

Systematic analysis of the methodological structure of the lean literature

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Abstract

Purpose – The purpose of this paper is to analyse and evaluate the methodological structure of the Lean literature so that its characteristics and influence among academics and practitioners might be better understood. We define ‘methodological structure’ to be comprised of six categorical components: publication category, degree of methodological disclosure, research strategies, data collection instruments, type of data collected & analysed, and type of research informants.

Design/methodology/ approach – This study is a systematic bibliometric analysis of the Lean literature. It has a two-stage research design. The first stage involves the identification of the top fifty most highly cited publications on ‘Lean’, with the resultant reference details being entered into a Focal Population Set (FPS) spreadsheet. The second stage involves coding and adding the six component fields of the methodological structure for each of the FPS entries. Both citation analysis and publication counting are then used to analyse patterns in these six components of methodological structure.

Findings – The top fifty publications in the FPS represent over 52,700 citations. All are either journal papers or books, but books are the most influential. Based upon this FPS sample, the Lean literature is found to be both largely atheoretical in nature and also methodologically weak. Over half of the FPS publications are *Viewpoint*-type publications and 46% have no methodological disclosure. The Lean literature is predominantly qualitative in nature. Where disclosed, the most common research strategy is the case study and the most common data collection instrument is the interview. High and mid-level managers are the most frequently encountered research informants, whilst shop floor workers are infrequently utilised.

Originality/value - This paper starts with the most extensive known systematic review of systematic reviews of the Lean literature; the result of which is the characterisation of a number of gaps in this body of knowledge. One of these gaps is the lack of any previous citation analysis (CA). The paper then proceeds to address this gap by providing the first CA within the Lean literature. This is also the most comprehensive known CA within the field of Operations and Supply Chain Management more generally. As a consequence of this analysis, previously unknown patterns and insights into the methodological structure of the Lean literature are revealed.

Keywords Lean literature, Bibliometric analysis, Citation analysis, Publication counting

Paper type Research paper

1. Introduction

Since the term ‘Lean’ entered the management lexicon via Krafcik’s (1988) *Sloan Management Review* paper, the Lean paradigm has become firmly established within the field of operations and supply chain management (e.g. Marodin and Saurin, 2013; Jasti and Kodali, 2014; Samuel *et al.*, 2015). Indeed, the body of literature on Lean has continued to evolve (Hines *et al.*, 2004) from its automotive origins to provide practitioners with implementation advice in a variety of new application domains. This body of material has now achieved a truly massive scale; a crude *Google Scholar* query for publications with the word ‘Lean’ in the title alone (excluding patents and citations) for the period since 1988 yields over 32,700 results. Indeed, there have been fourteen articles published on this topic in *International Journal of Quality and Service Sciences* alone (see for example Crema *et al.*, 2015; Chi-Kuang *et al.*, 2019 and Ingelsson *et al.*, 2020). Lean therefore remains a topical subject for both academics and practitioners.

The systematic review (after Tranfield *et al.*, 2003) of the Lean literature that was conducted at the outset of the study reported upon within this paper identifies that ten systematic reviews of the Lean literature already exist. However, these are all of the publication counting-type (see for example Marodin and Saurin, 2013; Jasti and Kodali, 2014; Hu *et al.*, 2015; Samuel *et al.*, 2015); premised upon simply counting the total number of instances of publication. For example, to identify the most prolific authors or journals in a given field.

Publication counting provides no information about the significance of the scholarly impact and influence of the publications concerned (Peng and Zhou, 2006). The established method for doing so is citation analysis (CA), which has a legacy within operations and supply chain research but which currently represents a gap within the Lean literature. CA involves an evaluation of the number of times that researchers cite a particular published work in the reference list section of their published work (Aguinis *et al.*, 2014) and is based upon the premise that a publication’s frequency of citation is an indicator of its importance, impact and influence within its field of study (Pilkington and Meredith, 2009). As such, CA is therefore by nature a simple technique that does not utilise sophisticated statistical calculations nor tests.

The purpose of the study reported upon in this paper is to draw upon the CA approach to help analyse and evaluate the methodological structure of the Lean literature so that its characteristics and influence among academics and practitioners might be better understood. We define ‘*methodological structure*’ to be comprised of six categorical components: publication category, degree of methodological disclosure, research strategies, data collection instruments, type of data collected & analysed, and type of research informants. Ten synonym search phrases for “Lean” are applied to the source population articles on Lean within *Google Scholar*; the world’s most extensive bibliometric search and indexing database. These articles are then filtered and distilled into a focal population set (FPS) of the 50 most highly cited publications on Lean (see *Appendix A*); collectively representing over 52,000 citations. Once this FPS is identified its methodological structure is systematically analysed using both citation analysis and publication counting to uncover previously unknown patterns and insights within the six categories above.

The paper starts with a review of bibliometric approaches used within the operations and supply chain literature to contextualise the standard CA method and its

limitations. This also includes a systematic review of the application of bibliometric approaches within the Lean literature. We then elaborate upon and justify the CA-based methodology employed to achieve the research objective stated above. Next, we present the results obtained using this methodology. Lastly, we detail the conclusions, limitations of the study, and proposed agenda for future research.

2. Literature review

2.1 Bibliometric approaches within operation and supply chain research

Undertaking a literature review is an important feature of any research project, during which the researcher both maps and assesses the relevant intellectual territory in order to identify knowledge gaps to be addressed for the further development of the knowledge base (Tranfield *et al.*, 2003). The most common type of such review is a subjective, qualitative critique (after Pilkington and Fitzgerald, 2006). Tranfield *et al.* (2003) classify these to be of a 'narrative' type, which they criticise for being descriptive, lacking in critical assessment, and exhibiting the implicit biases of the researcher. To redress these issues and present a more objective view, these authors suggest that literature reviews should be evidence-informed and modelled upon the replicable and transparent process used in the medical sciences. They classify these as 'systematic reviews', and drawing upon the work of Cook *et al.*, (1997), suggest that they should aim '*to minimize bias through exhaustive literature searches ... providing an audit trail of the reviewers decisions, procedures and conclusions*' (Tranfield *et al.*, 2003, p.209).

