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Advancing lean management: The missing quantitative approach

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ABSTRACT

For 25 years, the methodologies employed to study lean management have gone relatively unchallenged. This paper reviews the development of the lean body of knowledge and reveals that the vast majority of research, being qualitative, relied heavily on researcher subjectivity. Quantitative analyses are needed to verify and strengthen existing literature and especially confirm the critical factors for lean success. Various theories requiring validation were identified and studies that incorporate Structural Equation Modelling were proposed. Such studies would advance industry practice, giving the tangible statistical evidence needed for educating practitioners. Practitioners are encouraged to consider the empirical basis of lean publications.

1. Introduction

Lean developed in the Japanese automobile industry as a management strategy. It focuses on continuous improvement at creating value with the elimination of waste [1–4]. Lean management is now applied well beyond its manufacturing roots [5] and said to enhance business practice universally [3]. However, as a popularised management system, it is subject to the lifecycle of a fad; creation, development, and ultimately after time, decline [6].

Whilst being considered the industry standard for systematic productivity improvement [7,8], the success of lean in a large variety of industries is tainted by many failed implementations [9,10] with reports of 60–90% of improvement programs failing [11–13]. Due to this, lean has been labelled in industry as a fad and critiqued for not being applicable beyond mass production [14,15]. Earlier critiques [16–18] have been addressed as misunderstanding lean [4,19] but the question of what successful lean management is contingent or reliant on, is still being raised [20–22]. And whilst outright acceptance of the critiques would neglect the growing number of successful implementations in a wide variety of industries [14,23,24], the high failure rate and disparate views on its benefits and even its definition [25–28] show inadequacies in the body of knowledge. It is not clear what in lean is just fad as opposed to what can be leveraged for truly enhancing business practice.

The purpose of this work was to reassess and recalibrate the direction of lean research, to identify how best to address the inadequacies and thereby advance the body of knowledge. The objective being to identify which scientific approach and specific research-method is best suited to achieving this goal.

Although many studies of lean management have taken place over the past 25 years, the research philosophies and methodologies used in these studies have not been challenged. This is not that the methods used are necessarily wrong, but that other research approaches could have been overlooked or some methods may not have been used to their full potential. Such approaches could strengthen weaknesses in the existing studies, providing further insight and understanding of lean and its success factors. Further research that develops a better understanding of lean and its implementation can be stimulated by identifying the type of questions that need to be asked and the specific approaches that needs to be taken. Ultimately, what is the fad can be separated from what provides true value to organisations.

2. Methodology

This work did not repeat the analysis of contemporary systematic reviews [29–32] but purposed to provide the next step and a definite direction for lean research. To do this, first the body of knowledge and its development were reviewed. Second, the research methods used in its development were critiqued and the core research deficiencies were identified. This critique was heavily supported by existing works including the systematic reviews by Jasti and Kodali [29,30]. Third, and based on the initial findings, an approach to address the gaps in lean research, utilising Structural Equation Modelling (SEM), was proposed. Finally, the specific lean-SEM literature was systematically reviewed and the research findings were expanded on in discussion.

The general literature searches took ‘lean’ as the primary phrase

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combined optionally with 'implementation', 'success', 'manufacturing', 'production' and 'management'. Initially it utilised the engineering focused Ei Compendex database and then Google Scholar for a more inclusive search and citation its index [33,34]. Searches focused on lean literature, post its coining [35] and dissemination [36] with other earlier and related publications incorporated.

The literature reviews were not restricted by industry sector. The roots of lean research are in manufacturing [2,36] and understanding its application by sector is beneficial, e.g. lean service [37], in the public sector [38], in construction [39,40], in transportation [41] in food supply [42], health services [43,44], or in knowledge work [45]. However, it is argued that the lean principles, methods and challenges of change apply across industries [3,24,46,47]. Such that a most recent review of 'lean production' [30] would incorporate articles from multiple service industries.

3. The body of knowledge

In order to understand the shortcomings in lean research it is important to understand how the body of knowledge developed. The lean *body of knowledge* developed solidly in the West from the 1980s, being particularly defined in the '90s by the works of Womack et al. [3,36], interpreting the success of Japanese manufacturing [48]. In this century, the focus has been how to gain and sustain the advantages of a lean management system [4,49,50].

By the late 1970s Toyota had developed a uniquely Japanese production system [2] and it began to be noticed in the west [51,52], along with Japanese management in general [53]. The lean body of knowledge advanced further through the 1980s [1,2,54–57], with documentation, research, and implementation [58]. Early implementations were strong in some places, e.g. in Connecticut due to the local concentration of forward thinking managers [5]. However, the majority of western manufacturers still thought they had little to learn from Japan. They contributed Japanese success to cultural differences, fortune (luck), perceived lower costs, high levels of automation, as well as government orchestration and policies [48]. They were slow to realise that the Japanese had stumbled on a superior management system [19]. The first real success for lean research came from the MIT based International Motor Vehicle Program (IMVP) which finally distilled the term lean [35] and proved its supremacy through case study with clear measures. Their work was disseminated to industry with the book *The Machine that Changed the World* [36]. With further case studies, Womack and Jones wrote another seminal work *Lean Thinking* [3] as a 'how to' for lean, presenting five principles: defining value, mapping the value stream, creating flow and implementing pull unto perfection. From the turn of the century, there have been other good and in-depth studies of Japanese manufacturing, JIT and the Toyota Production System that incorporated empirical research and addressed implementation problems practitioners are facing to truly advance the lean body of knowledge [23,59–63]. The research more recently has responded to the critiques of lean, showing that lean has progressed from a stage of prescription [19] where tools and techniques have typically been prescribed by consultants, to a deeper stage of understanding specific contexts and the needs involved, especially the human aspects [49,64,65] and how the methods should be applied [24,46].

3.1. Lean research methods

To understand how to advance lean research, or where gaps in knowledge exist, it was important to understand not only the knowledge progression but what research methods enabled that progression.

3.1.1. Qualitative case studies prominent

The vast majority of lean research exhibits an interpretivist philosophy. In the best of these studies, qualitative interpretations are made from case studies. Inference from recent systematic reviews by Jasti and Kodali [29,30] showed around 54% of articles took an entirely conceptual or descriptive approach, leaving only 46% with any empirical basis. Half of these empirical works were single case studies, 95% being cross sectional only. Sound quantitative assessment of lean and its success and failure factors was practically nonexistent. Notably a lack of empirical rigor is not a unique or new problem [66].

Case studies have a significant part and have been used extensively from defining lean itself by analysing the Toyota Production System [e.g. 35,36] to discovering factors for lean success [23,48]. According to Thomas [67]:

> Case studies are analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods. The case… provides an analytical frame—an object—within which the study is conducted and which the case illuminates and explicates.

Case studies allow a researcher to see causal relationships unfold in real scenarios and provide vivid examples that practitioners can follow [68]. The methods of gathering data are multifarious and so are the outputs. A researcher immerses themselves in a case seeking observation of particular matters with which to form or confirm hypotheses [67,69]. The collected data may have no recordable value, being very much qualitative. Many variables, such as management styles and cultural considerations, may be difficult to measure quantitatively but observations can be made of their presence and apparent effects, with relevance being intuitively subscribed. Various qualitative methods have been developed and are appropriate for studying lean, including Grounded Theory and Action Research amongst others [70]. Single or repeated survey and other readily available measurement, like financial or production performance, can be incorporated into these studies [45]. The researcher may further develop their own measures as with the seminal International Motor Vehicle Program (IMVP) study [35,36,48]. Researches need access to comprehensive information concerning a case, with its internal and external factors, so that they can draw accurate conclusions and form appropriate mental models of what is observed. The type of case studies reported in lean research vary from personal experiences, e.g. with the conception of the TPS [1,2] and the development of specific aspects like lean accounting [71], to more extensive research programs, e.g. the IMVP [35,36] amongst others [48].

3.1.2. Quantitative methods underutilised

Qualitative case studies and related methodologies [70] fit well with interpreting the complex nature of lean implementation, but appropriate quantitative methods are also available and should be utilised for their specific benefits. A common quantitative approach in managerial sciences is survey accompanied by statistical analysis [72]. From the 1980′s empirical research in operations management increased to improve the fields usefulness and scientific recognition. And by 2002 survey methods accounted for 60% of these empirical works [73]. This approach has been employed in lean research in limited way. Although Jasti and Kodali [29] identified a number of quantitative and survey based empirical works do exist, survey based verification of lean theory only made up 5% of the research [29]. Of these studies, we found only one particularly significant survey based study of the causality of lean success [74] along with a few related studies [10,75–77].

For researchers of a more engineering and less social science bias, it is important to point out that survey based research does not merely involve polling for opinion. It can be used to gather data on specific cases and identify significant correlation and implied causality between factors. Commonly survey questions will be designed for Likert type scalar response, e.g. 'Rate the level of staff morale on a scale of 1–5?'. These scales produce a quantitative value from a somewhat qualitative question. This gives a pragmatic approach to solving real world problems as long as the researcher understands the data and its limitations [78–82].

Various statistical methods can be used to analyse Likert type data. *Pearson's r* correlations and *analysis of variance* [83,84] are common for comparing two or more variables. More advanced methods can be used to uncover key predictors, test relationships and model underlying causality. These include various data mining algorithms, *exploratory factor analysis*, and *structural equation modelling* [85–87].

Survey methods are clearly not the only approaches to gathering or utilising quantitative data. Other forms of experimental research can leverage measured data and has in lean from early stages. For example the International Motor Vehicle Program (IMVP) [37] developed performance comparison measures utilising floor area, component parts and number of spot welds [49]. In that example, quantitative data was being used to support case study research. Large samples of data can also be mined for experimental purposes without surveys e.g. from ERP systems and general Big Data sources [88].

3.1.3. Comparing approaches—qualitative versus quantitative methods

Qualitative methods provide researchers with a rich source of contextual data, not readily available in quantitative works [89,90]. A case study allows the researcher to develop an understanding of the possible causality for an observed effect. However, each case study has an intense requirement on a researcher's time, limiting the number of cases that can be analysed and invariably resulting in small sample sizes. Over generalising from a small sample leads to bias with weakened external validity [91]. Defendants of small or selective samples argue that special cases do occur and their characteristics can be identified, i.e. research need not be so general [92]; and for some cases a sample of one may be sufficient [93]. Nonetheless, understanding case selection and possibility of bias is important [89]. For example, the research for *Lean Thinking* [3] followed 50 exemplary lean cases, leaving a very solid founding for their statements. However regardless of intention and effort, some subjectivity would have unavoidably been present in their selection of cases.

