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Author and institution Citation Analysis of the Lean Literature

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Abstract: The lean paradigm is now firmly established within the field of operations and SCM. However, even though a large number of narrative reviews exist on this topical body of material, no citation analysis (CA) has yet been conducted. This paper presents the first CA of the lean literature, and also represents the most extensive known CA study within the wider field. It uses ten search phrases over a source population of over 15,000 Google Scholar publications. These are filtered into a dataset of the 241 most highly cited publications on lean that account for an aggregated total of 98,829 citations. The research reveals a surprising degree of influence of academics within the supposedly a theoretical lean literature. US institutions dominate, with MIT being the most influential. Both practitioners and management consultants almost exclusively co-authoring with their own type. Japan has the second largest number of management consultant authors after the USA.

Keywords: citation analysis; lean production; literature; bibliometric analysis

Introduction

It has been 30 years since the term 'lean' entered the management lexicon via Krafcik's (1988) *Sloan Management Review* paper and over 20 years since the publication of Womack and Jones' (1996a) seminal book on the application of the lean paradigm. In the intervening period the topic of lean has become firmly established, especially within the field of operations and supply chain management, with numerous scholars highlighting the level of ongoing interest in this topic among both the academic and practitioner communities (e.g., Marodin and Saurin, 2013; Jasti and Kodali, 2014; Samuel et al., 2015). Indeed, in this period of time, lean has diffused to become the de facto operating norm in many industries. For example, a visit to production or supply chain firm operating in the automotive, aerospace or grocery sector in the UK would reveal the widespread application of lean principles, practices and terminology. As a consequence of this diffusion the body of literature on lean has continued to evolve (Hines et al., 2004) to document new application domains, and to provide practitioners with implementation advice. It has now achieved a massive scale; a *Google Scholar* (GS)query for publications with the word 'lean' in the title (excluding patents and citations) for the period since 1988 yields over 25,300 results. Lean therefore remains a topical subject to both management practitioners and academics.

As a body of literature evolves and expands, it is useful to analyse the influences upon it (Peng and Zhou, 2006). 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 17 significant reviews of the lean literature already exist. Nine of these are narrative literature reviews (*op cit*.) of lean tools, techniques and principles. The remaining eight are bibliometric-type reviews. 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 publications produced by top contributors in a field. However, publication counting provides no information about the significance of the scholarly impact of the publications concerned (Peng and Zhou, 2006). Consequently, there is no research on literature influence patterns within the lean literature; representing an important gap in this massive body of material.

The established method for evaluating the impact and influence of literature is citation analysis (CA), which has a legacy within production research with publications in a number of high quality journals (see for example Vokurka, 1996; Pilkington and Fitgerald, 2006; Pilkington and Meredith, 2009). 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), even if this is a negative citation (for citing a reference for reasons of criticism or as an example of bad practice). As such, CA is therefore by nature a simple technique that does not utilise sophisticated statistical calculations or tests.

The first stage of the research programme reported upon within this article involved the first known such CA of the lean literature (Francis et al., 2016, 2017). Within that study a new CA method was developed. This utilised a source population of 15,588 articles on lean that were drawn from GS; the most extensive bibliometric search and indexing database. These articles were then distilled into a focal dataset of the 241 most highly cited publications on lean (see Appendix). These in turn collectively represent 98,829 citations. Drawing upon this focal dataset, this paper details the second stage of that programme. It aims to use CA to address the earlier identified research gap. Again using citation as the measure of influence, it sets out to:

1. analyse the characteristics and influence of different types of author within the lean literature – specifically academics, practitioners and consultants respectively

2. analyse the characteristics and citation influence of the institutions to which the above authors are affiliated.

By addressing these two research objectives, this paper makes the contribution that is inherent to any CA study; namely uncovering previously unknown patterns of influence within the focal (lean) literature. This is the yardstick by which all previously published CA research has been judged. However, given the sheer diffusion and influence of the lean paradigm amongst operations and supply chain practitioners, this study provides valuable insight into the source and nature of what, who and where is most significantly impacting the evolution and application of the lean paradigm. Due to the space constraint inherent in a journal paper, this is of course merely the essential prerequisite for understanding the complex relationship between the advice offered in the lean literature and the resultant economic and human relations consequences of applying this advice in increasingly diverse work settings.

The paper starts with a review of bibliometric approaches used within the operations and supply chain literature to contextualise the legacy of the CA method within this field, along with the limitations of this method. This also includes a systematic review of the application of bibliometric approaches within the lean literature. We then describe and justify the methodology employed to achieve the research objectives stated earlier. Next, we present the results of our CA of the lean literature. Lastly, we detail the conclusions, limitations of the study, and proposed agenda for future research.

2 Literature review

2.1 Citation analysis within operations research

CA research has a legacy within the operations field. For example, Biehl et al. (2005) 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 business disciplines relate to one-another. These included some drawn from Operations Management (OM). Likewise, Pilkington and Meredith (2009) applied both CA and co-citation analysis (where the focus of the study is the relationships that exist between publications that are commonly cited together) to the 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. This amounted to 75,000 aggregated citations. They highlight that Vokurka (1996) used CA to establish the most important journals within OM. They also identified that Pilkington and Liston-Heyes (1999) used both CA and co-citation analysis to analyse IJOPM citations between 1994–1997 in order to plot

the sub-fields of OM, and that Pilkington and Fitzgerald (2006) was an update to this study that drew upon *IJOPM* citations between 1994–2003.