Bibliometric studies are perhaps the most widely used form of systematic review, and involve the quantitative analysis of literature (Peng and Zhou, 2006; Pilkington and Fitzgerald, 2006), with the publication-counting and CA methods summarised in the previous section being the most commonly encountered approaches. CA research is firmly established within the wider management literature (see for example Di Benedetto *et al.*, 2018 and Sarin *et al.*, 2018), and also has a legacy within the operations and supply chain management fields. Biehl *et al.* (2005) for example conducted a large-scale CA of 31 'top management journals' as defined by the Financial Times list of top journal outlets to establish how top journals in various academic disciplines relate to one-another. These included some journals drawn from Operations Management. Likewise, Pilkington and Meredith (2009) applied both CA and CCA to all of the papers published between 1980-2006 in the three oldest OM journals (JOM, POM and IJOPM) to reveal the intellectual structure of the OM field. In a similar vein, Seebacher and Winkler (2013) applied CA to 153 journal papers in order to explore the structure of the research on manufacturing and supply chain flexibility.

However, whilst CA is an established and objective method, it is not without limitations. Aguinis *et al.* (2014) recognise that within CA, each individual citation is considered to have the same ultimate influence within its field. They also make the important observation that the standard CA method is based upon a single stakeholder; the academic. This is because it is researchers within academia who tend to cite the work of others, and are therefore the only stakeholder considered when impact and influence are based upon citations. In a similar vein, Pilkington and Meredith (2009) point out the danger of using citations to make inferences when only the first author rather than all authors of publications are used, and hence missing important contributions and collateral

citations by secondary and later authors. Due to differing naming and citation conventions, they also emphasize the problem of identifying the correct author or publication among sets of such with the same or similar names. By contrast Peng and Zhou (2006) highlight that older publications on average are likely to accumulate more citations, so that CA is more likely to generate a measure of a publication's long-run impact rather than recent influence. Other potential limitations of CA include the inflation of publication citation statistics via author self-citation practices; negative citations (citing a reference as a bad example of practice); and the fact that theoretical, conceptual, methodological review papers tend to attract higher citations than empirical papers (Peng and Zhou, 2006; Biehl *et al.*, 2005; Pilkington and Meredith, 2009).

2.2 *Bibliometric approaches within the lean literature*

A precursor to any systematic study necessitates effective definition of the focal topic. However, 'Lean' is difficult to define. Samuel *et al.* (2015) recognise this issue, and highlight criticism of Lean on the basis of its practitioner-led and atheoretical nature. They find that this is in part due to it transforming into a polymorphic construct; meaning '*... different things to different people, at different moments in time*' (p.1388). They suggest two reasons for this. The first is a lack of common definition within the literature; a diagnosis supported by numerous other authors (see Shah and Ward, 2007; Hasle *et al.*, 2012; Bhamu and Sangwam, 2014; Darlington *et al.*, 2016). Indeed, Bhamu and Sangwam (2014) alone compile 33 different scholarly definitions of Lean, and conclude from these that it can be conceived as a way, process, set of principles, set of tools and techniques, approach, concept, philosophy, practice, system, programme, model or manufacturing paradigm (p.878). Samuel *et al.*'s second reason is that the Lean construct has continued to evolve over time. For example, Schonberger (2008) asserts that Lean manufacturing was well established in the USA in the early 1980s, but was practiced under different names such as 'just-in-time', 'stockless production' and 'zero defects'. Likewise, Hines *et al.* (2004) describe the diffusion of Lean manufacturing practices from the automotive shop floor to other functional areas and other manufacturing and non-manufacturing contexts.

With this polymorphic limitation in mind, we conducted a systematic review (after Tranfield *et al.*, 2003) to identify and characterise existing *systematic reviews* of the Lean literature. It was rationalised that such reviews were most likely to be found in academic journal papers. In order to be comprehensive, ten search queries were applied to each of two source bibliographic databases. The two selected databases were Business Source Premier (BSP) and Scopus. BSP was selected because it claims to be the largest database of business and management journal papers; the category in which most Lean journal papers are likely to reside. Scopus was selected to triangulate the above, and also to identify papers matching the search criteria in non-business and management disciplines. It is the world's largest abstract and citation database of research literature, covering nearly 16,500 journal titles from over 4,000 publishers, of which 15,400 are peer-reviewed journals in the scientific, technical, medical and social sciences.

No date restrictions were applied within the search queries. Search string matches were sought in publication titles. The ten query search strings used were the word "lean" AND one of the exact phrases "literature", "systematic review", "literature review", "literature analysis", "bibliographic analysis", "bibliometric analysis", "citation

analysis”, “lexical analysis”, “content analysis” or “social network analysis”. After duplicates were removed, this exercise yielded over 100 separate papers. These were then screened for relevance. The screening criteria were that the paper had to apply specifically to the Lean paradigm (as opposed for example to Lean *and* Agile), and also had to address this paradigm holistically (as opposed to considering Lean only in the context of a specific industry or application domain). All of the remaining papers were then read to check whether they constituted a systematic type review as conceived by Tranfield *et al.* (2003).

Table I provides a summary of the ten papers identified and provides a number of useful insights for subsequent research design. The most extensive existing review in terms of number of search phrases used, date range *and* resultant data set size is Samuel *et al.* (2015). Whilst these authors used 15 search phrases for their study, all of the others used between one to nine, with an average of between four to five each. Nearly all used the search phrases “lean production”, “lean manufacturing”, “JIT” and/or “Toyota/production system”. Regardless of the previously articulated concern about the atheoretical nature of Lean, the content of the table underlines the prevalence of academic publication types, and particularly the peer-reviewed journal paper, as the source material for existing systematic reviews within this body of literature. In fact, the absence of publication types specifically associated with the practitioner (such as the trade journal) to identify articles for subsequent analysis is a great surprise. With regard to the size of the data sets of such articles, these systematic reviews of the Lean literature vary greatly. Samuel *et al.* (2015) is notable for drawing upon over 4,000, although it is unclear whether this figure is pre or post the application of any filtering protocol. The remainder draw on between 59-546 articles. However, the most important finding highlighted within the table is that all of the existing systematic reviews of the Lean literature are of a publication counting type. Currently, there are no citation analysis (CA), co-citation analysis nor content analysis studies of the Lean literature.