The key advantage of quantitative survey methods is the ease of data gathering and analysis [89,90]. A large sample can easily be gathered by web based survey. Although survey distribution needs to be monitored for bias, a large sample enables a better approximation of an entire population and the ability to easily compare sub-populations. Statistical methods can test theory showing relative effect sizes and gives the confidence of statistical power. However, because of the remoteness of the researcher to the case, these methods can miss important contextual factors. A lack of detail with missing variables or inadvertently neglecting a specific analysis may cause the wrong conclusion or generalisation to be made. Even though a statistically significant correlation is observed and reported, it may just be a secondary effect, removed from actual causality or not addressing a specific subsection of the population or other contingent item. Thus whether the study is qualitative or quantitative, care must be taken in making causal inferences [94,95]. These factors also make it difficult to utilise measures found in ERP and Big Data [88] without the help of further contextual data from survey or case study.

Besides general care in research design and execution, combining the findings from quantitative and qualitative research in various ways and phases is recommended for mitigating these methodological constraints [96,97].

Notably other methods available in lean research include computer modelling, e.g. to analyse a process or supply chain [98,99] and various inductive reconciling and modelling techniques [100]. However the findings from computer or intuitive modelling are withdrawn from reality and not trustworthy for testing of theory [74]. True empirical validation is needed in lean research [30].

3.2. Assessment of the body of knowledge

Positively, the prominent case study approach to empirical lean research has given a rich contextual understanding. Negatively, theses qualitative approaches necessitated the subjective interpretations of the researchers from small sample sizes. This basic weakness of the qualitative studies prominent in lean literature highlights the need to further investigate the findings of existing research [101,102]. The related field, organisational development was criticised in the past for propagating and exaggerating conjecture, lacking sound research [103], forming a ‘cumulative and falsifiable body of knowledge’ growing from ‘repeated theoretical propositions’ and having ‘statements quoted with reverence but not refinement’ [104]. Similar concerns were raised in general operations research [74]. The lean literature in many ways is bordering this. Many contextual experiences and cases studies have developed the body of knowledge. Some of the studies are more detailed and others lack empirical basis and scientific meticulousness. This review agrees with Challis, Samson and Lawson [105], although research was existing, the depth of the research was lacking, it was fragmented and without sufficient data. For example, a comprehensive study of the success and failure factors was not found, except in broader contextual terms. There is no doubt that excellent work has been done to identify many critical success factors for lean (CSFs) [4,49]. What is lacking in lean is further development of and empirical proof for contextualised findings. Software such as NVivo [106] can be used to analyse unstructured case data, and potentially larger data sets can be mined. But, this still only identifies important factors and does not fully clarify the relative importance of factors and their relationships. To build on, provide clarity to, and confirmation of the qualitative works, a quantitative exploration of the specific factors, relationships, and underlying causality is needed [107,108]. A series of these studies could address the critiques of lean, shining new light on the benefits of lean along with pitfalls of its application. The tangible statistics from these kinds of studies, based on significant data sets, would also aid in educating practitioners, adjusting any misunderstandings related to lean's benefits or how it should be applied [50,51].

It is clear that whilst both quantitative and qualitative approaches can be strongly argued for, for many years lean research has neglected key quantitative methods. Although quantitative methods are prone to missing key contextual factors, this is not a problem in lean as the contextual work is now well developed. Quantitative research is needed to test the qualitatively developed theory.

4. Filling the quantitative gap—verifying the qualitative theory

To advance the lean body of knowledge, by addressing the shortage of empirically validated lean theory, it is important to identify first which theories need validating and second the best methodology for this.

4.1. Theory for validation

Systematic literature reviews are needed to extract the specific factors [37,109], identify core frameworks [e.g. 32] and other components of lean theory for validation. Because the research in lean is not quantitatively verified, any of the theories from lean literature, especially existing models and frameworks, could be verified in this manner. This will require multiple studies for addressing the various theories. However, some of these theories should be addressed first due to their significant import to practitioners. As covered in the introduction, the remaining unaddressed critique of lean is related to the factors lean successes are contingent on. This is reflected in the high failure rate of implementations and the struggles practitioners continue to have in sustaining lean practices [4,110].

In-depth studies of actual implementations are needed to investigate the many lean success factors. Such studies should moderate cases for industry, business size and product type, as well as test the lean tools used along with other critical factors for lean implementation and organisational development. Existing frameworks could be incorporated in these moderation studies. A specific example would be verifying the lean iceberg model [4]. This study could survey a large sample of lean implementations to see what factors are most important, like employee involvement as compared to the various methods of lean. Such a study, if of a large sample, could also test the universality of lean [3] by moderating for business size and product variety. Other factors common to lean could be simultaneously tested, e.g. the involvement of consultants [61] and their utilisation as opposed to internal resources, or the problems of managing human resources [111]. Also the effectiveness of six-sigma based implementations [112], which have undergone critique [61], or the real relationship between lean's five principles [3] and business performance. These matters have been conceptually addressed in lean literature but findings have not yet been adequately verified.

Additional studies could investigate the effect of increased lean knowledge on how lean is understood and its competitive advantages gained. The way lean is defined and therefore understood could have profound effects on the advantages that are perceived and realised [51]. Although lean is operationalised to an extent [113] an accurate definitions is hard to crystallise [25–27]. An analysis of this might require a relatively short survey that reviews participants understanding of different components of lean and its perceived advantage.

The outcomes of the above proposed studies would both address the critiques of lean, by verifying the benefits of lean implementation and support practitioners in reaping those benefits. These works require that multiple systematic reviews of the literature be undertaken to crystallise critical success factors, including those within existing frameworks [32]. Cases of such research certainly exist [114] but need further development, refinement and then validation. These reviews should embody not only the lean literature but also broader literature in operations management [115,116] including change leadership with organisational development.

4.2. Method of validation—structural equation modelling

To maximise the meaningful contribution of future work [117], we specifically sought to identify the most comprehensive method for validating these existing theories. A research question generally drives the choice of methodology and, whilst an exact research question is not proposed, the basis for the questions has been set. That is, the need to address the remaining major concerns and critiques of lean management by verifying the complex causality between multiple factors and lean success, verifying the benefits of lean implementation and supporting practitioners in reaping those benefits. With this basis, path analysis by Structural Equation Modelling (SEM) was eventually identified as the best approach to further lean research.

SEM is an advanced method used for confirming hypotheses (CFA) and exploring data (EA), having significant advantages over alternative techniques, being referred to as a silver bullet [118], the preeminent multivariate technique [119]. Lean theory involves complex causality of social and technical aspects [4] lending itself to multivariate analysis. SEM gives the researcher the ability and flexibility to model and test such theory within a data set. It enables the researcher to *'(a) model relationships among multiple predictor and criterion variables, (b) construct unobservable LVs, (c) model errors in measurements for observed variables, and (d) statistically test a priori substantive/theoretical and measurement assumptions against empirical data'* [120]. This is its considerable advantage over other multivariate statistical methods like multivariate analysis of variance [119], multiple regression, discriminant analysis, principal components analysis and factor analysis [119,120] that are commonly used [e.g. 75,76]. SEM uses measured variables, often survey data, to indicate underlying (latent) factors that are otherwise difficult to measure [121]. This is similar to the other multivariate methods, but goes further to test multiple paths (causal relationships) between the constructs [118] as illustrated in Fig. 1. And now, with the advances in software, SEM models can be used to easily and flexibly test and explore complicated theories of causality [120]. In a sense, this method even forces explicit development of the researcher's theory, requiring the specification of a models underlying structure [118]. Especially relevant to lean may be its use in longitudinal studies [122–124]. In the past, this would have required a series of detailed surveys over a number of years. Now with the extensive use of technology systems, e.g. Enterprise Resources Planning, Human Resource Information Systems and Customer Relationship Management; it is possible these existing databases, whether private or public, could be leveraged for longitudinal studies. That aside, it is because of the above many advantages of Structural Equation Modelling in quantifying causal relationships, that it is seen as the most suitable method for verifying lean theory.

4.2.1. SEM lacking in lean works—systematic analysis

The need to test operations theory by SEM was suggested strongly as early as 2004 [109]. SEM has been extensively used in psychology [123] and has become an important and widely used tool in operations management research [121], but its application to lean has been very limited. A foundational literature review in 2013 uncovered one significant lean-SEM publication [75] along with 10 articles with very limited scope. Initial work operationalising lean constructs and scales had begun [113,125,126]. A systematic review of lean-SEM publication for this work did highlight a great increase in lean-SEM publications since then.

The systematic analysis of lean-SEM papers, first utilised the Scopus database. It searched for 'lean' within the keyword field, one of SEM and lean variants within the documents ('structural equation model', 'structural equation modelling[1]', 'partial least squares', 'partial least square', 'pls', or 'SEM' and 'lean manufacturing', 'lean management' or 'lean production'), published up to December 2015 and excluded review papers and book sections. It is acknowledged that related works, e.g. just-in-time or kaizen based research may have relevant insight. However, this review focused on research advancing the lean body of knowledge specifically, as indicated by publication keywords and content. Of the 112 articles returned, 68 were rejected for not being SEM and two, although highly relevant for the development of scales [i.e. 113,125] were excluded for not being path analyses. This left 42 articles. To ensure a comprehensive search was achieved, the Scopus search was complemented with searches of Google Scholar. As a further effort to ensure no significant works were missed, a specific search of all operations management journals ranked three or higher by the Academic Journal Guide [128] were conducted at their publishers website. The combined searches resulted in 52 articles.

Of the 52 articles found, 37 (or 67%) were published the previous three years, compared with only 15 articles the previous nine. To provide an external measure of the articles quality, they were categorised by the 2015 Scientific Journal Ranking (SJR) [129], where SJR > 1.3 equates to top ranked '3 and 4' journals [128]. Whilst citations indices and journal rankings are not full proof measures of paper quality, the outcomes of these measures do correlate well [130]. Detailed review of all 52 articles also confirmed this as an adequate indicator of quality. Noteworthy articles can and did exist at lower SJR publications, i.e. the earlier identified work [131, SJR = 0.71] along with the work by Pont, Furlan and Vinelli [132], but otherwise the articles of SJR < 1.3 showed low contributions (see the full list of the lean SEM articles found in the appendix with an abbreviated description of each study). The categorisation of articles (Fig. 2) showed that since 2012 the majority of them were published in lower impact publications and by implication were of lower quality [130].