However, whilst CA is an objective method that has a legacy within the OM field, it is not without limitations. Inherently, the citation statistics revealed by CA will represent a snapshot in time. Likewise, the selection of the source database and search strategy will influence the subsequent findings. Drawing upon Garfield (1977), Pilkington and Meredith (2009) highlighted the danger of using data only on the first author citation to make inferences, rather than using data derived from all cited authors. They likewise emphasised the problem of identifying the correct author or publication among sets with the same or similar names derived using differing naming or referencing conventions. Similarly, Aguinis et al. (2014) warn that within CA, each individual citation is considered to have the same ultimate influence within its field. They also observed 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. Other potential limitations of CA include the inflation of publication citation statistics via author self-citation practices and for older publications; negative citations; 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 Lean production

The origins of the lean production paradigm can be traced to the Toyota production system (TPS) pioneered by the Japanese industrial engineer Taiichi Ohno (1988). The term 'lean production' itself was coined by the Massachusetts Institute of Technology researcher John Krafcik whilst working on the International Motor Vehicle Program (IMVP), and entered common management parlance via his 1988 *Sloan Management Review* article. However, the lean production concept was popularised in the best selling management book entitled *The Machine that Changed the World* by Womack et al. (1990), which described the large scale IMVP benchmarking study of the Japanese and western automotive industries (Bhamu and Sangwan, 2014; Jasti and Kodali, 2014). This popularity and influence was subsequently reinforced by Womack and Jones' (1996a) seminal book entitled *Lean Thinking*; which detailed a set of five principles to be followed for an organisation to achieve the status of a 'lean enterprise'. Whilst the lean paradigm has now been in existence for over 30 years and has been discussed extensively within the literature, it has so far eluded a consensus on definition (Shah and Ward, 2007; Hasle et al., 2012; Bhamu and Sangwan, 2014; Darlington et al., 2016). Probably the most commonly encountered definition is the teleological version provided by Womack et al. (1990, p.13): "… compared to mass production it uses less of everything – half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time."

However, Bhamu and Sangwan (2014, p.878) alone compiled 33 different scholarly definitions of lean and concluded from these that lean 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. As a consequence of this lack of common definition, taken in conjunction with the continued evolution of the lean paradigm over time, Samuel et al. (2015, p.1388) warn that the lean paradigm has transformed into a polymorphic construct; meaning "… different things to different people, at different moments in time." They suggest that this issue has contributed to the claims of a number of commentators such as Anderson et al. (1989), Flynn et al. (1990) and Schmenner and Swink (1998) that the lean paradigm is inherently atheoretical in nature.

Clearly, a literature review is an integral feature of every research paper, as the researcher is called upon to develop the focal topic in order to identify the knowledge gaps to be addressed by that article. Pilkington and Fitzgerald (2006) stated that the most common type of such a review is a subjective, qualitative critique. 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 such deficiencies and present a more objective view, these authors suggest that literature reviews should instead be modelled upon the replicable and transparent process used in the medical sciences. They classify these as 'systematic reviews'. With the above considerations in mind, a systematic

review (after Tranfield et al., 2003) was conducted to identify existing systematic reviews of the lean literature. It was deduced that such reviews were most likely to be found in academic journal papers. Eight search queries were consequently applied to each of business source premier (BSP) and Scopus; two of the largest bibliographic databases of business and management journal papers. No date or article type restrictions were applied, although patents, case law, citations and non-English articles were excluded. Search string matches were sought in publication titles, author-supplied keywords OR abstracts. The eight query search strings used were the word 'lean' and one of the phrases 'literature review', 'literature analysis', 'bibliographic analysis', 'bibliometric analysis', 'citation analysis', 'lexical analysis', 'content analysis' or 'social network analysis'. This exercise yielded 98 separate papers. After screening each for relevance, eight papers were identified that utilised a systematic review of at least one bibliographic database (Suarez-Barraza et al., 2012; Marodin and Saurin, 2013; Curatolo et al., 2014; Jasti and Kodali, 2014, 2015; Garza-Reyes, 2015; Hu et al., 2015; Samuel et al., 2015). The most extensive of these reviews in terms of number of search phrases used is Samuel et al. (2015). Whilst these authors used 15 search phrases for their study, all of the others used between one to nine. Nearly all used the phrases 'lean production', 'lean manufacturing', 'JIT' and 'Toyota production system'.

Likewise, these eight reviews used a variety of date ranges within their respective search strategies. Nearly all ended the range at the last complete year prior to the publication of the article. The widest date ranges was used by Bhamu and Sangwan (2014), Jasti and Kodali (2015) and Samuel et al. (2015); all of whom started the range in 1988 – the year of publication of Krafcik's seminal paper in which the term lean entered the management lexicon. As a consequence of the different search strategies employed, the resulting data sets of articles that form the focus of analysis within the eight reviews vary considerably. It is often also unclear whether quoted data set sizes are pre or post the application of any filtering protocol to screen such articles for relevance. The smallest data set is used by Poksinska (2010) at circa 30 articles. The largest data set seems to be that used by Jasti and Kodali (2015) at 546 articles.

One notable finding of the analysis of these eight existing systematic reviews of the lean literature is that *all* employ a simple *publication counting* approach to address their respective research purposes. This typically focuses upon an analysis of the diffusion of lean publications over time or the influence of different journal titles within the focal dataset reported upon within the publication. This approach is exemplified by Jasti and Kodali (2014) who use six search queries to derive a dataset of 178 lean articles drawn from 24 journal titles. The authors then rank these titles according to the number of dataset articles that each supply, and also provide a chronological distribution of the dataset articles over the period 1990–2009. However, notable gaps remain in this mature body of knowledge. These include a lack of empirical data on the influence of different types of author within the lean literature; most notably academics in comparison to practitioners and management consultants. Likewise, there is still a lack of empirical data on institutional influence in terms of type, region (geographic locale) and the contributions from individual institutions. The aim of this paper is to address these omissions.

3 Research methodology

The research programme had a two-stage research design. The first stage involved the identification of the most highly cited publications on the lean paradigm, and had 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; which therefore precluded the selection of a database such as Scopus, Science Direct or Web of Science.

Instead, GS was selected. 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. The choice of search phrases would clearly influence the subsequent publications considered for analysis. Therefore to purposively select a keyword search phrase to 'hit' a known, highly cited lean publication would bias the results and would be methodologically unsound within the CA approach. It is for this reason that Womack et al.'s (1990) seminal book *The Machine that Changed the World* and its greater than 3,300 citations is a notable omission from the resulting dataset. In addition, 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 for being impractical and too deterministic.

The authors therefore decided to utilise the lean synonym search phrases used in the eight previous systematic reviews of the lean literature. Ten search phrases were subsequently agreed, making this 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).