Table I. Summary of systematic reviews of the lean literature

PLEASE INSERT TABLE I HERE.

3. Research methodology

The resultant CA-based study had a two-stage research design. The first stage involved the identification of the most highly cited publications on the Lean paradigm, and in turn contained three process steps. The first of these was to select the bibliographic database that was to host the source population of publications for subsequent descriptive analysis. Any such database needed to provide searchable citation statistics on an individual, un-aggregated publication level. In addition, extensive personal experience of the authors of the Lean literature suggested that many of its most highly cited publications were likely to be books rather than journal papers and other peer reviewed academic sources. It was therefore important to select a database that encompassed the widest range of publication types. Google Scholar (GS) was therefore selected as it is the most extensive indexing source and draws material from publishers, professional societies and university

repositories in a broad range of academic disciplines. In addition to journal papers, conference papers, theses, dissertations, abstracts it also includes books, pre-prints and technical reports. GS therefore encompasses material associated with practitioners as well as academics; thereby partly addressing the concern raised by Aguinis *et al.* (2014) regarding the single (academic) stakeholder focus of the standard CA approach.

Having established the source database, the second step of the research process was to design the search strategy to be used to query it in order to identify relevant publications. Taken in conjunction with lay meanings of the word 'Lean', the polymorphic nature of the Lean concept highlighted by Samuel *et al.* (2015) poses particular challenges to constructing query search phrases that identify the population set of publications that are specific and most pertinent to the Lean paradigm.

Because of the large number of tools and techniques such as 'SMED' and 'kanban' that are associated with the Lean paradigm, the use of such terms within the search queries was rejected as impractical and too deterministic. Drawing upon the Lean synonym search phrases used in the ten previous systematic reviews of the Lean literature that were listed in Table I, ten search phrases were subsequently agreed upon, making it the most comprehensive search strategy of its type. These phrases were: '*Lean manufacturing*', '*Lean production*', '*Lean thinking*', '*Lean management*', '*value stream*', '*Toyota*', '*world class manufacturing*', '*Japanese manufacturing*', '*just in time*' (OR '*JIT*') and '*kaizen*'. All employed an exact phrase match in the publication title, no date restrictions, and were for all publication types (excluding patents, case law and citations). Please note that it was recognised at conception that this search strategy would exclude one of the most highly cited publications on Lean; Womack *et al.*'s (1990) seminal book *The Machine That Changed The World*. However, this was considered an acceptable limitation for the development of an objective and rational search strategy.

The third step was to implement this search strategy, resulting in over 15,500 hits. The detailed results of each query were presented in highest to lowest number of citations per publication sequence, with some queries resulting in thousands of hits. The top 25 most relevant publications for each query were then identified, and the full reference details copied into an Excel worksheet. This entailed reading the abstracts of each publication in sequence to ensure it was *relevant* to the Lean paradigm, until the 25 most highly cited relevant publications were identified. The net result was 250 individual publication reference details contained within ten worksheets. These were then merged and ranked in highest to lowest citation order to identify the focal population set (FPS) of the top 50 most highly cited publications on Lean (*Appendix A*). For each publications in this population, the following fields were captured during this first stage of the process: total citations, reference details (author/s, year of publication, publication title, publication outlet) and type of publication.

Having identified the most influential Lean publication, the second stage of the research design involved enhancing the FPS worksheet with the six additional fields that embodied the methodological structure of the Lean literature. These fields were: *publication category*, *degree of methodological disclosure*, *research strategies*, *data collection instruments*, *type of data collected & analysed* and *type of research informant*. Strict definitions and labels were established for each field/ option. Each FPS publication was then again scrutinised and all content relevant to each field was cut and pasted into the Excel (cell) 'Comment' feature. In an attempt to be as objective and consistent as

possible, this material was used as a point of reference for each of the authors to independently review and code the field content against the definitions established earlier. Lastly, these independent reviews were moderated by the authors to establish the final content for each publication/ field. In the interest of clarity, further details on field coding options are deferred to the relevant point of discussion in the following section, although space constraints curtail the amount of detail that can be provided.

4. Discussion of Findings

The 50 publications in the FPS represent an aggregated total of 52,745 citations. All were either journal papers or books. A surprising number of these were journal papers (n = 36, 72%), accounting for 29,868 (56.6%) of the total citations. However, the most influential publications were books, representing four of the top five and seven of the top ten ranking positions within the FPS; collectively (n = 14, 28%) accounting for 22,877 (43.4%) of the total citations.

Publication Category

The definition of the publication category options for each of the FPS publications was based upon the article classification used by Emerald Group Publishing. These options in summary were *Viewpoint* (content is dependent upon the author's opinion and interpretation; including journalistic pieces); *Research Publication* (the construction or testing of a model or framework, action research, testing of data, market research or surveys, empirical, scientific or clinical research); *Literature Review* (where the main purpose is to annotate and/or critique the literature in a particular subject area); *General Review* (provides a descriptive or instructional overview or historical examination of some concept, technique or phenomenon); *Conceptual Publication* (not based on research; likely to be discursive and cover philosophical discussions; develops hypotheses) and *Case Study* (describes actual interventions or experiences within organizations; may well be subjective and will not generally report on research).

Over half (n=27, 54%) of the FPS publications are *Viewpoints*; with nearly all (12) of the books, and surprisingly nearly half (15) of the journal papers, being comprised of this publication category. These were found to typically be aimed at the practitioner, and focused on why and how to implement Lean. Figure 1 reveals the citation influence of the *Viewpoint* for each of the publication types, which collectively represent 33,071 (62.7%) of the FPS citations. Collectively, the second largest publication category is the *Case Study*, with both of the remaining books and eight of the journal papers conforming to this type. These (n=10, 20%) publications collectively accounted for 6,185 (11.7%) of the citations. The remaining (n=13, 26%) journal papers in the FPS comprised nine *Research Publications*, two *Literature Reviews* and one each *General Review* and *Conceptual Paper*; collectively accounting for 13,489 (25.6%) of total citations. The prevalence and citation influence of the arguably practitioner-centric *Viewpoint* and *Case Study* publication categories within this FPS would seem to support the assertion that the Lean literature is largely atheoretical in nature. This issue is explored further within the following sections.