It was clear from initial review that this quantitative technique, SEM had now been adopted in lean research. However, this had only really happened in the past few years and further analysis (Table 1) showed

[1] The British English spelling was used however Scopus will automatically search the American English variants also [127].

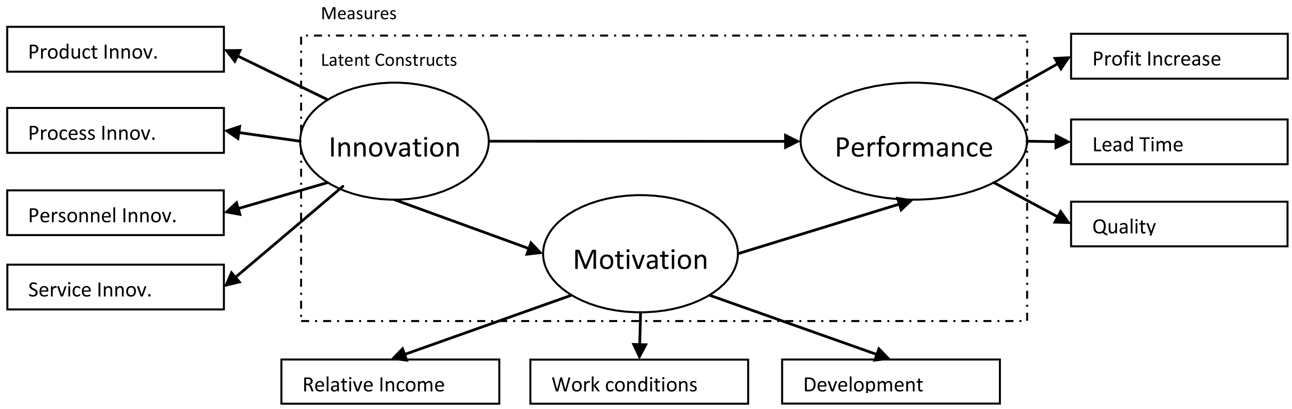

Fig. 1. Example layout for a Structural Equation Model showing measured and latent variables and paths (computations not shown).

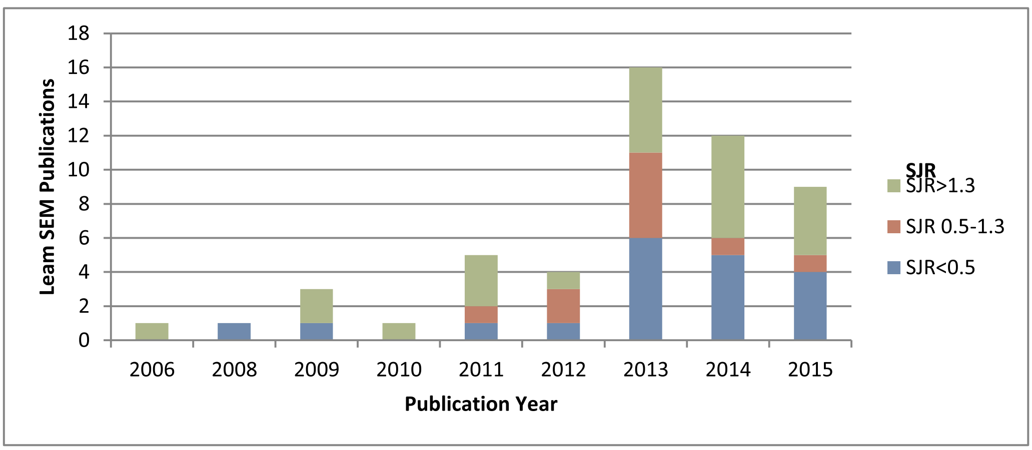

Fig. 2. Lean-SEM publications by year published and SJR ranking (52 articles). SJR > 1.3 implies top tier journals.

these methods still had not been utilised to their potential, specifically the potential to address the core gaps in the body of knowledge, addressing the critical factors for the success and permanence of lean implementation (see Section 4.1).

For further analysis, the 23 lean-SEM articles from journals with SJR > 1.3 were coded according to 22 categories as follows (also see Table 1). As an indicator of article quality, the coding included SJR 2015 [129] and ABS [128] journal rankings along with article citations (Google Scholar). The other categories chosen were decided based on what was commonly observed in the review of the papers. Whilst a general analysis was conducted (see Appendix), the categorisation particularly focused on how the papers quantitatively addressed the major concerns and critiques of lean management: the critical success and failure factors, verifying the benefits of lean and supporting practitioners in achieving them. It also coded whether existing theories were being validated, as is needed [30]. The categories were divided into three main sections for Table 1; firstly 'Sample' for common sample characteristics, secondly 'Focus' for research focus and thirdly 'Analysis' for characteristics of the analysis. The Sample categories firstly assessed the generalisability of the studies. That is, did the paper look beyond the manufacturing roots of lean to other industries; were the studies localised to one country or global; was there a good sample size for statistical power and enabling multi-sampling; and did the study address differences by business size e.g. differentiating between larger businesses and small to medium sized businesses (SMEs). Additionally, whether or not a shared data set was used e.g. did the researcher have full control over the data. The Focus categories included whether the article presented lean as tools and methods or as a more holistic business system [4,50] and what specific fields were covered. Four major fields were identified through the review; supply chain management, agile management, environmental sustainability and the just in time (JIT) methodology. Finally, for Analysis categories, the research was coded as to whether actual business performance was measured. It also noted whether performance was mediated through a leanness construct [113] or if alternative model paths were tested to disambiguate findings; whether the analysis was a validation of existing theory and/or based on existing frameworks and models; and also included an assessment of how much each analysis contributed to the body of knowledge, specifically to the significant problems faced by practitioners in implementing and sustaining lean practices in a wide variety of circumstances. The specific SEM approach was also recorded; i.e. whether the SEM was covariance (Cov) or component (Comp) based and the specific method used. Following the identification of these various categories, additional reviews of the papers were used to complete and confirm the analysis.

The aggregate analysis identified clearly that the majority of these articles were limited in contribution, not addressing the core critiques of lean, the factors that lean success is contingent on. As examples, 91% addressed manufacturing only (typically high volume manufacture), 61% were localised to a specific country and only one addressed small enterprises; thus limiting generalisability and understanding of lean beyond manufacturing, geographical region and business size. Also 35% utilised a shared data set limiting the researchers control over the research design and possible contribution. Overall 70% took a tools perspective to lean, neglecting the human aspects considered critical to success with lean practices. Articles integrating agile methods with lean (17%) were more in line with the factors needed for flexibility, although models were small and overall contributions limited. Business performance was measured by 18 (78%) of the articles which is significant to proving the benefits of lean; but contributions were

Table 1
Analysis of Lean-SEM articles published in top ranked journals - SJR > 1.3 (by date).

Article					Sample					Focus	
Author and date	Journal	ABS 2015	SJR 2015	Citations	Sample size	Manufacturing sector	Localised (country)	Shared data set	SME coverage	Tool/Method	Supply chain
Ward & Zhou, 2006	DECISION SCIENCES	3	1.4	199	769	X	X	X		X	
Fullerton & Wempe, 2009	INT J OPER PROD MAN	4	1.9	233	121	X	X				
Hallgren & Olhager, 2009	INT J OPER PROD MAN	4	1.9	199	379	X		X		X	
Jeffers P., 2010	INT J OPER PROD MAN	4	1.9	46	64					X	X
Roh, Min, & Hong, 2011	INT J PROD RES	3	1.4	43	761	X		X			X
Yang, Hong, & Modi, 2011	INT J PROD ECON	3	2.8	325	309	X		X			
So & Sun, 2011	INT J PROD RES	3	1.4	1	558	X		X			X
Vinodh & Joy, 2012	INT J PROD RES	3	1.4	53	75	X	X		X		
Bortolotti, Danese, & Romano, 2013	INT J PROD RES	3	1.4	32	244			X		X	
Fullerton, Kennedy, & Widener, 2013	ACCOUNTING ORG S	4*	2.2	70	244	X	X			X	
Hajmohammad, Vachon, Klassen, & Gavronski, 2013	J CLEANER PROD	0	1.6	121	85	X	X			X	X
Jabbour, Jabbour, Govindan, Teixeira, & Freitas, 2013	J CLEANER PROD	0	1.6	82	75	X	X			X	X
Qrunfleh & Tarafdar, 2013	SUPPLY CHAN MAN: INT J	3	1.9	59	205	X	X			X	X
Belekoukias, Garza-Reyes, & Kumar, 2014	INT J PROD RES	3	1.4	48	104	X				X	
Fullerton, Kennedy, & Widener, 2014	J OPER MAN	4*	6.6	60	244	X	X			X	
Ghobakhloo & Hong, 2014	INT J PROD RES	3	1.4	8	231	X	X			X	
Roh, Hong, & Min, 2014	INT J PROD ECON	3	2.8	78	559	X		X		X	X
Khanchanapong et al., 2014	INT J PROD ECON	3	2.8	23	186	X	X			X	
Qrunfleh & Tarafdar, 2014	INT J PROD ECON	3	2.8	15	205	X	X			X	X
Chavez et al., 2015	INT J PROD ECON	3	2.8	19	228	X	X				
Marin-Garcia & Bonavia, 2015	INT J PROD RES	3	1.4	7	101	X	X				
Bortolotti, Danese, Flynn, & Romano, 2015	INT J PROD ECON	3	2.8	16	317	X		X		X	
Kou, Lee, & Wei, 2015	INT J OPER PROD MAN	4	1.9	1	237	X	X			X	

Article	Focus			Analysis							
Author and date	Agile	Enviro./ Sustainability	JIT	Business performance	Performance mediated by leanness	Validation of theory	Based on existing frameworks/ models	Contribution small to moderate	Contribution high	Key to lean practice	SEM method
Ward & Zhou, 2006				X	X			X			Cov-LISREL
Fullerton & Wempe, 2009				X				X			Cov -AMOS
Hallgren & Olhager, 2009	X			X	X			X		X	Cov -AMOS

(*continued on next page*)

Table 1 (*continued*)