The third step was to implement this search strategy. All queries were executed between 12–16 September 2016. 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 duplicate publication entries removed. This formed a dataset of 241 unique publication reference details; representing an aggregated total of 98,829 citations. For each reference in the dataset, individual field details included the rank position (according to-); total citations; author/s; year of publication; publication title and relevant publication outlet data fields. The second stage of the research design involved enhancing the dataset with the additional data fields necessary to enable the planned evaluation of the lean literature. This exercise entailed two categories of data field coding, which mirrored the two research objectives detailed in the Introduction.

To facilitate the first objective, *author* coding was undertaken. Every individual author who contributed to each publication was itemised within the dataset, then sorted to form a master list of all dataset authors. A manual check was subsequently conducted on authors who shared the same surname and initial. This was to address the perennial CA problem identified by Pilkington and Meredith (2009) regarding author identification due to differing publication naming and citation conventions. Once completed, an author-type ('academic', 'practitioner', 'management consultant', 'journalist' or 'not discernible') was added to each author in the master list. This coding was derived from the author biography information supplied for each publication. The author master list could then be sorted according to any desired criteria. For example, the total number of dataset publications or aggregated citations for every author, in any/all contribution sequence position (from first to eighth contributing author); hence addressing the limitation of the CA method identified by Pilkington and Meredith (2009) regarding a reliance on only first author citation data.

The second research objective necessitated institution coding. In a process that was similar to that above, a master list of the host institutions was derived from the affiliation information supplied for each author within each of the dataset publications. In the interest of consistency, the university rather than faculty,

school or department-level affiliation name was recorded for academic institutions. Once completed, the geographic location (country) of each institution was added, along with its institution type ('academic', 'non-academic' or 'not discernible'). Again, the completed master list could be sorted according to any criteria. For example, to inform the influence of individual institutions or their host geographic regions within the lean literature.

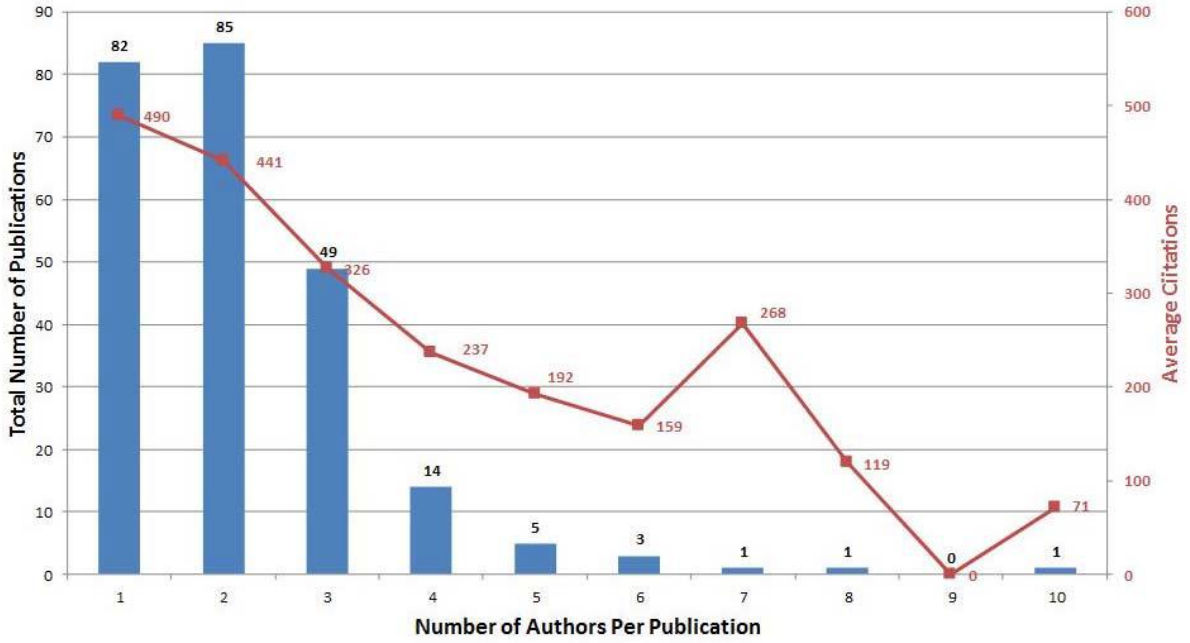
4 Discussion of findings

The results obtained from the execution of the research methodology are organised within this section according to the two research objectives stipulated in the introduction to the paper.

4.1 Author analysis

The 241 publications in the dataset contained 405 distinct contributory authors. These were dispersed across a maximum of ten named co-author sequence positions, amounting to 511 named author instances. Of these distinct authors, 325 (80.3%) were academics. The remaining 80 non-academic authors appeared in 86 of the dataset publications, comprised of 47 (11.6%) practitioners, 36 (8.9%) management consultants and three (0.7%) journalists. Figure 1 summarises the number of named co-authors per publication within the dataset, along with the average number of citations for publications with each of that number of co-authors. It illustrates that 82 (34.0%) were single authored, 85 (35.3%) had two authors, 49 (20.3%) had three authors and 25 (10.4%) had four or more authors. The figure reveals a negative correlation between the number of authors and the citation influence of the associated publications. Indeed, 167 (69.3%) of the dataset publications are either single or double authored, and these account for 77,640 (78.6%) of the aggregated dataset citations.

Figure 1 Number of co-authors per publication



Conventionally, where co-authors exist, citation influence is attributed to the first named author (Pilkington and Meredith, 2009). Table 1 therefore lists the ten most influential authors on the topic of lean as measured by first author citations. They collectively yield 25 (10.4%) of the dataset publications as first author; which in turn account for 41,409 (41.9%) of its total citations.