Figure 1. Citations by publication type/ category

PLEASE INSERT FIGURE 1 HERE

Methodological Disclosure

To further contextualise the FPS prior to the detailed characterisation of its methodological structure, its degree of methodological disclosure was analysed (Figure 2). Three options were coded for this field: *Comprehensive* (contains a chapter/section on the research methodology used and/or justification of the methodology and data collection procedures; including the relationship of these to the findings and conclusions); *Partial* (some reference to methodological considerations, but lack of transparency and/or justification of methodology and data collection procedures); *None* (no research methodology chapter/section nor any meaningful justification of methodology or data collection procedures).

Figure 2. Degree of methodological disclosure by publication type

PLEASE INSERT FIGURE 2 HERE.

Only (n=15, 30%) of the FPS publications had *Comprehensive* methodological disclosure, whilst (n=23, 46%) had *None*. Generally, and unsurprisingly, books exhibited less methodological disclosure than journal papers. The single book with *Comprehensive* disclosure was a *Case Study* based publication, whereas all nine books with a disclosure of *None* were *Viewpoints*. By contrast the 14 journal papers with *Comprehensive* disclosure encompassed most (n=8) of the *Research Publications*, three *Case Studies* and both of the *Literature Reviews*. However, 14 journal papers were also found to have no meaningful methodological disclosure, and all were *Viewpoints*. Of the eight remaining partially disclosed publications five were *Case Studies* and one each were a *Viewpoint*, *General Review* and *Research Publication*. When considered from the perspective of citations, nearly twice as many were attributable to Lean publications with no methodological disclosure (27,517, 52.2%) compared to those with *Comprehensive* disclosure (14,431, 27.4%).

Whilst recognising the subjective nature of this exercise, we would argue that the moderated procedures adopted to establish the objective and consistent coding of the degree of methodological disclosure make this field a useful proxy for methodological rigour. If so, the findings suggest that the Lean literature is in general methodologically weak, with the methodological rigour of the population of journal papers being particularly disconcerting.

Research Strategies

Many writers such as Burrell and Morgan (1979), Stoecker (1991) and Yin (1994) have differentiated between ‘research strategy’ and ‘data collection instrument’ (DCI). The authors therefore interpreted research strategy to mean the higher order methods after Yin’s (1994) definition: “[comprising] an all-encompassing method – with the logic of

design incorporating specific approaches to data collection and analysis” (p.13). Having established this guiding definition, a number of impediments were encountered to the consistent coding of the research strategy field options. For example, the terms ‘survey’ and ‘questionnaire’ were often used interchangeably within the FPS publications. The authors consequently standardised on the use of ‘survey’ as a research strategy option and ‘questionnaire’ as a DCI. Likewise, the term ‘case study’ was found to be used with great inconsistency, with FPS publications entitled as such instead found to be comprised of interviews, observations or a process mapping exercise. Again, the authors turned to Yin (1994) and used his definition of a case study as a guide for consistently coding this research strategy option: “[a case study is] an empirical enquiry that investigates a contemporary phenomenon within its real-life context ... in which multiple sources of evidence are used” (p.23). Because of the application context this definition differs from that used to code the *Publication Category*, hence explaining the discrepancy between the number of publications categorised using the label ‘case study’ between Figure 1 and the following.

Figure 3 reveals that the research strategy of half (n=25, 50%) of the FPS, equating to 31,630 (60.0%) citations was *Unknown*. The great majority (n=24) of these publications were *Viewpoints*, although it should be pointed out that the research strategies of three of the *Viewpoints* were disclosed; albeit all *Partially*. For the remaining publications whose research strategies were disclosed, the *Case Study* was the most influential. Of these eight publications, half were of single case studies and half were of multiple case studies (with two publications containing three, one of four and one of six comparative cases). Seven of these publications defined the case as a single unit of analysis at the individual firm or plant level, whilst the eighth was a multiple unit of analysis case of a production network. The second most influential research strategy was the *Survey*.

Figure 3. Citations by research strategy

PLEASE INSERT FIGURE 3 HERE.

Data Collection Instruments

In contrast to the higher-order research strategies discussed in the previous section, the authors defined a DCI to be an individual technique or source of evidence. Indeed, (n=24, 48%) of the publications did not disclose details of the DCI used and are hence coded as *Unknown*. Of the remainder of the FPS, (n=12, 24%) deployed a single DCI whilst (n=14, 28%) deployed multiple DCIs (seven publications used two DCIs, six publications used three and one used four). Citation data is therefore precluded from Figure 4 as it would be misleading. In the interest of consistency, the following standard field option labels were mapped on to disclosed FPS descriptions: *Interview* (unstructured, semi-structured, structured, in-depth, seminar, workshop); *Questionnaire*; *Document Analysis* (secondary sources, historical and contemporary documents, archival documents); *Observation* (participant, plant visits); *Database Analysis* (of environmental or bibliographic databases); *Mapping* (‘Learning to See Map’ after Rother & Shook, 1998) and *Simulation*.

Of those publications for which it was possible to determine their applied DCIs, the *Interview* was the most frequently deployed technique. Given the emphasis on ‘gemba’ within the Lean paradigm it was surprising to find that three times as many publications drew upon the *Questionnaire* (n=12) compared to *Observation* (n=4). Likewise, it was also surprising to find only one publication utilising *Mapping* as a DCI.

Figure 4. Type of data collection instrument by number of FPS publications

PLEASE INSERT FIGURE 4 HERE.

Type of Data Collected & Analysed

Taking the findings from the analysis of the research strategies and DCIs collectively, it is possible to gain yet further insight by categorising the type of data collected & analysed as a product of these methods. Only nine publications were categorised by the authors as concerning themselves exclusively with *Quantitative* data. Their 6,292 collective citations represent 11.9% of total FPS citations. By comparison, 12 publications representing (11,265, 21.4%) were categorised as exclusively *Qualitative* and six publications representing (7,407, 14.0%) were categorised as genuinely *Mixed Methods*. These findings highlight the predominantly qualitative nature of the Lean literature.