Article	Focus			Analysis							
Author and date	Agile	Enviro./ Sustainability	JIT	Business performance	Performance mediated by leanness	Validation of theory	Based on existing frameworks/ models	Contribution small to moderate	Contribution high	Key to lean practice	SEM method
Jeffers P., 2010		X		X				X			Comp - PLS
Roh, Min, & Hong, 2011								X			Cov -AMOS
Yang, Hong, & Modi, 2011		X		X	X			X		X	Cov -AMOS
So & Sun, 2011						X		X			Cov -AMOS
Vinodh & Joy, 2012				X		X			X	X	Comp - PLS
Bortolotti, Danese, & Romano, 2013			X	X				X			Cov-LISREL
Fullerton, Kennedy, & Widener, 2013						X	X	X			Cov -AMOS
Hajmohammad, Vachon, Klassen, & Gavronski, 2013		X						X			Comp - PLS
Jabbour, Jabbour, Govindan, Teixeira, & Freitas, 2013		X		X				X			Comp - PLS
Qrunfleh & Tarafdar, 2013	X			X	X	X		X			Cov -AMOS
Belekoukias, Garza-Reyes, & Kumar, 2014	X		X	X		X			X		Cov -AMOS
Fullerton, Kennedy, & Widener, 2014				X	x	X			X		Cov -AMOS
Ghobakhloo & Hong, 2014				X	X	X		X			Comp - PLS
Roh, Hong, & Min, 2014						X	X	X			Cov -AMOS
Khanchanapong et al., 2014				X	X	X		X			Cov-LISREL
Qrunfleh & Tarafdar, 2014	X			X	X			X			Comp - PLS
Chavez et al., 2015			X	X	X				X		Cov-LISREL
Marin-Garcia & Bonavia, 2015				X	X	X		X		X	Comp - PLS
Bortolotti, Danese, Flynn, & Romano, 2015				X	X		X	X			Cov-LISREL
Kou, Lee, & Wei, 2015				X		X	X	X			Cov -AMOS

restricted by the above mentioned factors and that 11 (61% of these) articles moderated performance through a single "leanness" variable, operationalising lean as a single construct but obscuring the effects that the individual components of a lean system had on performance. Finally, while 11 (48%) had a theory validation component, only four papers were aligned with existing frameworks or models. As a result, 83% (19/23) were considered to contribute in only a small or at most moderate way to the body of knowledge, and only four contributed to key lean theory. The other articles did clearly contribute something to the body of knowledge, but did not address the core critiques, the understanding of the critical success factors which is needed for lean practice.

The articles categorised as addressing key theory, also had significant limitations (Table 3). Of the four articles found, all were from the manufacturing sector, half localised in geography and half utilising shared data sets. In three of the four articles performance was mediated via a 'leanness' construct, two did focus on validation of theory but none on existing frameworks or models. And three of four had only a small or moderate contribution in their outcomes. Only one of these articles addressed the key critiques of lean, its basic success factors [133] although it addressed an arguably small sample of 75 Indian manufacturers. This was the only article that addressed SMEs, which on one hand is positive, but also limits the scope of the study itself by not being able to make comparison by business size. Other research also quantitatively addresses contingency [76,77] but again are limited in scope, not SEM (not testing integrated causal chains) and, like many of the SEM works, tend towards a leanness or production perspective [27,113]. Such operationalising has issues [134] and sets a bias towards taking lean as a mere set of production methods.

Significant lean-SEM studies are slow to emerge and the development of constructs is similarly lacking [113,125,126]. Theory in lean, especially lean implementation, is contextually mature but not verified empirically [30,133], let alone at a quantitative level [30]. The lack of developed lean-SEM theory suggests that an initial explorative approach is required. Of the various SEM methods available, Partial Least Squares (PLS) SEM provides a platform for this.

4.2.2. Partial least squares versus component based SEM

PLS-SEM has been in the shadow of other SEM methods [135] Traditional SEM methods [88] are covariance-based (e.g. LISREL), PLS-SEM is a component-based technique [135,136]. The difference between these has been compared to the difference between Factor Analysis and Principal Component Analysis [137]. Previously covariance-based approaches were held in more regard than component-based ones; but these two should be considered as alternatives rather than competing models [135,138–140] as strongly evidenced by Hair et al. [141]. Papers that undermine the legitimacy of PLS [142,143] neglect to differentiate between cases of misuse and appropriate use [144] nor provide adequate scientific evidence [138,145].

Until recently the most common reasons given for using PLS-SEM was its ability to handle variations from normality and analyse small samples [~50% of articles, 146], but is most suitable where research objectives relate to the original purpose of the algorithm [118]. That is, for use in exploratory research, predictive analysis, explaining variance in latent constructs, or where theory is not well developed. Specifically, although identification issues (model accuracy and problems of improper solutions) are concerns in alternative methods, they do not constrain PLS-SEM even if models are highly complex. Problems of PLS-SEM, and other component-based methods, are overestimation of indicator loadings (measurements) and underestimation of paths [135,147]. The poor estimation of indicator loadings and paths coefficients can be reduced by simply increasing the number of indicators and sample size [141]. PLS-SEM can also handle both reflective and formative constructs. There are many practical guides on where and how PLS-SEM should be used [118,140,148–150].

In lean research, SEM is at the stage of explorative modelling with the theory under development. Therefore the most appropriate approach is component-based, of which PLS-SEM is not only the most common [151] but also most suited method [141]. Additionally, its ability to handle non-normal data and the flexibility to investigate smaller samples is beneficial [146,147]. Although a minimum of 100–200 samples has been recommended for covariance based methods, much smaller samples, as low as $n = 20$ [152], have proven successful in PLS-SEM [136]. Besides meaning less investment is required for data gathering; this can also allow multil-sampling; slicing existing datasets into smaller samples for moderation.

PLS-SEM has been used in 30% of the lean-SEM publications (Table 2) with the majority of lean-SEM research being covariance-based. However, PLS-SEM may be the most appropriate method for this stage of lean research. As with other fields [139], incorporating the PLS-SEM approach has great potential for advancing lean research by verifying the complex causality between multiple factors, verifying the benefits of implementation and how practitioners can reap those benefits.

5. Discussion and conclusions

While various methods of research are available, they are generally categorised as either quantitative or qualitative. Each of these approaches have their respective pros and cons. Ultimately the researcher has to use their knowledge and intuition to build a methodology from the available techniques that will provide the best outcome for a project considering its particular constraints; whether they are time, financial, geographical, ethical, or otherwise. However, for a specific theory to be properly verified an appropriate mix of qualitative and quantitative studies is recommended. The lean body of knowledge is unbalanced in this regard. It has historically been dominated by conceptual and qualitative empirical studies, with the quantitative works needed for validating theory being practically non-existent. Lean case studies have shown the significant benefits of lean, identified many critical factors for implementation and thereby were able to respond to the critiques of lean management. The problem is that the evidence for this existing theory is somewhat weak and not convincing to practitioners and researchers alike, as it relies on interpretive methods without quantitative validation. The result is that practitioners are not clear what aspects of lean provide true value and what are just fad.

Lean research could be advanced to a new level by properly utilising the quantitative methods common to managerial sciences, specifically the statistical analysis of survey data. These methods firstly benefit from large sample sizes, and thereby give observed relationships a measurable correlation and statistical power (effect size and significance). Second, the strength of relationships can be compared and used to rank critical success and failure factors, showing what factors are most important and making spurious relationships more recognisable. Third, complex causal relationships can be tested by advanced statistical techniques. Finally, this approach does not negate the qualitative studies but builds upon them to develop new insights as well as validate findings and mitigate any subjectivity present in the existing work.

In the past, quantitative survey methods would have been disregarded for many reasons. First, it is logical that as a field is initially emerging, more interpretive paradigms would be applied in its research to furnish an initial understanding. The early lean work for contextualising lean necessarily relied on the more qualitative approaches and this simply continued as the prevailing approach. New researchers by default may have also followed in the footsteps of their mentors, continuing with similar qualitative research approaches. Second, the ease at which conceptual articles can be written, as opposed to the rigour of empirical work, would have also played a part in the lack of empirical validation. Third, quantitative contributions would have been less due to a of lack awareness of more advanced techniques and their practical application to management science. Even Structural Equation

Table 2
Analysis of Lean-SEM articles published in top ranked journals - SJR > 1.3.

SJR > 1.3	Count	% of total
Total SJR > 1.3	23	100%
Sample		
Average of sample size	274	N/A
Manufacturing Sector	21	91%
Localised	14	61%
Shared data set	8	35%
SME	1	4%
Focus		
Tool/Method	16	70%
Supply Chain	8	35%
Agile	4	17%
Enviro/Sustainability	4	17%
JIT	3	13%
Analysis		
Business performance	18	78%
Performance mediated by leanness	11	
Validation of theory	11	48%
Based on existing frameworks/models	4	17%
Key to lean practice	4	17%
Contribution small to moderate only	19	83%
SEM method		
Covariance-AMOS	11	48%
Covariance-LISREL	5	22%
Total (Cov.)	16	70%
Component - PLS	7	30%

Models, which are more graphical and intuitive than some other statistical approaches, still need a significant level of explanation to be interpreted by those who are unfamiliar. Finally, at the early stages of lean there were insufficient numbers of lean implementations for collection of a worthwhile sized data set. As surveys need to be quite detailed to cover multiple factors, the projection of low survey responses from a small pool of available cases would have discouraged these studies, even though the importance of a high response rate may be overstated [153–155].

Now, with 25 years of lean management practiced in the West, the situation for quantitative lean research is very different. The theory of lean and its critical factors has been developed with multiple theoretical frameworks. There are many cases of lean to analyse and the advancement of information technology (email, web surveys, and social media) has made data collection much more practical. Another technological help is the advancement of software for statistical analysis, especially with techniques like Structural Equation Modelling (SEM) becoming more accessible with user friendly graphical interfaces. SEM was identified here as the most appropriate method to advance lean research. This is because SEM enables the clear statistical modelling of the complex theories of causality seen in lean change; effectively testing factor interactions, moderation and mediation in a way that is not possible with other methods. SEM allows and even forces the researcher to explicitly identify the underlying structure of their theory.

Table 3
Analysis of Lean-SEM articles with SJR > 1.3 and with a focus key to lean theory, e.g. core critiques and critical success factors.

SJR > 1.3 & key lean theory	Count	% of total
Total	4	100%
Sample		
Manufacturing Sector	4	100%
Localised	2	50%
Shared data set	2	50%
Analysis		
Business performance	4	100%
Performance mediated by leanness	3	75%
Contribution small to moderate only	3	75%
Validation of theory	2	50%
Based on existing frameworks/models	0	0%

The systematic analysis of lean-SEM papers showed that in the recent years many more lean-SEM articles have been published but that these have neglected to focus on validating the core lean theory. It is believed this increased number of articles inadvertently neglects the core frameworks due to the simplicity of producing alternative statistical work, exchanging core theory for academically interesting but sometimes obscure topics. The current application of SEM in this field has been piecemeal and generally restricted to a few minor factors and commonly tested by simple shared data sets. They have not advanced the understanding of the real challenges being faced by practitioners, the struggles of implementation but rather other minor and secondary matters that may be viewed as novel or interesting. This was seen with other quantitative works also, e.g. quantifying the effect of industry clock speed [77]. The articles are typically tool focused and persistently operationalise lean as a selection of production methods neglecting the significance of human factors. The resultant papers have contributed to lean generally but not to the core critiques and validation of the critical theories that is needed.