Table 1 Top ten lean authors by first author citations

Rank position	*Author name*	*Publications (#)*	*Citations (#)*	*Author-type*	*Country*
1	Womack, J.P.	2	7,966	Academic	USA
2	Liker, J.K.	5	5,918	Academic	USA
3	Ohno, T.	2	5,396	Practitioner	Japan
4	Schonberger, R.	4	4,792	Mgt. consultant/ academic	USA
5	Imai, M.	2	4,117	Mgt. consultant	Japan
6	Dyer, J.	1	3,848	Academic	USA
7	Shah, R.	2	2,708	Academic	USA
8	Hines, P.	4	2,344	Academic	UK
9	Seth, D.	2	2,309	Academic	India
10	Monden, Y.	1	2,011	Academic	Japan
	TOTAL	25	41,409		

Based upon the affiliation details declared in each of these authors' publications, the table also details their author-type and country within which their institution is located. Richard Schonberger (1982a; 2008; 2010) is listed with two author-types. This is because three of his publications are books where his biography details identify him as the President of the consulting firm Schonberger & Associates Inc. However, in a fourth publication (Schonberger, 1982b) he is affiliated to the University of Nebraska in the USA. Of the remaining nine authors, seven are academics, one a practitioner and one is a management consultant. In terms of geographical location, the table hints at the influence of US institutions, with half of the leading authors being affiliated to institutions in the USA. Of the remainder, three are in Japan and one each in the UK and India. Heeding Garfield's (1977) warning about making inferences based only upon first author citation, citation data was also analysed for *all* sequence positions per author. By this criterion, the list of top ten lean authors changes. Monden, Seth and Hines disappear from the list, although the relative rank sequence of the remaining authors stays the same. Under this regime the most notable inclusion is the UK academic Dan Jones, who is ranked as the most influential author (8,106 citations) as a consequence of his co-authorship of Womack and Jones (1996a, 1996b) and Oliver et al. (1994). The Japanese academic Kentaro Nobeoka enters the list in sixth position (4,341 citations) due to his co-authorship of Cusumano and Nobeoka (1998) and Dyer and Nobeoka (2000).

The US academic Peter Ward becomes joint ninth ranked with his writing partner Rachna Shah as a consequence of their co-authorship of Shah and Ward (2003, 2007). Please note that in the Research Methodology section we highlighted that the seminal lean book *The Machine that Changed the World* was omitted from the dataset for reasons of methodological integrity. If included, its 3,300+ citations would have further reinforced the status of both Jim Womack and Dan Jones in the above discussion. Reverting to the use of the first author as the basis for citation analysis, Table 2 provides a breakdown of the whole dataset by author-type. It was possible to discern the author-type of 228 of these first authors. The table clearly reveals the degree of influence of academics, who account for over three quarters of both its total publications and citations. Of the 41 publications first authored by non-academics, none are first authored by a journalist (all three journalists acted as second authors). Management consultants account for 26 (11.4%) of the dataset publications and 12,195 (12.7%) of its citations. Practitioners are less influential at this aggregated level, accounting for 15 (6.6%) of the publications and 10,456 (10.9%) of the citations. However, if the average number of citations per publication for each of the author-types is considered, the relationship is inverted; practitioners emerge as the most influential category in the dataset, with academics being the least influential.

Table 2 Author-type performance by first author

Author-type	*Publications*		*Citations*		*Average per publication*
	#	%	#	%	
Academic	187	82.0	73,345	76.4	392
Practitioner	15	6.6	10,456	10.9	697
Mgt. consultant	26	11.4	12,195	12.7	469
Journalist	0	0	0	0	0
TOTAL	228	100.0	95,996	100.0	410

Further analysis of the 187 publications first authored by academics establishes that they tend to collaborate widely, and do not tend to co-author with any specific other author-type. However, 54 (28.9%) of these publications were single authored, accounting for 19,636 (26.8%) of the academic first author citation total. This equates to an average of 364 citations per publication; making academic single authored publications the least influential of the single authored sub-categories (see following).

Table 3 Distribution of co-authorship where first author-type is 'practitioner'

Co-authorship	*Publications*		*Citations*		*Average per publication*
	#	%	#	%	
Single authored	5	33.3	7,101	67.9	1,420
Practitioner and all practitioners	5	33.3	1,851	17.7	370
Practitioner and all academics	3	20.0	1,017	9.7	339
Practitioner and all mgt. consultants	0	0	0	0	0
Practitioner and all journalists	0	0	0	0	0
Practitioner and various author-types	2	13.3	487	4.7	244
TOTAL	15	100.0	10,456	100.0	697

Equivalent co-authorship analysis of the publications with non-academic first authors produces further interesting insights. Table 3 shows the distribution of such co-authorships for the 15 publications that have a practitioner as first author. This again highlights the importance of single authored publications within the lean literature. Indeed, single authored practitioner publications are the most influential sub-category within the whole literature, with the five publications averaging 1,420 citations each; nearly four times the figure for equivalent academic publications. Table 3 also highlights the ghettoisation of lean practitioner publications: there are no practitioner first authored collaborations with either management consultants or journalists. Instead, most frequently (and influentially), the co-authors of such publications are also all practitioners. There is relatively little collaboration with academics. Table 4 shows the distribution of co-authorships for the 26 publications that have a management consultant as first author. Single authored publications are again the most frequent and influential sub-category, representing over 90% of management consultant citations. Further ghettoisation is also in evidence, with the second most frequent and influential sub-category having co-authors are also *all* management consultants. There is likewise little co-authorship with either academics or practitioners.

