone and apply such tools and techniques in pragmatic ways which support process and business improvement and are aligned to strategies rather than pre-applying a single methodology to an organisation or continuous improvement programme. It is therefore speculated by the authors that the journey to integration of Lean and Six Sigma may also recognise the deployment of only lean or only six sigma tools as appropriate to the challenge faced but will reflect all options available in a pragmatic sense.

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