Type of Research Informant

The research informants were the actual people from whom data was collected using the previous research strategies and DCIs. Again, a large proportion (n=26, 52%) of the publications were found to provide no disclosure of the informants used and are hence coded as *Unknown* (Figure 5). Likewise, many of the remaining FPS publications used multiple types of informant; again precluding the inclusion of citation data within the figure. To compound matters, many of the (n=24, 48%) of the publications that *did* disclose the nature of their research informants did so using vague terms; necessitating a high degree of interpretation. For example the terms ‘Managers’ and ‘Employees’ were encountered relatively frequently. As a consequence, the following standard field option labels were developed and used: *High Level Mgr* (Director, Executive); *Mid Level Mgr* (Plant/ Production Manager, Managers); *Shop Floor* (Supervisor, Team Leader, Shop Floor Worker, Employee); *Trade Union* (Shop Steward, Convenor, Representative, Member); *Engineer* (including Chief Engineer); *Support Staff* (Administrator, Clerical, Purchasing) and *Other* (non-company informant or secondary sources).

Figure 5. Type of research informant by number of FPS publications

PLEASE INSERT FIGURE 5 HERE.

The most interesting finding revealed in the above figure is the emphasis (n=23) on *High and Mid Level Managers* as informants within Lean research. By contrast, *Shop Floor* informants appear in only approximately as third as many (n=8) publications; and even the *Shop Floor* and *Trade Union* informants combined represent less than half (n=11) the combined management figure. This represents a dichotomy as the Lean paradigm has traditionally placed an emphasis on the shop floor ('gemba') and production line operator as both the source and focus for process improvement activities (Womack and Jones, 1996; Imai, 1997; Rother and Shook, 1998), yet the Lean literature instead prefers to solicit the management hierarchy as its source of information.

5. Conclusions and future research opportunities

This study is a bibliometric analysis of the Lean literature. It utilised ten synonym search phrases for Lean over a source population of over 15,500 Google Scholar publications to yield a FPS of 50 of the most influential publications on lean; collectively representing over 52,000 citations. Both citation analysis and publication counting are used to analyse patterns in the publication category, degree of methodological disclosure, research strategies, data collection instruments, type of data collected & analysed and type of research informants manifest within this sample of the literature.

As a first contribution, this study conducted the most comprehensive and extensive known systematic review (after Tranfield *et al.*, 2003) of systematic reviews on the topic of Lean. Ten search phrase queries were applied to both BSP and Scopus. This exercise yielded over 100 separate papers. After screening for relevance, only ten 'true' systematic reviews (*op cit.*) were revealed (Table 1). Further analysis of these papers established that all were of a publication counting type. There were no existing CA, co-citation analysis nor content analysis studies on the Lean literature; identifying gaps for a potentially fertile future research agenda.

The second contribution of this paper is the revelation of previously unknown patterns and insights in the methodological structure of the Lean literature. Conducted in response to the identification of the first gap (above), this study is the first application of CA within Lean. The resultant methodology is again also the most comprehensive and extensive known study of its type-not only within Lean, but also within the field of Operations and Supply Chain Management more generally. We found that all the most highly cited (hence influential) Lean publications contained within the FPS were either books or journal papers. Many academics claim that the Lean literature is atheoretical in nature, so it was surprising to find that such a high proportion (72%) of these were journal papers. However, four of the top five and seven of the top ten most highly cited publications were books.

Over half (54%) of the FPS publications were uncritical *Viewpoints* that were based upon the author's opinion and interpretation, with nearly all of the (highly influential) books falling into this category. Most of these Viewpoints were methodologically opaque. Indeed, only 30% of the FPS publications had *Comprehensive* methodological disclosure in comparison to 46% that had *None*. If the citation influence

of these comparators is considered, only 27.4% of the citations refer to Lean publications with *Comprehensive* disclosure compared to 52.2% with *None*. The evidence therefore supports the assertion that the Lean literature is largely atheoretical in nature and also that it is in general, methodologically weak. **Given the large and indisputable influence that these publications have exerted among both practitioners and academics alike, this raises challenges for researchers to better understand the raison d'être for such influence.**

Other interesting patterns were also revealed. For example, of those publications for which it was possible to discern relevant information, it was found that the *Case Study* followed by the *Survey* were the most prevalent and influential research strategies. In terms of data collection instruments the *Interview* followed by the *Questionnaire* were the most frequently deployed types, with *Observation* and *Mapping* being surprisingly infrequent. Consequently, when the type of data collected & analysed was evaluated it was found that only nine publications representing 11.9% of total citations could be categorised as being concerned exclusively with *Quantitative* data; highlighting the predominantly qualitative nature of the Lean literature. The last notable finding concerned the type of research informants utilised within the Lean literature, as *High Level* and *Mid Level Managers* are encountered nearly three times more frequently than *Shop Floor* informants as sources of evidence. This is counter-intuitive for a paradigm that places an emphasis on the shop floor ('gembu') as both a source and focus for process improvement activities. **More primary research involving the soliciting of the activities, perceptions and opinions of shop floor informants must surely represent an opportunity to extend the boundaries of knowledge within the mature field of lean research?**

The CA method used to identify the FPS for this study did mitigate a number of the limitations of the standard CA approach. However, a number of methodological limitations do remain. These include an ongoing concern regarding the omission of relevant publications due to a non-exhaustive database search strategy. Also, the inherent underlying reliance of all CA approaches on accurate referencing discipline by authors within their publication reference lists.

Notwithstanding these limitations, considerably more insight into the intellectual structure of the lean literature is promised. An obvious starting point for future research is to expand the size of the FPS to help provide greater confidence in the findings, with the researchers currently working to expand the FPS to the 250 most highly cited Lean publications. Deeper insight might also be sought. An informative study would be to code the faculty/ school of every contributory author of every FPS publication to evaluate the level and influence of multi-disciplinary research within the lean literature (for example, collaborations between Business and Engineering schools). Likewise, to analyse the industry/ sector and geographical application domains discussed within lean publications and use a bibliometric approach to map objectively for the first time the diffusion of the lean paradigm through these domains. A similar study would be to evaluate the diffusion and pattern of usage of the Lean synonym phrases themselves over time; this being of potentially high utility to academics working within the field. Other gaps in the lean literature identified by our study promise additional fruitful research opportunities. These include co-citation analysis to better understand the relationships that exist between publications cited together within the lean literature. Also, to conduct a content analysis of the FPS articles to better understand the way in which fundamental lean constructs such as 'value' and 'flow' are conceived and communicated within such

influential material. We therefore hope this study marks the start of this exciting research agenda.