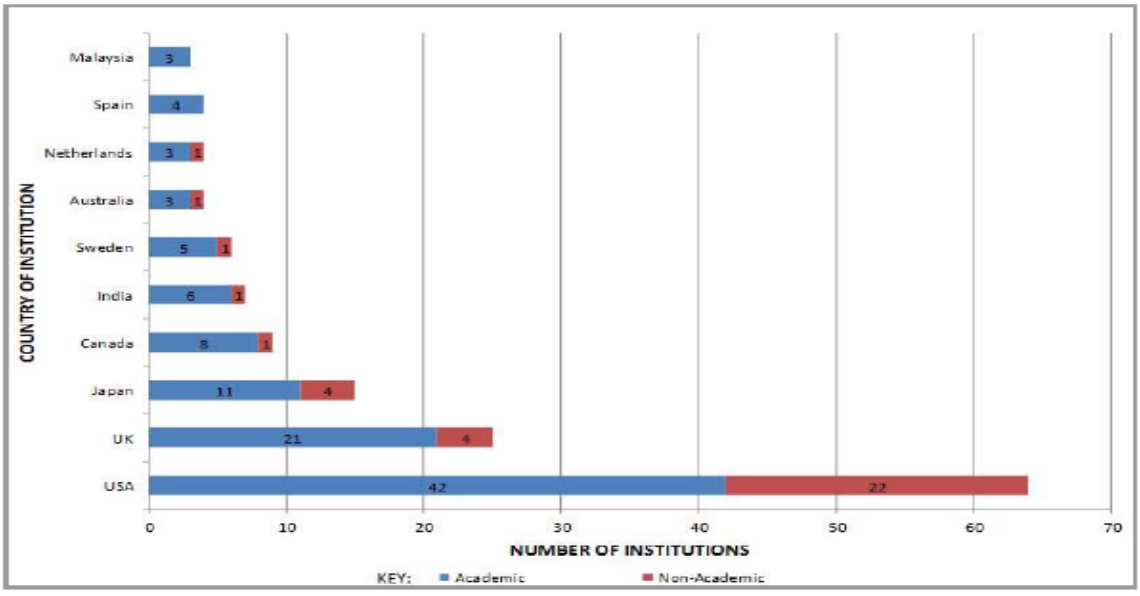
Table 4 Distribution of co-authorship where first author-type is 'management consultant'

Co-authorship	*Publications*		*Citations*		*Average per publication*
	#	%	#	%	
Single authored	16	61.5	10,996	90.2	687
Mgt. consultant and all mgt. consultants	5	19.2	774	6.3	155
Mgt. consultant and all academics	2	7.7	174	1.4	87
Mgt. consultant and all practitioners	1	3.9	101	0.9	101
Mgt. consultant and all journalists	2	7.7	150	1.2	75
Mgt. consultant and various author-types	0	0	0	0	0
TOTAL	26	100.0	12,195	100.0	469

4.2 Institution analysis

Using the methodology discussed in the previous section it was possible to discern the name and type of the host institutions for the authors identified in 230 (95.4%) of the 241 dataset publications; representing 93,966 (95.1%) of the total dataset citations. Within these discernible publications, 218 distinct institutions were identified across all named author sequence positions. Of these, 164 (71.6%) were academic institutions and 54 (24.8%) non-academic. They were distributed across 24 different countries Analysis of the first authors reveals that they are drawn from all 24 countries and are affiliated with 158 of the above institutions; 121 (76.6%) being academic and 37 (23.4%) non-academic. Figure 2 provides a breakdown of the number of institutions of both types per country. Due to space constraints this highlights the top ten of these 24 countries as measured by their total number of constituent institutions. These ten collectively contain 141 (89.2%) of the institutions concerned, with 106 of these being academic and 35 non-academic. Of these, the USA is clearly the dominant country in terms of the proportion of both academic institutions (42 or 39.6%), and especially the non-academic institutions 22 or 62.9%). Unsurprisingly, the UK provides the second largest total of institutions whose staff have contributed to the lean literature, yielding 21 (19.8%) of the academic and four (11.4%) of the non-academic institutions. Japan is ranked third, with 11 (10.4%) of the academic and four (11.4%) of the non-academic totals. What is perhaps more surprising is the relative ranking of the other countries represented within the figure, and likewise the number contributory institutions they contain. The inclusion of Canada with nine institutions is particularly noteworthy.

Figure 2 Top 10 countries by number of first author institutions (see online version for colours)



Whereas the above summarises the number of distinct institutions found in each country, Table 5 summarises their citation influence within the lean literature. Again, the top ten countries are emphasised, and are presented in descending rank order as measured by total citations of first authors at academic and non-academic institutions located within them. Using the method detailed in the previous section, the total number of citations discernible by country was 96,185; a figure that was higher than that attributable to individual institution-types. The influence of the top three ranked countries is particularly notable as they alone yield 84.5% of the total dataset citations (including 81.8% of the academic and 93.2% of the non-academic citations). Also of interest is the ranking of Canada and Sweden in fourth and fifth position respectively, with many academics and practitioners likely to be surprised by the relative influence within the lean literature of the authors/ institutions from these countries. The USA is clearly dominant as measured by the number of citations as well as number of institutions, being responsible for 52,348 (54.4%) of the total. This is over three times as many as the second ranked country. Actually, the USA's academic dominance is even more pronounced, with its institutions accounting for 44,149 (60.2%) of all the academic citations. The second highest ranked country is Japan, with 17,279 (18.4%) of the citations. This position is attributable largely to the influence of Japanese non-academic authors, who are collectively responsible for 12,315 (53.9%) of all the non-academic citations. The UK is ranked third, yielding 11,651 (12.1%) of the total citations. In contrast to Japan, the UK's rank position is attributable to its academic citations; 10,889 (14.9%) being the second highest figure and over twice the equivalent for Japan. The number of non-academic citations for the UK is surprisingly low.

Table 5 Top 10 countries by number of first author citations *Institution country Academic Non-academic Total*

Institution country	*Academic*		*Non-academic*		*Total*	
	#	%	#	%	#	%
USA	44,149	60.2	8,199	35.9	52,348	54.4
Japan	4,964	6.8	12,315	53.9	17,279	18.0
UK	10,889	14.9	762	3.3	11,651	12.1
Canada	3,082	4.2	360	1.6	3,442	3.6
Sweden	2,892	3.9	259	1.1	3,151	3.3
India	2,654	3.6	63	0.3	2,717	2.8
Australia	649	0.9	379	1.7	1,028	1.1
Kuwait	733	1.0	0	0.0	733	0.8
Netherlands	472	0.6	228	1.0	700	0.7
Spain	559	0.8	0	0.0	559	0.6
Others	2,302	3.1	275	1.2	2,577	2.7
TOTAL	73,345	100.0	22,840	100.0	96,185	100.0