SEM method needs to be used to model more of the specific causality within lean, the causality between factors as depicted in lean implementation models and frameworks, the core drivers for success and the common causes of failure. Researchers need to take full advantage of the advances in technology, including the large data sets that can now be gathered through web survey, and the advances in understanding what factors drive lean success. This work will require multiple systematic reviews of the literature be undertaken to crystallise the critical success factors, including those within existing frameworks [32], in order to develop the survey instruments. Cases of such research certainly exist [114] but need further development, refinement and then validation. These systematic reviews should embody not only the lean literature but also broader literature in operations management including change leadership or organisational development.

With the lack of quantitatively validated lean theory, the field contains many theories for testing and therefore opportunities for future research. However, because of the importance to practitioners, it is especially crucial that the existing theories of lean implementation be verified first. A number of theories needing validating were extracted from the literature and discussed. These included a study of the effect of increased lean knowledge on the understanding of lean and its competitive advantage and also a detailed analysis of lean implementations. Many other factors also warrant investigation, e.g. the effect of relying on consultants as opposed to internal resources. These matters have been addressed conceptually or qualitatively in lean literature, but the findings have not yet been adequately verified.

Partial Least Squares SEM (PLS-SEM) is most suited to this current stage of lean research, as the theory is still under development. Once initial PLS-SEM explorative modelling is completed, more constructs for lean can be developed and other SEM techniques could be incorporated.

The proposed studies would provide clear statistical evidence of the benefits of lean and the contingencies for obtaining them. It will show with more clarity where practitioners have misstepped and also address the existing critiques of lean. The quantifiable outcomes (the real numbers) will become a powerful tool for the education of practitioners, as opposed to the current qualitative evidence.

It should be clear, the emphasis of this study is not merely that in the past quantitative studies were less and more are needed. Quantitative techniques like SEM are now being used in lean but this work points out that, this has only really developed in the recent years and these methods have not been utilised to address the core gaps in the body of knowledge in the way that is needed. Effort is needed to verify and develop the existing theory, especially to validate and advance the existing models and frameworks for lean change. Other literature [30,31] has identified in general terms that quantitative work is less but this work goes further in addressing how the lean literature developed and in giving a specific direction for advancing lean research.

For practitioners the implications of this work is that they need to understand the development of the lean body of knowledge and the difference between conceptual and empirically validated theory. Specifically they should be aware that the lean body of knowledge is not fully mature. The critical success factors and associated frameworks in lean literature require further validation and refinement by quantitative empirical study. Hence, mixed opinions and approaches exist in the literature and they should be taken with consideration of their empirical basis and the acknowledgement that alternate views may exist.

5.1. Limitations

The analysis of SEM articles relied on subjective classification by the authors. This work also uses the evidence found in others systematic reviews. Whilst seen unnecessary to immediately repeat the analysis of others, it is acknowledged that those reviews include subjective classification outside of the control of this work.

The systematic analysis of lean-SEM articles had a relatively small sample size. That is a sample of 53 compared with 254 for other studies [31]. This was unavoidable due to the narrowness of the field under investigation but nonetheless a limitation.

Other techniques, experimentation and data may also add value to the qualitative work. A current trend is 'Big Data' analysis e.g. of consumer behaviours. Innovative use of all available data to aid research needs further exploration along with various related fields, including agile methods and general continuous improvement or kaizen, which have similar issues but were outside this review's scope.

5.2. Conclusion

The purpose was to reassess and recalibrate the direction of lean research. Although many studies have taken place over the past 25 years, the research philosophies and general methodologies used were not challenged. This has left room for weakness in the lean body of knowledge. This review demonstrated that (1) the vast majority of research in this field has been conceptual or qualitative in nature relying heavily on researcher subjectivity; (2) quantitative analyses are needed to verify these past studies and strengthen the body of knowledge; (3) these studies should utilise the statistical methods common in managerial sciences, especially Structural Equation Modelling (SEM); (4) this quantitative work should be used to investigate the complex causality amongst the core factors needed for lean's success instead of the minor matters being addressed in existing SEM studies; and (5) this kind of analysis will provide a better understanding of the factors that affect lean implementation giving the tangible statistical evidence needed for educating practitioners and addressing the critiques. Specific theories requiring validation were identified and multiple systematic analyses of the lean and related literature are needed to identify the factors in further detail. Finally, (6) practitioners themselves should not take any opinions of lean without the consideration of their empirical basis and the realisation that alternate views may exist. In this way, practitioners will learn to discern between what is just fad and what will truly enhance business performance and provide value to an organisation.

Disclosure statement

The authors affirm that there is no undeclared conflict of interests regarding the publication of this article.

Appendix. lean structural equation modelling articles sorted by author

Author date	Article title and publication (Abbreviated)	Reviewer's notes (Abbreviated)[i]
Agus & Hajinoor, 2012	Lean production supply chain management as driver towards enhancing product quality and business performance. INT J QUAL RELIBILITY MANAGE	200 cases; covering understanding of the extent to which lean production permeates manufacturing companies in Malaysia.
AL-Tahat & Jalham, 2013	A structural equation model and a statistical investigation of lean-based quality and productivity improvement. J INTELIGENT MAN	300 industrial organizations; 9 constructs - 8 had one or less paths to the model; all cases Jordanian.
Belekoukias, Garza-Reyes, & Kumar, 2014	The impact of lean methods and tools on the operational performance of manufacturing organisations. INT J PROD RES	140 organisations; manufacturing performance vs lean methods - JIT, autonomation, kaizen, TPM and VSM.
Bortolotti, Danese, & Romano, 2013	Assessing the impact of just-in-time on operational performance at varying degrees of repetitiveness. INT J PROD RES	JIT practices focused; 244 plants; impact of JIT on efficiency and responsiveness performance and the moderating effects on these relationships. Showed product customisation does not significantly moderate the impact of JIT on performance. Instead demand variability negatively moderates the relationship between JIT and responsiveness.
Bortolotti, Danese, Flynn, & Romano, 2015	Leveraging fitness and lean bundles to build the cumulative performance sand cone model. INT J PROD ECON	317 Plants; the role that external resources like suppliers can play in mastering lean.
Boyle, Scherrer-Rathje, & Stuart, 2011	Learning to be lean: the influence of external information sources in lean improvements. J MAN TECH MANAGE	109 Responses; Canada; manufacturing; 50 plus employees. Effect of information sources on lean; correlated exposure to lean information with management commitment and in turn management commitment is linked to successful implementation.
Chavez et al., 2015	Internal lean practices and performance: The role of technological turbulence. INT J PROD ECON	228 manufacturing companies in the Republic of Ireland;SEM and OLS regression. While lean practices can stimulate improved operational and organizational performance, this relationship is not monotonic and is timely to consider the rate of technological change at the time of implementing lean manufacturing.
Cullinane, Bosak, Flood, & Demerouti, 2014	Job design under lean manufacturing and the quality of working life. INT J HUM RESOUR MANAGE	200 employees from one multinational pharmaceutical manufacturer.
Fullerton & Wempe, 2009	Lean manufacturing, non-financial performance measures, and financial performance. INT J OPER PROD MAN	121 US manufacturing company executives. Lean practices; non-financial performance measures and profit.
Fullerton, Kennedy, & Widener, 2013	Management accounting and control practices in a lean manufacturing environment. ACCOUNTING ORG S	244 US companies that attend a specific conference; good paper reference but still relatively small scope; simple relationships and only assessed leanness (change) and not actual outcomes of implementation.
Fullerton, Kennedy, & Widener, 2014	Lean manufacturing and firm performance: The incremental contribution of lean management accounting practices. J OPER MAN	Survey data from 244 US manufacturing firms to construct a structural equation model; lean management accounting practices relationship to leanness and indirectly performance. Promotes the holistic view of lean.