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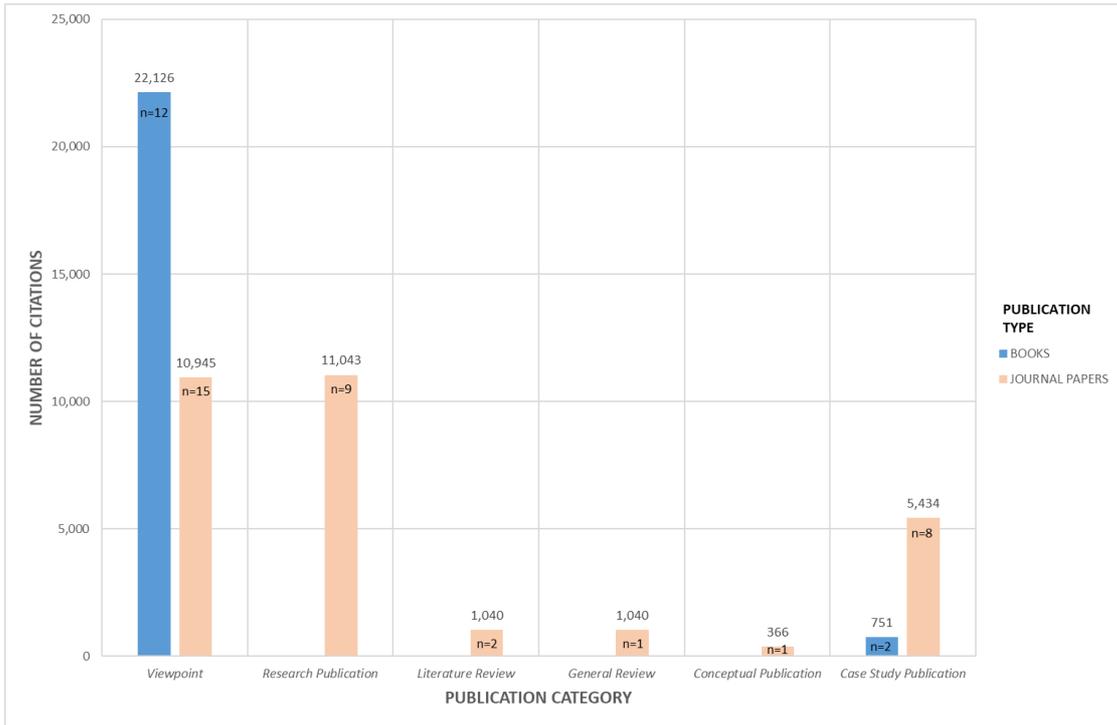
APPENDIX A – Top 50 Most Highly Cited Lean Publications

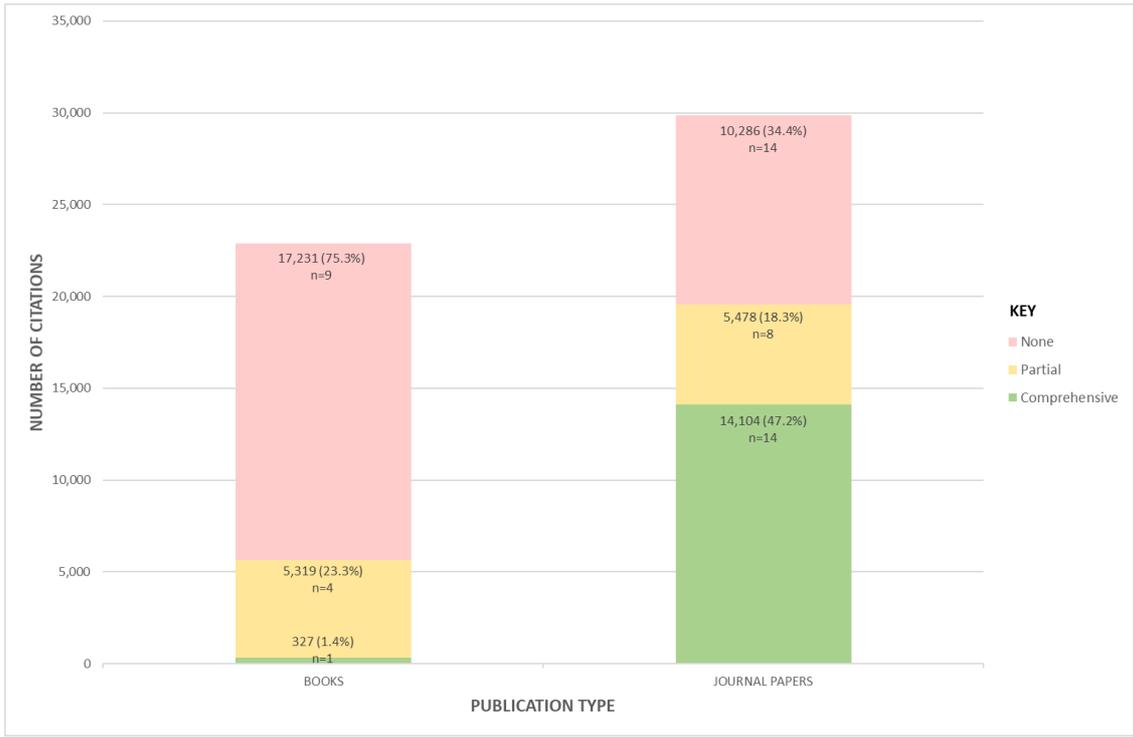
The first stage of the research programme reported upon within this article distilled a focal dataset of the 50 most highly cited publications on Lean. These are summarised in table A1.