The author analysis section discussed author-type performance for the dataset as a whole. Deeper analysis of the publications summarised within Table 5 provides further valuable insight into non-academic author-type performance at the individual country level. Recalling from the previous section that 26 of the publications within the dataset were first authored by management consultants, it was found that 17 (65.4%) of these were from the USA; accounting for 7,051 of the citations. Four (15.4%) of the remaining management consultants were Japanese, making Japan the second largest grouping of management consultants within all of the countries identified. This finding was highly surprising as the contribution of Japanese management consultants to the lean paradigm is given little if any recognition within the existing lean literature. Indeed, driven by Imai (1986, 1999) these Japanese publications account for 4,290 citations; four times the average number of citations per publication of their US counterparts. Of the 15 dataset publications first authored by a practitioner, the two leading countries

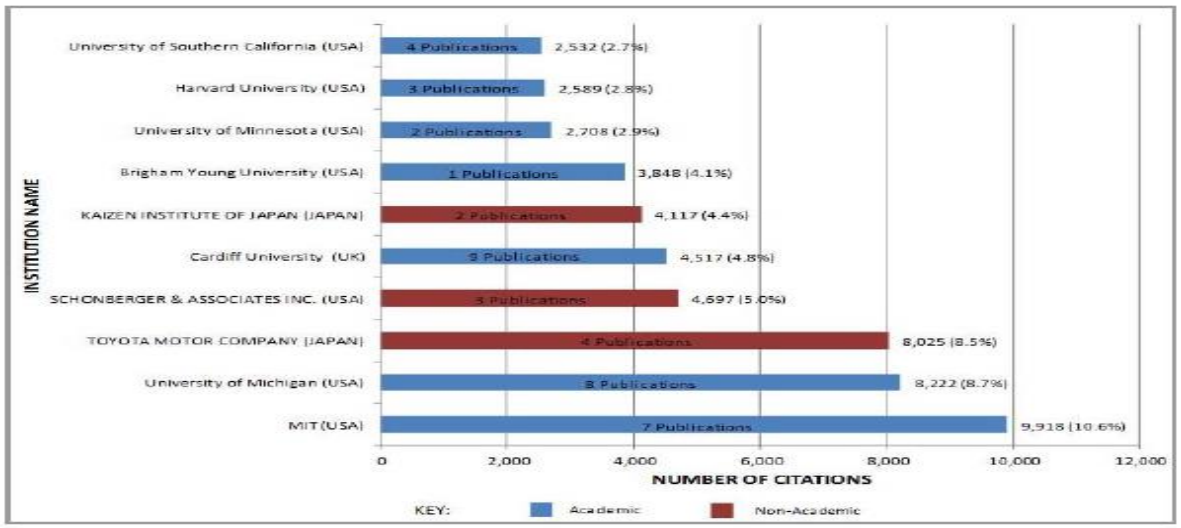
were again the USA and Japan. The USA supplied four (26.7%) of these. Japan also supplied four. However, the Japanese publications are significantly more influential. Driven by the seminal lean publications of Sugimori et al. (1977), Ohno (1988) and Shingo (1989), the Japanese practitioner publications account for 8,025 citations. Having completed the previous analysis, it is also possible to provide some insight into the extent of collaboration in evidence within the lean literature. Table 6 categorises the type of collaboration for the 230 dataset publications for which it was possible to discern the type and geographic locale of the host institutions to which all the contributory authors were affiliated. There are four categories: SIA-single author publication, hence from a single institution and country; MASI-multiple authors, but they are all from the same host institution and hence same country; MISC-multiple authors from different institutions, but all institutions are in the same country; MIMC-multiple authors from different institutions, but these institutions are drawn from at least two separate countries. The prevalence and influence of single authored (SAI) publications within the lean literature was noted earlier, and this is reinforced within the table above. However, the other key feature of this analysis is the relative rarity but high citation influence of multi-national (MIMC)-type collaboration. These 24 publications comprise 19 journal papers and five books, and as a group, represent an average of 759 citations per publication.

Table 6 Geographic collaboration by author-institution

Type of collaboration	*Publications*		*Citations*		*Average per publication*
	#	%	#	%	
Single author/institution (SAI)	78	34.0	37,922	40.4	486
Multiple authors/same institution (MASI)	61	26.5	17,399	18.5	285
Multiple institutions/same country (MISC)	67	29.1	20,436	21.8	305
Multiple institutions/multiple countries (MIMC)	24	10.4	18,209	19.4	759
TOTAL	230	100.0	93,966	100.0	410

To complete the institution analysis, Figure 3 illustrates the ten institutions that have yielded the largest citation influence within the dataset. The chart differentiates between academic and non-academic institution types, and the number of underlying publications is annotated onto each bar. Data labels at the end of each indicate the aggregated number of citations attributable to the first authors affiliated with that institution, along with the percentage of the 93,966 discernible dataset total that each such figure represents.

Figure 3 Top 10 institutions by number of first author citations



These ten institutions yielded 51,173 (54.5%) of these discernible citations. Seven are academic institutions; accounting for 34,334 of the citations. The remaining three non-academic institutions yield 16,839 citations. Unsurprisingly, one of the latter is the Toyota Motor Company (practitioner). However, the remaining two non-academic institutions in the top ten are both management consulting firms. In terms of geographical locale, the USA again dominates, with seven of the ten institutions. Two are Japanese and one is in the UK. The most influential individual institution is MIT, with 9,918 (10.6%) of the citations. University of Michigan is the second most influential with 8,222 (8.7%), and is closely followed by The Toyota Motor Company at 8,025 (8.5%); the highest ranked non-academic institution. Whilst Cardiff University would be ranked first by publication count (nine publications), it falls to fifth position in the above list with 4,517 (4.8%) of the discernible citations. Of course, if the above figure were to be based upon the average number of citations per institution paper within the dataset, then the rankings would change considerably. By this measure the most influential institution would be Brigham Young University, with 1,283 citations courtesy of its single highly cited paper (Dyer and Nobeoka, 2000). The second ranked institution would be the management consulting firm Schonberger & Associates (1,174 citations per publication), whilst the third would be the Toyota Motor Company (1,146 per publication). Cardiff University would rise one position to fourth (1,129 per publication) whilst MIT would drop to fifth (1,102 per publication) in the list.