Gelei, Losonci, & Matyusz, 2015	Lean production and leadership attributes J MAN TECH MANAGE	GLOBE project data; profile of a production manager; based on Liker (2004); 89 cases; leadership styles/behaviours related to 'leanness'.
Ghobakhloo & Hong, 2014	IT investments and business performance improvement: the mediating role of lean manufacturing implementation. INT J PROD RES	121 cases from Iranian and 110 from Malaysian auto-part manufacturers; role that the direct IT investments could play in enhancement of LMS implementation.
Gunasekharan, Elangovan, & Parthiban, 2014	A Comprehensive Study to Evaluate the Critical Success Factors Affecting Lean Concept in Indian Manufacturing Industries. APPL MECH MATL	Analysis of lean manufacturing factors; incorporation of SEM; Indian.
Hajmohammad, Vachon, Klassen, & Gavronski, 2013	Lean management and supply management: their role in green practices and performance. J CLEANER PROD	Canadian manufacturing; supply management and lean methods focus on relationship with environmental factors.
Hallgren & Olhager, 2009	Lean and agile manufacturing: external and internal drivers and performance outcomes. INT J OPER PROD MAN	Comparison between lean and agile drivers and outcomes.
Harumi, Ken, & Dong, 2011	Structural Equation Modelling of human factors and their impact on productivity of cellular manufacturing. CONF-ICPR 2011	71 students; laboratory experiment – toy robot building. Suggests that operators'aptitude has significant effects on cell's efficiency and the impact of operators'aptitude is largely stronger than the learning effect.
Hong, Roh, & Rawski, 2012	Benchmarking sustainability practices. BENCHMARKING INT J	379 companies; sustainability practices in the context of the competitive business environment; strategic driver; operational and supply chain practices.
Ismail, Razak, & Lazim, 2014	Manufacturing Technology Impact on Environmental Factors and Manufacturing Performance. APPL MECH MATL	Very basic SEM with limited information in this article about approach.
Jabbour, Jabbour, Freitas, & Teixeira, 2013	Lean and green? Empirical evidence from the brazilian automotive industry. GESTAO E PRODUCAO	Portuguese language; 75 companies;. lean manufacturing (LM) is positively associated with environmental management (EM); but the explanation power of LM over EM is considered weak/moderate.
Jabbour, Jabbour, Govindan, Teixeira, & Freitas, 2013	Environmental management and operational performance in automotive companies in Brazil. J CLEANER PROD	75 participants; Brazil. See title.
Freitas, Jabbour, Teixeira, Jabbour, 2014	Human resource management and lean manufacturing. PRODUCAO	Portuguese Language; 75 Studies. Demonstrates that human resource management tends to influence the adoption of lean in a weak-moderate manner.
Jayamaha, Wagner, & Grigg, 2014	The moderation effect of the cultural dimension. CONF-2014 IEEE	Investigating how individualism/collectivism moderates the relationships between people development, process improvement and Toyota Way deployment.
Jeffers P., 2010	Embracing sustainability: Information technology and the strategic leveraging of operations in third-party logistics. INT J OPER PROD MAN	64 participants; mediating role of an 'operations-as-marketing' strategy in framing IT investment decisions.
Khanchanapong et al., 2014	The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance. INT J PROD ECON	186 manufacturing plants in Thailand; compares manufacturing technologies and lean practices; RBV; focus on tools and methods. Synergistic effects of manufacturing technologies and lean practices on cost; product quality; lead-time; and flexibility.
Kou, Lee, & Wei, 2015	The role of product lean launch in customer relationships and performance in the high-tech manufacturing industry. INT J OPER PROD MAN	Taiwan; high-tech contract manufacturers; 237 usable questionnaires. Analysis of product launch; investigated lean launch strategies from the customer relationship perspective.
Li, Nahm, Wyland, Ke, & Yan, 2015	Reassessing the role of Chinese workers in problem solving. ASIA PAC BUS R	6 plants; manufacturing; 240 Reponses; China; outcome was power distance and the concern for saving face potentially hinder employees' willingness to participate in such problem solving.
Marin-Garcia & Bonavia, 2015	Relationship between employee involvement and lean manufacturing and its effect on performance in a rigid continuous process industry. INT J PROD RES	101 ceramic tile plants in Spain; employee involvement on lean manufacturing (LM); and the effect of LM on production outcomes.
Monge, Cruz, & López, 2013	Impact of lean manufacturing, sustainable manufacturing and continuous improvement on operational efficiency and environmental responsibility in Mexico. INFORMACION TECNOLOGICA	México; Spanish Language. It relates lean manufacturing; sustainable manufacturing and continuous improvement with the operational efficiency and environmental responsibility in the manufacturing industry.
Moori, Pescarmona, & Kimura, 2013	Lean manufacturing and business performance in Brazilian firms. J OPER SUPPLY CHAIN MANAGE	68 Brazilian companies; positive relationship between lean manufacturing and business performance. Results also suggest that managers lack awareness about the importance of the competitive skills to enhance business performance.
Nahm, Lauver, & Keyes, 2012	The role of workers' trust and perceived benefits in lean implementation success. INT J BUS EXCELENCE	180 production workers; Midwest US; critical role of perceived job security; trust in management and lean training in enhancing the perception of personal benefits of lean; which leads to lean implementation success. The results support the notion that lean implementation success depends upon conducive mind-set for lean among production workers.
Noori, 2015	The critical success factors for successful lean implementation in hospitals. INT J PROD QUAL MANAGE	Lean implementation in hospitals - strategic orientation; organisation culture; management system; implementation process and implementation team; effect on success.
Nurul Fadly Habidin & Sha'ri Mohd Yusof, 2013	Critical success factors of Lean Six Sigma for the Malaysian automotive industry. INT J LSS	252 Malaysian automotive organisations; perception based; limited insights available.
Pont, Furlan, & Vinelli, 2009	Interrelationships among lean bundles and their effects on operational performance. OPER MANAGE RES	266 manufacturing plants located in nine countries; more than 100 employees each; relating bundles/scales (HRM and TQM and JIT) to performance.
Qrunfleh & Tarafdar, 2013	Lean and agile supply chain strategies and supply chain responsiveness: the role of strategic supplier partnership and postponement. SUPPLY CHAN MAN: INT J	205 cases; supply chain only; focusing on agile/postponement.
Qrunfleh & Tarafdar, 2014	Supply chain information systems strategy: Impacts on supply chain performance and firm performance. INT J PROD ECON	205 cases; information system versus lean/agile strategies.
R.A.M. Shamah, 2013	A model for applying lean thinking to value creation. INT J LSS	A model for applying lean thinking to value creation; Egyptian cases; small scope.
R.A.M. Shamah, 2013	Measuring and building lean thinking for value creation in supply chains. INT J LSS	Egyptian industrial sector. Seeking instrument to measure the impact of lean thinking on supply chain value.

Ravikumar, Marimuthu, Parthiban, & Abdul Zubar, 2013	Leanness evaluation in 6 manufacturing MSME"s using AHP & SEM techniques. INT J MECH MECHTRON ENG	Relatively basic paper. See title.
Roh, Hong, & Min, 2014	Implementation of a responsive supply chain strategy in global complexity. INT J PROD ECON	International Manufacturing Strategy Survey (IMSS); 559 manufacturing cases. Supply chain aspects and pull production.
Roh, Min, & Hong, 2011	A co-ordination theory approach to restructuring the supply chain. INT J PROD RES	Data from International Manufacturing Strategy Survey (IMSS) IV; 761 manufacturing units of 24 countries. Supply chain restructuring and the impact of supply chain restructuring on manufacturing practices. Co-ordination theory; greater co-ordination and information sharing with suppliers turned out to be a major driving force behind supply chain restructuring.
So & Sun, 2011	An extension of IDT in examining the relationship between electronic-enabled supply chain integration and the adoption of lean production. INT J PROD RES	Electronic-enabled supply chain integration and the adoption of lean production. 558 manufacturers around the world. Leanness measured.
So & Sun, 2015	Lean thinking as organisational practice in enabling supply chain sustainability. INT J ENVIROTECH MANAGE	527 manufacturing firms in 17 industrialised countries; sustainable supply chain.
Sureeratta, Napompech, & Panjakhajo, 2014	Model of Leadership and the Effect of Lean Manufacturing Practices on Firm Performance in Thailand's Auto Parts Industry. RES J BUS MANAGE	Basic model. The latent variables were leadership, lean manufacturing practices and firm performance. The results suggest significant relationships among leadership, lean manufacturing practices and firm performance.
Taggart & Kienhöfer, 2013	The effectiveness of lean manufacturing audits in measuring operational performance improvements. SOUTH AFRICAN J INDU ENG	64 manufacturing sites. The findings are that lean manufacturing audits are effective in measuring improvements in operational performance provided that the audit scope and the lean characteristics are aligned up front.
Vinodh & Joy, 2012	Structural Equation Modelling of lean manufacturing practices. INT J PROD RES	75 small manufacturing firms; India; environmental uncertainty –> lean practices.
Vivek & Ravichandran, 2008	An empirical study on the impact of environmental uncertainty on the lean practices of small manufacturing firms. J CONTEMP RES MANAGE	60 small manufacturing firms. Factors affecting world-class manufacturing.
Ward & Zhou, 2006	Impact of Information Technology Integration and Lean/Just-In-Time Practices on Lead-Time Performance. DECISION SCIENCES	769 responses; supply chain; relationships between lead time and information technology. Covers IT integration, intrafirm IT integration, lean/JIT practices and lead-time performance.
Xia & Kamoshida, 2015	An Empirical Study of the Effect of SCM Practice on Corporate Performance. CONF-KMO 2015	Supply chain; China focus. Se title.
Yang & Yang, 2013	An Integrated Model of the Toyota Production System with Total Quality Management and People Factors. HUM FAC & ERGO MAN & SERV IND	153 cases; Taiwan based. The conclusion is that an integrated model (of technical and social) provides a much more effective "lean system".
Yang, Hong, & Modi, 2011	Impact of lean manufacturing and environmental management on business performance. INT J PROD ECON	309 manufacturing firms worldwide; relationship between lean management, environmental management, business outcomes and environmental outcomes.
Zhang & Niu, 2013	Influence mechanism of lean production to manufacturing enterprises' competitiveness. CONF-ICIE 2013	SEM using SMOS17.0. Analysis result demonstrates the influence mechanism of lean production to competitiveness clearly. The study of this paper has practical sense to lean implementation in China.

[i] These reviewer's comments include their own synopsis, paraphrased statements and small amounts of direct quotations from the associated paper.

References

[1] Shingo S. A study of the Toyota production system: from an industrial engineering viewpoint, rev sub. Productivity Press; 1989.

[2] Ohno T. Toyota production system: beyond large-scale production. 1st ed. Productivity Press; 1988.

[3] Womack JP, Jones DT. Lean thinking, banish waste and create wealth in your corporation. 1st ed. Productivity Press; 1996.

[4] Hines P. How to create and sustain a lean culture. Dev Learn Org 2010:24. https://doi.org/10.1108/dlo.2010.08124fad.007.

[5] Emiliani ML. Origins of lean management in America: the role of Connecticut businesses. J Manag Hist 2006;12:167–84. https://doi.org/10.1108/13552520610654069.

[6] Birnbaum R. The life cycle of academic management fads. J Higher Educ 2000;71:1–16. https://doi.org/10.2307/2649279.

[7] Selko A. Strategies to help manufacturers compete successfully. IndustryWeek; 2012http://www.industryweek.com/companies-amp-executives/strategies-help-manufacturers-compete-successfully.

[8] Seth D, Gupta V. Application of value stream mapping for lean operations and cycle time reduction: an Indian case study. Prod Plan Control 2005;16:44–59. https://doi.org/10.1080/09537280512331325281.

[9] Schröders T, Cruz-Machado V. Sustainable lean implementation: an assessment tool. In: Xu J, Nickel S, Machado VC, Hajiyev A, editors. Proceedings of the ninth international conference on management science and engineering management. Springer; 2015. p. 1249–64http://link.springer.com/chapter/10.1007/978-3-662-47241-5_105 Accessed 23 August 2015.

[10] Bortolotti T, Boscari S, Danese P. Successful lean implementation: organizational culture and soft lean practices. Int J Prod Econ 2014. https://doi.org/10.1016/j.ijpe.2014.10.013.

[11] Bhasin S. Improving performance through lean. Int J Manag Sci Eng Manag 2011;6:23–36. https://doi.org/10.1080/17509653.2011.10671143.

[12] Goodyer J, Murti Y, Grigg NP, Shekar A. Lean: insights into SMEs ability to sustain improvement. Cambridge, United Kingdom: University of Cambridge; 2011.

[13] Shin D, Kalinowski JG, Abou El-Enein G. Critical implementation issues in total quality management. SAM Adv Manag J 1998;63:10–4.