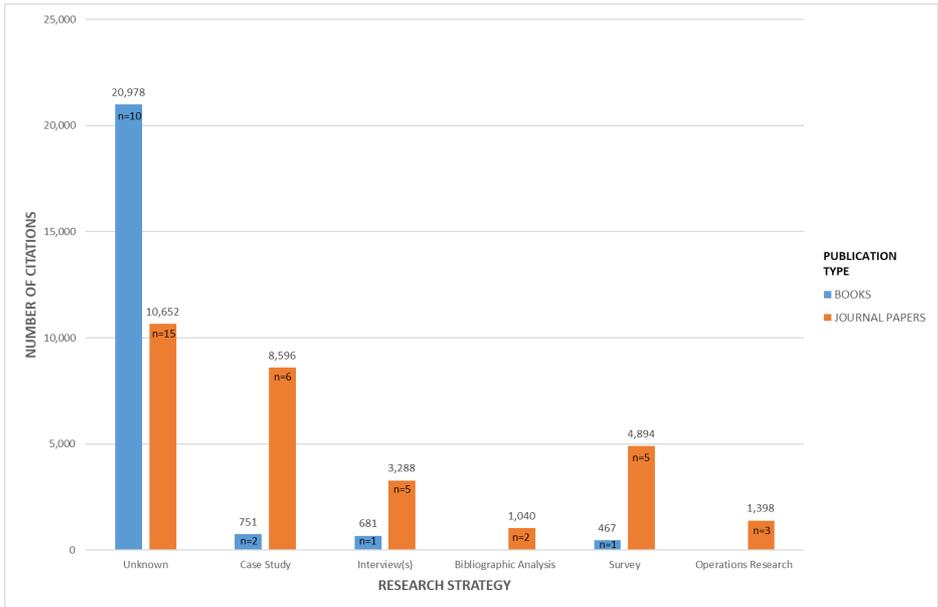
Table A1. Top 50 most highly cited publications on Lean

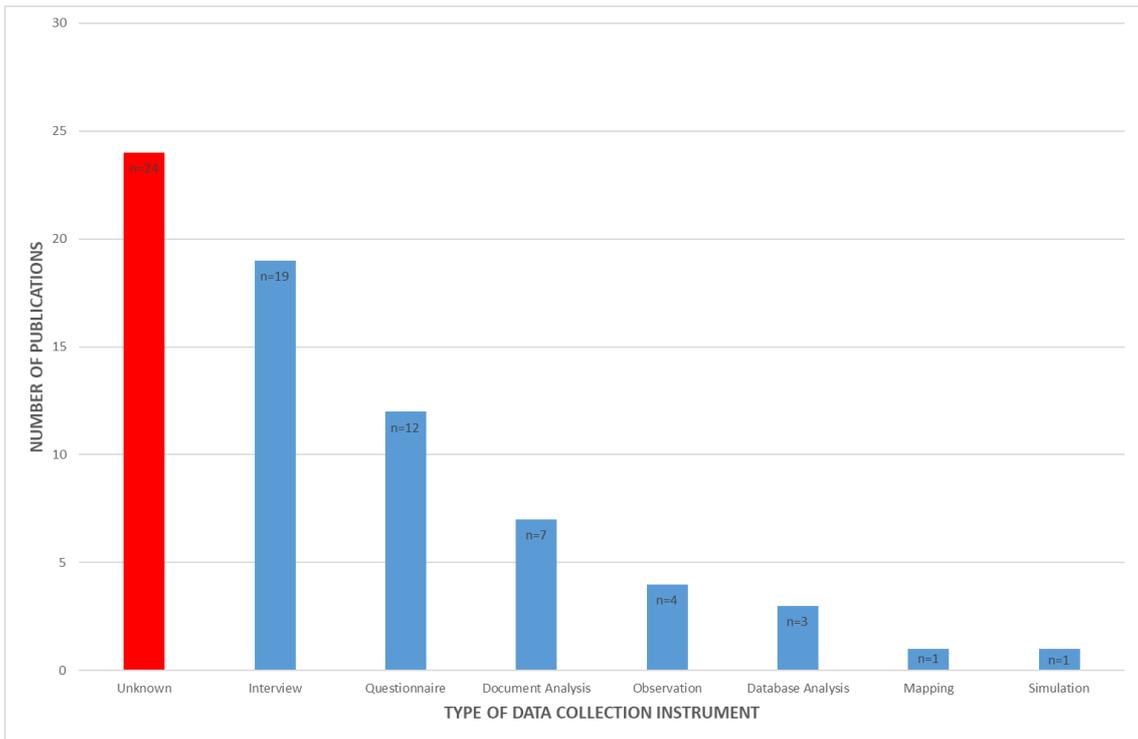
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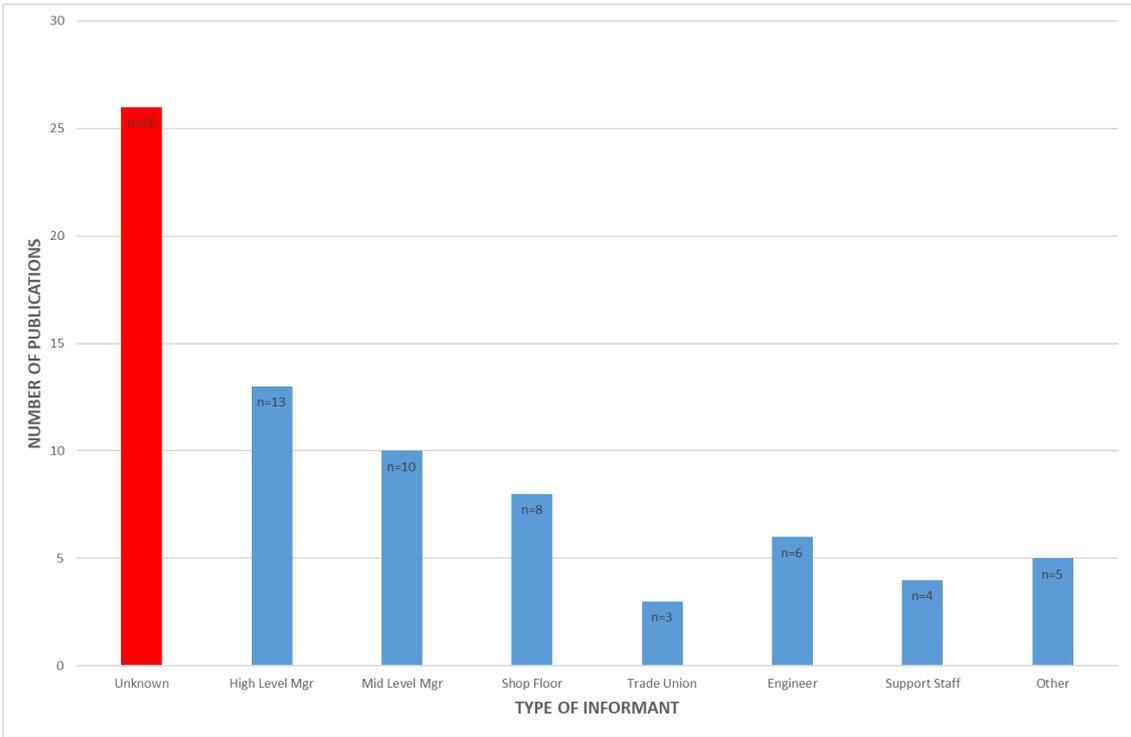
DATABASE SEARCH QUERY DETAILS								
Authors	Search Phrases (#)	Date Range	Publication Types	Data Set Size (# articles)	PC?	CA?	CCA?	Content Analysis?
Psomas and Antony (2019)	N/D	2005 – 2016	<i>Peer reviewed academic journals</i>	120	Y	N	N	N
Danese <i>et al.</i> (2018)	1	Jan 2003 – Dec 2015	<i>Academic peer reviewed journals</i>	240	Y	N	N	N
Garza-Reyes (2015)	4	1997-2014	<i>Peer reviewed articles in journals or international conferences</i>	59	Y	N	N	N
Hu <i>et al.</i> (2015)	3	-Feb 2015	<i>English only scholarly journals, Trade journals</i>	101	Y	N	N	N
Jasti and Kodali (2015)	9	1988-2011	<i>Journal papers</i>	546	Y	N	N	N
Samuel <i>et al.</i> (2015)	15	1987-2013	N/D	4,130	Y	N	N	N
Curatolo <i>et al.</i> (2014)	3	N/D	<i>Academic peer-reviewed journals (in English and French)</i>	267	Y	N	N	N
Jasti and Kodali (2014)	6	1990-2009	<i>Empirical research articles</i>	178	Y	N	N	N
Marodin and Saurin (2013)	1	1996-2012	<i>Scientific papers in international peer-reviewed journals</i>	102	Y	N	N	N
Suarez-Barraza <i>et al.</i> (2012)	1	-Dec 2009	<i>[Most were] peer reviewed journal papers (in English)</i>	172	Y	N	N	N