5 Conclusions

The CA method used for this study utilised ten lean synonym search phrases over a source population of over 15,500 GS publications. These were filtered into a dataset of the 241 most highly cited publications on lean that accounted for an aggregated total of 98,829 citations; making this the most extensive known CA study within production research, and yielded a rich set of findings. Following a systematic review (after Tranfield et al., 2003) of the lean literature, two research objectives were derived to redress current gaps in this mature body of material. Drawing upon the above dataset, the first research objective was to analyse the characteristics and influence of different types of author within the lean literature. With this objective in mind we profiled the number of co-authors per publication; identified the top ten lean authors by citations, author-type and country of affiliation; characterised author-type performance by both publication count and citation, and analysed the distribution of co-authorship by both publication count and citation for academic, practitioner and management consultant first author-types.

The second research objective was to analyse the characteristics and influence of the institutions to which the above authors are affiliated. We consequently profiled the top ten countries by the number of different first author institutions and by both academic and non-academic first author citations. We also analysed the extent of author-institution geographic collaboration evidenced within the lean literature, and profiled its top ten most influential institutions by both publication count and citations; characterising this list by both institution-type and country of location. Given the extent and nature of the findings detailed in the previous section, this study adds significant rather than incremental new insight into the structure and characteristics of the increasingly influential lean literature. As a consequence, it addresses existing gaps in this mature body of material by uncovering previously unknown patterns of influence. This has practitioner as well as academic implications. For example, identifying and signposting the most influential authors and institutions that are promoting the lean tools, techniques and implementation principles that are most significantly impacting the application and evolution of the lean paradigm. Likewise, profiling the extent of regional influence on this body of knowledge. The CA method used for this research addresses 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, and the inherent underlying reliance of all CA approaches on accurate referencing discipline by authors within their publication reference list.

Notwithstanding these limitations, it is important to note that the standalone contribution of this paper should be evaluated as merely the essential prerequisite (bound by space constraints) in understanding the complex relationship between the advice offered in the lean literature and the resultant economic and human relations consequences of applying this advice in increasing diverse work settings.

Considerably more insight into the intellectual structure of the lean literature is promised by further analysis of the dataset articles in subsequent publications. For example, a methodological analysis could characterise the publication categories, nature and type of research strategies, data collection instruments and informants used within this set of most highly influential publications. Such a study would therefore permit an evaluation of the relationships between methodological approaches and rigour, and the resulting influence among academics and practitioners of such publications. Another informative study would be to revisit the institution coding detailed within the Research Methodology section and re-analyse the data at the faculty or school level. This would reveal for the first time the level and influence of multi-disciplinary research within the lean literature (for example, collaborations between business and engineering schools). CA therefore offers the potential to further advance the field of lean research. It also offers similar utility within production research more widely.

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Appendix

The first stage of the research programme reported upon within this article distilled a focal dataset of the 241 most highly cited publications on lean. Due to space constraints, only the top 50 of these are itemised in Table A1.

Rank no.	*Total citations*	*Authors*	*Year*	*Publication title*	*Publication details*
1	6,729	Womack, J.P. and Jones, D.T.	1996, 2010	*Lean Thinking: Banish Waste and Create Wealth in your Corporation*	Simon & Schuster, New York
2	4,751	Dyer, J. and Nobeoka, K.	2000	Creating and managing a high performance knowledge-sharing network: the Toyota case	*Strategic Management Journal*, Vol. 21, No. 3, pp.345–367
3	4,329	Ohno, T.	1988	*Toyota Production System: Beyond Large-Scale Production*	Productivity Press, New York
4	3,747	Liker, J.K.	2005	*The Toyota Way*	McGraw-Hill, New York
5	1,920	Shah, R. and Ward, P.T.	2003	Lean manufacturing: context, practice bundles, and performance	*Journal of Operations Management*, Vol. 21, No. 2, pp.129–149
6	1,804	Naylor, B., Naim, M.M. and Berry, D.	1999	Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain	*International Journal of Operations and Production Management*, Vol. 62, Nos 1–2, pp. 107–118.
7	1,679	Monden, Y.	2011	*Toyota Production System: An Integrated Approach to Just-In-Time*	4th ed., CRC Press: Boca Raton, Florida
8	1,545	Shingo, S.	1989	*A Study of the Toyota Production System: From an Industrial Engineering Viewpoint*	Productivity Press, New York
9	1,520	Adler, P.S., Goldoftas, B. and Levine, D.I.	1999	Flexibility versus efficiency? A case study of model changeovers in the Toyota production system	*Organization Science*, Vol. 10, No. 1, pp.43–68.
10	1,317	Hines, P., Holweg, M. and Rich, N.	2004	Learning to evolve: a review of contemporary lean thinking	*International Journal of Operations and Production Management*, Vol. 24, No. 10, pp.994–1011
11	1,310	Spear, S. and Bowen, H.K.	1999	Decoding the DNA of the Toyota production system	*Harvard Business Review*, September–October, Vol. 77, No. 5, pp.96–106.
12	1,297	Sugimori, Y., Kusunoki, F., Cho, F. and Uchikawa, S.	1977	Toyota production system and kanban system materialization of just-in-time and respect-for-human system	*International Journal of Production Research*, Vol. 15, No. 6, pp.553–564
13	1,286	Shah, R. and Ward, P.T.	2007	Defining and developing measures of lean production	*Journal of Operations Management*, Vol. 25, No. 4, pp.785–805
14	1,259	Rother, M. and Shook, J.	2003	*Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*	The Lean Enterprise Institute, Cambridge, MA.