[14] Crute V, Ward Y, Brown S, Graves A. Implementing Lean in aerospace – challenging the assumptions and understanding the challenges. Technovation 2003;23:917–28. https://doi.org/10.1016/S0166-4972(03)00081-6.

[15] Cooney R. Is "lean" a universal production system?: Batch production in the automotive industry. Int J Oper Prod Manag 2002;22:1130–47. https://doi.org/10.1108/01443570210446342.

[16] Garrahan P, Stewart P. The Nissan enigma: flexibility at work in a local economy. Continuum International Publishing; 1992.

[17] Williams K, Haslam C, Williams J, Adcroft A, Johal S. Against lean production. Econ Soc 1992;21:321–54. https://doi.org/10.1080/03085149200000016.

[18] Delbridge R. Life on the line in contemporary manufacturing. Oxford University Press; 1998.

[19] Hines P, Holweg M, Rich N. Learning to evolve: a review of contemporary lean thinking. Int J Oper Prod Manag 2004;24:994–1011. https://doi.org/10.1108/01443570410558049.

[20] Cox A, Chicksand D. The limits of lean management thinking: multiple retailers and food and farming supply chains. Eur Manag J 2005;23:648–62. https://doi.org/10.1016/j.emj.2005.10.010.

[21] Johnstone C, Pairaudeau G, Pettersson JA. Creativity, innovation and lean sigma: a controversial combination? Drug Discov Today 2011;16:50–7. https://doi.org/10.1016/j.drudis.2010.11.005.

[22] Radnor Z, Holweg M, Waring J. Lean in healthcare: the unfilled promise? Soc Sci Medicine 2012;74:364–71. https://doi.org/10.1016/j.socscimed.2011.02.011.

[23] Hines P, Found P, Griffiths G, Harrison R. Staying lean: Thriving, not just surviving. Lean Enterprise Research Centre; 2008.

[24] Bateman N, Hines P, Davidson P. Wider applications for Lean: an examination of the fundamental principles within public sector organisations. Int J Prod Perform Manag 2014;63:550–68. https://doi.org/10.1108/IJPPM-04-2013-0067.

[25] Arlbjørn JS, Freytag PV. Evidence of lean: a review of international peer-reviewed journal articles. Eur Bus Rev 2013;25:174–205. https://doi.org/10.1108/09555341311302675.

[26] Bhasin S. Performance of organisations treating lean as an ideology. Bus Process Manag J 2011;17:986–1011. https://doi.org/10.1108/14637151111182729.

[27] Bhasin S. Lean management beyond manufacturing. Cham: Springer International Publishing; 2015http://link.springer.com/10.1007/978-3-319-17410-5 Accessed 10.

[28] Mirdad WK, Eseonu CI. A conceptual map of the lean nomenclature: comparing expert classification to the lean literature. Eng Manag J 2015;27:188–202. https://doi.org/10.1080/10429247.2015.1082068.

[29] Jasti NVK, Kodali R. A literature review of empirical research methodology in lean

manufacturing. Int J Oper Prod Manag 2014;34:1080–122. https://doi.org/10.1108/IJOPM-04-2012-0169.
[30] Jasti NVK, Kodali R. Lean production: literature review and trends. Int J Prod Res 2015;53:867–85. https://doi.org/10.1080/00207543.2014.937508.
[31] Jasti NVK, Kodali R. A critical review of lean supply chain management frameworks: proposed framework. Prod Plan Control 2015;0:1–18. https://doi.org/10.1080/09537287.2015.1004563.
[32] Martínez-Jurado PJ, Moyano-Fuentes J. Lean management, supply chain management and sustainability: a literature review. J Clean Prod 2014;85:134–50. https://doi.org/10.1016/j.jclepro.2013.09.042.
[33] Bakkalbasi N, Bauer K, Glover J, Wang L. Three options for citation tracking: google Scholar, Scopus and Web of Science. Biomed Digit Libr 2006;3:7. https://doi.org/10.1186/1742-5581-3-7.
[34] Falagas ME, Pitsouni EI, Malietzis GA, Pappas G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. FASEB J 2008;22:338–42. https://doi.org/10.1096/fj.07-9492LSF.
[35] Krafcik J. The triumph of the lean production system. Sloan Manag Rev 1988:41–52.
[36] Womack JP, Jones DT, Roos D. The machine that changed the world. Scribner; 1990.
[37] Hadid W, Mansouri SA. The lean-performance relationship in services: a theoretical model. Int J Oper Prod Manag 2014;34:750–85. https://doi.org/10.1108/IJOPM-02-2013-0080.
[38] Radnor Z, Johnston R. Lean in UK Government: internal efficiency or customer service? Prod Plan Control 2013;24:903–15. https://doi.org/10.1080/09537287.2012.666899.
[39] Ribeiro FL, Fernandes MT. Exploring agile methods in construction small and medium enterprises: a case study. J Enterp Inf Manag 2010;23:161–80.
[40] Tommelein I. Journey toward lean construction: pursuing a paradigm shift in the AEC industry. J Constr Eng Manag 2015;141:04015005. 10.1061/(ASCE)CO.1943-7862.0000926.
[41] Villarreal B, Garza-Reyes JA, Kumar V. Lean road transportation – a systematic method for the improvement of road transport operations. Prod Plan Control 2016;27:865–77. https://doi.org/10.1080/09537287.2016.1152405.
[42] Vlachos I. Applying lean thinking in the food supply chains: a case study. Prod Plan Control 2015;26:1351–67. https://doi.org/10.1080/09537287.2015.1049238.
[43] Haddad MG, Zouein PP, Salem J, Otayek R. Case study of lean in hospital admissions to inspire culture change. Eng Manag J 2016;28:209–23. https://doi.org/10.1080/10429247.2016.1234896.
[44] van Leeuwen KC, Does RJMM. Quality quandaries: lean nursing. Qual Eng 2010;23:94–9. https://doi.org/10.1080/08982112.2010.529486.
[45] Staats BR, Brunner DJ, Upton DM. Lean principles, learning, and knowledge work: evidence from a software services provider. J Oper Manag 2011;29:376–90. https://doi.org/10.1016/j.jom.2010.11.005.
[46] Balle M. Takt time thinking for a low-volume high-mix company. Michael Ballé's Gemba Coach Column; 2011http://www.lean.org/balle/ [Accessed 28 August 2011).
[47] Lander E, Liker JK. The Toyota Production System and art: making highly customized and creative products the Toyota way. Int J Prod Res 2007;45:3681–98. https://doi.org/10.1080/00207540701223519.
[48] Holweg M. The genealogy of lean production. J Oper Manag 2007;25:420–37.
[49] Womack JP. Moving beyond the tool age [lean management]. Manuf Eng 2007;86:4–5. https://doi.org/10.1049/me:20070101.
[50] Pearce A, Pons D, Neitzert T. Implementing lean—outcomes from SME case studies. Oper Res Perspect 2018;5:94–104. https://doi.org/10.1016/j.orp.2018.02.002.
[51] July Ashburn A. Toyota's famous Ohno System (a reprinted version of the article in the 'American Machinist. In: Monden Y, editor. Applying just In Time: the American/Japanese experience (1986), 1977. Industrial Engineering and Management Press, IIE; 1977. p. 1977.
[52] Sugimori Y, Kusunoki K, Cho F, Uchikawa S, System Toyota Production, System Kanban. Materialization of Just-In-Time and respect-for-human system. Int J Prod Res 1977;15:553–64.
[53] Vogel E. Japan as number one: lessons for America. Harvard University Press; 1979.
[54] Cusumano MA. The Japanese automobile industry: technology and management at Nissan and Toyota. Harvard University Asia Center; 1985.
[55] Imai M. Kaizen: the key to Japan's competitive success. 1st ed. McGraw-Hill/Irwin; 1986.
[56] Munzberg B. JIT – a flexible manufacturing philosophy for Australian manufacturers. Aust Mach Prod Eng 1984;37:19. 15, 17.
[57] Schonberger RJ. Japanese manufacturing techniques: nine hidden lessons in simplicity. Free Press; 1982.
[58] Schonberger RJ. Japanese production management: an evolution-With mixed success. J Oper Manag 2007;25:403–19.
[59] Fujimoto T. The evolution of a manufacturing system at Toyota. Oxford University Press; 1999.
[60] Liker J. The Toyota way. 1st ed. McGraw-Hill; 2004.
[61] Osono E, Shimizu N, Takeuchi H. Extreme Toyota: radical contradictions that drive success at the world's best manufacturer. 1st ed. Wiley; 2008.
[62] Spear S, Bowen HK. Decoding the DNA of the Toyota production system 77. Harvard Business Review; 1999. p. 96–106.
[63] Wakamatsu Y. The Toyota mindset: the ten commandments of taiichi ohno. Enna Inc.; 2009.
[64] Schmidt S. From hype to ignorance-a review of 30 years of lean production. Proc World Acad Sci Eng Technol 2011;73:1021–4.
[65] Pearce A, Pons D. Implementing lean practices: managing the transformation risks. J Ind Eng 2013:790291https://doi.org/10.1155/2013/790291.
[66] Schroeder RG, Anderson JC, Cleveland G. The content of manufacturing strategy: an empirical study. J Oper Manag 1986;6:405–15. https://doi.org/10.1016/0272-6963(86)90013-6.
[67] Thomas G. A typology for the case study in social science following a review of definition, discourse, and structure. Qual Inq 2011;17:511–21. https://doi.org/10.1177/1077800411409884.
[68] Stuart I, McCutcheon D, Handfield R, McLachlin R, Samson D. Effective case research in operations management: a process perspective. J Oper Manag 2002;20:419–33. https://doi.org/10.1016/S0272-6963(02)00022-0.
[69] Barratt M, Choi TY, Li M. Qualitative case studies in operations management: trends, research outcomes, and future research implications. J Oper Manag 2011;29:329–42. https://doi.org/10.1016/j.jom.2010.06.002.
[70] Myers MD. Qualitative research in business and management. SAGE; 2013.
[71] Cunningham JE, Fiume O. Real numbers: management accounting in a lean organization. Managing Times Press; 2003.
[72] Flynn BB, Sakakibara S, Schroeder RG, Bates KA, Flynn EJ. Empirical research methods in operations management. J Oper Manag 1990;9:250–84. https://doi.org/10.1016/0272-6963(90)90098-X.
[73] Forza C. Survey research in operations management: a process-based perspective. Int J Oper Prod Manag 2002;22:152–94. https://doi.org/10.1108/01443570210414310.
[74] Boyle TA, Scherrer-Rathje M, Stuart I. Learning to be lean: the influence of external information sources in lean improvements. J Manuf Technol Manag 2011;22:587–603.
[75] Kull TJ, Yan T, Liu Z, Wacker JG. The moderation of lean manufacturing effectiveness by dimensions of national culture: testing practice-culture congruence hypotheses. Int J Prod Econ 2014;153:1–12. https://doi.org/10.1016/j.ijpe.2014.03.015.
[76] Chavez R, Gimenez C, Fynes B, Wiengarten F, Yu W. Internal lean practices and operational performance. Int J Oper Prod Manag 2013;33:562–88. https://doi.org/10.1108/01443571311322724.
[77] Shah R, Ward PT. Lean manufacturing: context, practice bundles, and performance. J Oper Manag 2003;21:129–49. https://doi.org/10.1016/S0272-6963(02)00108-0.
[78] Grace-Martin K. Can Likert scale data ever be continuous. The Analysis Factor; 2008http://www.theanalysisfactor.com/can-likert-scale-data-ever-be-continuous/.
[79] Jacoby J, Matell MS. Three-point Likert scales are good enough. J Mark Res 1971;8:495–500. https://doi.org/10.2307/3150242.
[80] Jamieson S. Likert scales: how to (ab) use them. Med Educ 2004;38:1217–8.
[81] Kampen J, Swyngedouw M. The ordinal controversy revisited. Qual Quant 2000;34:87–102. https://doi.org/10.1023/A:1004785723554.
[82] Knapp TR. Treating ordinal scales as interval scales: an attempt to resolve the controversy. Nurs Res 1990;39:121–3.
[83] Fisher RA. The correlation between relatives on the supposition of mendelian inheritance. Trans R Soc Edinb 1918.
[84] Fisher RA. On the "probable error" of a coefficient of correlation deduced from a small sample. Metron 1921.
[85] Fabrigar LR, Wegener DT, MacCallum RC, Strahan EJ. Evaluating the use of exploratory factor analysis in psychological research. Psychol Methods 1999;4:272–99. https://doi.org/10.1037/1082-989X.4.3.272.
[86] Hill T, Lewicki P. Statistics: methods and applications. 1st ed. StatSoft, Inc.; 2005.
[87] Lei P-W, Wu Q. Introduction to structural equation modeling: issues and practical considerations. Educ Meas 2007;26:33–43.
[88] Elragal A, ERP, Data Big. The inept couple. Procedia Technol 2014;16:242–9. https://doi.org/10.1016/j.protcy.2014.10.089.
[89] Flyvbjerg B. Case-study research. In: Denzin Norman K, Lincoln Yvonna S, editors. 4th ed.Thousand Oaks, CA: The Sage Handbook of Qualitative ResearchSage; 2011. p. 301–16.
[90] Taylor GR. Integrating quantitative and qualitative methods in research. University Press of America; 2005.
[91] George AL, Bennett A. Case studies and theory development in the social sciences. MIT Press; 2005.
[92] Mook DG. In defense of external invalidity. Am Psychol 1983;38:379–87. https://doi.org/10.1037/0003-066X.38.4.379.
[93] Flyvbjerg B. Five misunderstandings about case-study research. Qual Inq 2006;12:219–45. https://doi.org/10.1177/1077800405284363.
[94] Holland PW. Statistics and causal inference. J Am Stat Assoc 1986;81:945–60. https://doi.org/10.1080/01621459.1986.10478354.
[95] Pearl J. Causality: models, reasoning and inference. Cambridge Univ Press; 2000.
[96] Punch KF. Introduction to social research: quantitative and qualitative approaches. SAGE; 2013.
[97] Neuman WL. Social research methods: qualitative and quantitative approaches. 7th ed. Pearson; 2013.
[98] Abdulmalek FA, Rajgopal J. Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study. Int J Prod Econ 2007;107:223–36. https://doi.org/10.1016/j.ijpe.2006.09.009.
[99] Mahfouz A, Shea J, Arisha A. Simulation based optimisation model for the lean assessment in SME: a case study, in: 2011 winter simulation conference (WSC 2011), 11–14 Dec. 2011. Piscataway, NJ, USA: IEEE; 2011. p. 2403–13. https://doi.org/10.1109/WSC.2011.6147950.
[100] Pons D. System model of production inventory control. Int J Manuf Technol Manag 2010;20:120–55.
[101] A. Baranek, K.H. Tan, M. Byrne, The DNA of Toyota revisited: issues and