TOTAL			Publication Type	AVG. PER ANNUM	
Rank No.	Citations (#)	Authors		Rank No.	Citations (#)
1	7,597	Womack and Jones (1996)	Book	3	380
2	5,049	Ohno (1988)	Book	7	180
3	4,365	Liker (2005)	Book	2	397
4	3,848	Dyer and Nobeoka (2000)	Journal Paper	4	241
5	3,817	Imai (1986)	Book	8	127
6	2,378	Schonberger (1982)	Book	23	70
7	2,219	Seth and Gupta (2005)	Journal Paper	6	202
8	2,011	Monden (2011)	Book	1	402
9	1,803	Schonberger (2008)	Book	5	225
10	1,593	Shah and Ward (2003)	Journal Paper	10	123
11	1,577	Shingo (1989)	Book	25	58
12	1,506	Rother and Shook (1998)	Book	11	116
13	1,440	Spear and Bowen (1999)	Journal Paper	17	85
14	1,417	Naylor <i>et al.</i> (1999)	Journal Paper	18	83
15	1,285	Adler <i>et al.</i> (1999)	Journal Paper	21	76
16	1,227	Head <i>et al.</i> (1995)	Journal Paper	25	58
17	1,138	Hines <i>et al.</i> (2004)	Journal Paper	14	95
18	1,115	Shah and Ward (2007)	Journal Paper	9	124
19	1,098	Krafcik (1988)	Journal Paper	41	39
20	1,052	Sugimori <i>et al.</i> (1977)	Journal Paper	64	27
21	947	Holweg (2007)	Journal Paper	13	105
22	928	Maskell (1991)	Book	43	37
23	925	Cua <i>et al.</i> (2001)	Journal Paper	24	62
24	847	Frazier <i>et al.</i> (1988)	Journal Paper	52	30
25	841	Hines and Rich (1997)	Journal Paper	35	44
26	808	Fujimoto (1999)	Book	33	48
27	808	Sewell and Wilkinson (1992)	Journal Paper	46	34
28	785	Kester (1986)	Journal Paper	71	26
29	774	Marston (1990)	Journal Paper	52	30
30	771	Morgan and Liker (2006)	Book	20	77
31	733	Abdulmalek and Rajgopal (2007)	Journal Paper	19	81
32	727	Ward <i>et al.</i> (1995)	Journal Paper	45	35
33	725	Liker and Meier (2006)	Book	22	73
34	684	Goto and Suzuki (1989)	Journal Paper	75	25
35	651	Flynn <i>et al.</i> (1995)	Journal Paper	49	31
36	594	Davies (2004)	Journal Paper	31	50
37	561	King and Lenox (2001)	Journal Paper	43	37
38	545	Karlsson and Ahlstrom (1996)	Journal Paper	64	27
39	516	Schonberger (2010)	Book	16	86
40	511	Miltenburg (1989)	Journal Paper	92	19
41	505	Kannan and Tan (2005)	Journal Paper	34	46
42	503	Bruce <i>et al.</i> (2004)	Journal Paper	39	42
43	501	Dahlgaard and Dahlgaard-Park (2006)	Journal Paper	31	50
44	493	Landsbergis <i>et al.</i> (1999)	Journal Paper	56	29
45	493	Cusumano and Nobeoka (1998)	Book	64	27
46	492	Dennis (2007)	Book	28	55
47	473	Arnheiter and Malayeff (2005)	Journal Paper	37	43
48	472	Woodward (1992)	Journal Paper	87	20
49	468	Sakakibara <i>et al.</i> (1997)	Journal Paper	75	25
50	446	Srinivasan <i>et al.</i> (1994)	Journal Paper	87	20