Rank no.	*Total citations*	*Authors*	*Year*	*Publication title*	*Publication details*
15	1,040	Holweg, M.	2007	The genealogy of lean production	*Journal of Operations Management*, Vol. 25, No. 2, pp. 420–437
16	972	Krafcik, J.F.	1988	Triumph of the lean production system	*Sloan Management Review*, Vol. 30, No. 1, pp. 41–52.
17	950	Hines, P. and Rich, N.	1997	The seven value stream mapping tools	*International Journal of Operations and Production Management*, Vol. 17, No. 1, pp. 46–64.
18	828	Abdulmalek, F.A. and Rajgopal, J.	2007	Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study	*International Journal of Production Economics*, Vol. 107, No. 1, pp. 223–236.
19	779	Davies, A.	2004	Moving base into high-value integrated solutions: a value stream approach	*Industrial and Corporate Change*, Vol. 13, No. 5, pp. 727–756.
20	750	King, A.A. and Lenox, M.J.	2001	Lean and green? An empirical examination of the relationship between lean production and environmental performance	*Production and Operations Management*, Vol. 10, No. 3, pp. 244–256
21	681	Morgan, J.M. and Liker, J.K.	2006	*The Toyota Product Development System*	Productivity Press, New York
22	659	Ward, A., Liker, J.K., Cristiano, J.J. and Sobek II, D.K.	1995	The second Toyota paradox: how delaying decisions can make better cars faster	*MIT Sloan Management Review*, Spring, Vol. 36, No. 3, pp. 43–61.
23	658	Karlsson, C. and Ahlstrom, P.	1996	Assessing changes towards lean production	*International Journal of Operations and Production Management*, Vol. 16, No. 2, pp. 24–41.
24	646	Landsbergis, P.A., Cahill, J. and Schnall, O.	1999	The impact of lean production and related new systems of work organization on worker health	*Journal of Occupational Health Psychology*, Vol. 4, No. 2, pp. 108–130.
25	640	Bruce, M., Daly, L. and Towers, N.	2004	Lean or agile: a solution for supply chain management in the textiles and clothing industry?	*International Journal of Operations and Production Management*, Vol. 24, No. 2, pp. 151–170.
26	583	Liker, J.K. and Meier, D.	2006	*The Toyota Way Fieldbook*	McGraw-Hill, New York
27	522	MacDuffie, J.P. and Helper, S.	2002	Creating lean suppliers: diffusing lean production through the supply chain.	*California Management Review*, Vol. 39, No. 4, pp. 118–151.
28	494	Lewis, M.A.	2000	Lean production and sustainable competitive advantage	*International Journal of Operations and Production Management*, Vol. 20, No. 8, pp. 959–978.

Rank no.	*Total citations*	*Authors*	*Year*	*Publication title*	*Publication details*
29	492	Cusumano, M.A. and Nobeoka, K.	1998	*Thinking Beyond Lean: How Multi-Project Management Is Transforming Product Development at Toyota and Other Companies*	The Free Press, New York
30	464	Spear, S.J.	2004	Learning to lead at Toyota	*Harvard Business Review*, May, Vol. 82, No. 5, pp.78–86.
31	452	Berggren, C.	1993	*Alternatives to Lean Production: Work Organization in the Swedish Auto Industry*	Cornell University Press, Ithaca, NY.
32	421	Dennis, P.	2007	*Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System*	2nd ed., Productivity Press, New York
33	451	Bowen, D.E. and Youngdahl, W.E.	1998	'Lean' service: in defense of a production-line approach	*International Journal of Service Industry Management*, Vol. 9, No. 3, pp.207–225.
34	407	Parker, S.K.	2003	Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics	*Journal of Applied Psychology*, Vol. 88, No. 4, pp.620–634
35	430	Dahlgaard, J.J. and Dahlgaard-Park, S.M.	2006	Lean production, six sigma quality, TQM and company culture	*TQM Magazine*, Vol. 18, No. 3, pp.263–281
36	394	Pettersen, J.	2009	Defining lean production: some conceptual and practical issues	*The TQM Journal*, Vol. 21, No. 2, pp.127–142
37	390	Sako, M.	2004	Supplier development at Honda, Nissan and Toyota: comparative case studies of organizational capability enhancement	*Industrial and Corporate Change*, Vol. 13, No. 2, pp.281–308.
38	387	Arnheiter, E.D. and Maleyeff, J.	2005	The integration of lean management and six sigma	*TQM Magazine*, Vol. 17, No. 1, pp.5–18
39	382	Feld, W.M.	2000	*Lean Manufacturing: Tools, Techniques, and How to Use Them*	CRC Press, Boca Raton, FL
40	366	De Treville, S. and Antonakis, J.	2006	Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues	*Journal of Operations Management*, Vol. 24, No. 2, pp.99–123
41	354	Pavnaskar, S.J., Gershenson, J.K. and Jambekar, A.B.	2003	Classification scheme for lean manufacturing tools	*International Journal of Production Research*, Vol. 41, No. 13, pp.3075–3090

Rank no.	*Total citations*	*Authors*	*Year*	*Publication title*	*Publication details*
42	347	Yang, M.G.M., Hong, P. and Modi, S.B.	2011	Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms	*International Journal of Production Research*, Vol. 129, No. 2, pp.251–261
43	327	Rinehart, J.W., Huxley, C.V. and Robertson, D.	1997	*Just Another Car Factory?: Lean Production and Its Discontents*	Cornell University Press, Ithaca, NY.
44	319	Womack, J.P. and Jones, D.T.	1996	Beyond Toyota: how to root out waste and pursue perfection	*Harvard Business Review*, September–October, Vol. 74, No. 5, pp.140–158
45	312	Liker, J.K. and Morgan, J.M.	2006	The Toyota way in services: the case of lean product development	*The Academy of Management Perspectives*, May, Vol. 20, No. 2, pp.5–20.
46	310	Lincoln, J.R., Ahmadjian, C.L. and Eliot, M.	1998	Organizational learning and purchase-supply relations in Japan: Hitachi, Matsushita, and Toyota compared	*California Management Review*, Spring, Vol. 40, No. 3, pp.241–264.
47	309	Forza, C.	1996	Work organization in lean production and traditional plants: what are the differences?	*International Journal of Operations and Production Management*, Vol. 16, No. 2, pp.42–62.
48	304	Liker, J.K. and Hoseus, M.	2008	*Toyota Culture*	McGraw-Hill, New York
49	303	Melton, T.	2005	The benefits of lean manufacturing: what lean thinking has to offer the process industries	*Chemical Engineering Research and Design*, Vol. 83, No. 6, pp.662–673.
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