challenges of lean implementation, in:2010: p. 0178. http://www.pomsmeetings.org/confproceedings/015/fullpapers/015-0178.pdf(accessed Accessed 3 February 3, 2014).
[102] Berthon P, Pitt L, Ewing M, Carr CL. Potential research space in MIS: a framework for envisioning and evaluating research replication, extension, and generation. Inf Syst Res 2002;13:416–27. https://doi.org/10.1287/isre.13.4.416.71.
[103] Sashkin M, Burke WW. Organization development in the 1980's. J Manag 1987;13:393–417. https://doi.org/10.1177/014920638701300212.
[104] Weick KE, Quinn RE. Organizational change and development. Annu Rev Psychol 1999;50:361–86. https://doi.org/10.1146/annurev.psych.50.1.361.
[105] Challis D, Samson D, Lawson B. Impact of technological, organizational and human resource investments on employee and manufacturing performance: Australian and New Zealand evidence. Int J Prod Res 2005;43:81–107.
[106] QSR International Pty Ltd., NVivo qualitative data analysis software, 2012. http://www.qsrinternational.com/products_nvivo.aspx.
[107] Marzec PE, Matthews RL. Refining the internal-external learning model via knowledge acquisition and organizational learning. 2012. Boston MA.
[108] Wold S, Eriksson L, Trygg J, Kettaneh N. The PLS method – partial least squares projections to latent structures – and its applications in industrial RDP (research, development, and production). 2004. Prague, Czech Republic.
[109] Rose AMN, Deros BM, Rahman MNA, Nordin N. Lean manufacturing best practices in SMEs. Proceedings of the (2011) international conference on industrial engineering and operations management. 2011. p. 22–4.
[110] Pakdil F, Leonard KM. Implementing and sustaining lean processes: the dilemma of societal culture effects. Int J Prod Res 2017;55:700–17. https://doi.org/10.1080/00207543.2016.1200761.
[111] Tan KH, Denton P, Rae R, Chung L. Managing lean capabilities through flexible workforce development: a process and framework. Prod Plan Control 2013;24:1066–76. https://doi.org/10.1080/09537287.2011.646013.
[112] Stankalla R, Koval O, Chromjakova F. A review of critical success factors for the successful implementation of Lean Six Sigma and Six Sigma in manufacturing small and medium sized enterprises. Qual Eng 2018;0:1–16. https://doi.org/10.1080/08982112.2018.1448933.
[113] Shah R, Ward PT. Defining and developing measures of lean production. J Oper Manag 2007;25:785–805. https://doi.org/10.1016/j.jom.2007.01.019.
[114] Martínez-Jurado PJ, Moyano-Fuentes J. Key determinants of lean production adoption: evidence from the aerospace sector. Prod Plan Control 2014;25:332–45. https://doi.org/10.1080/09537287.2012.692170.
[115] Pearce A, Pons D. Defining lean change—framing lean implementation in organisational development. Int J Bus Manag 2017. https://doi.org/10.5539/ijbm.v12n4p10.
[116] Yadav OP, Nepal BP, Rahaman MM, Lal V. Lean implementation and organizational transformation: a literature review. Eng Manag J 2017;29:2–16. https://doi.org/10.1080/10429247.2016.1263914.
[117] Boer H, Holweg M, Kilduff M, Pagell M, Schmenner R, Voss C. Making a meaningful contribution to theory. Int J Oper Prod Manag 2015. https://doi.org/10.1108/IJOPM-03-2015-0119.
[118] Hair JF, Ringle CM, Sarstedt M. PLS-SEM: indeed a silver bullet. J Mark Theory Pract 2011;19:139–52.
[119] Hershberger SL. The growth of structural equation modeling: 1994–2001. Struct Equ Model 2003;10:35–46. https://doi.org/10.1207/S15328007SEM1001_2.
[120] Chin WW. Commentary: issues and opinion on structural equation modeling. MIS Q 1998. vii–xvi.
[121] Shah R, Goldstein SM. Use of structural equation modeling in operations management research: looking back and forward. J Oper Manag 2006;24:148–69. https://doi.org/10.1016/j.jom.2005.05.001.
[122] Little TD. Longitudinal structural equation modeling. Guilford Press; 2009.
[123] MacCallum RC, Austin JT. Applications of structural equation modeling in psychological research. Annu Rev Psychol 2000;51:201–26. https://doi.org/10.1146/annurev.psych.51.1.201.
[124] McArdle JJ. Latent variable modeling of differences and changes with longitudinal data. Annu Rev Psychol 2009;60:577–605. https://doi.org/10.1146/annurev.psych.60.110707.163612.
[125] Furlan A, Vinelli A, Pont GD. Complementarity and lean manufacturing bundles: an empirical analysis. Int J Oper Prod Manag 2011;31:835–50. https://doi.org/10.1108/01443571111153067.
[126] Cherry HE. Exploring lean production through the diffusion of innovation : development of a new implementation effectiveness index, Thesis. Oregon State University; 2012.
[127] Elsevier, Scopus Quick Reference Guide, (2014). https://www.elsevier.com/__data/assets/pdf_file/0005/79196/scopus-quick-reference-guide.pdf (accessed January 22, 2019).
[128] ABS, Academic Journal Guide2015, Chartered association of business schools, 2015. http://charteredabs.org/academic-journal-guide-2015/.
[129] SCImago, Scimago Journal & Country Rank, (2007). http://www.scimagojr.com (accessed accessed 17 November 17, 2015).
[130] Mingers J, Yang L. Evaluating journal quality: a review of journal citation indicators and ranking in business and management. Eur J Oper Res 2017;257:323–37. https://doi.org/10.1016/j.ejor.2016.07.058.
[131] Boyle TA, Scherrer-Rathje M. An empirical examination of the best practices to ensure manufacturing flexibility: lean alignment. J Manuf Technol Manag 2009;20:348–66. https://doi.org/10.1108/17410380910936792.
[132] Pont GD, Furlan A, Vinelli A. Interrelationships among lean bundles and their effects on operational performance. Oper Manag Res 2009;1:150–8. https://doi.org/10.1007/s12063-008-0010-2.
[133] Vinodh S, Joy D. Structural equation modelling of lean manufacturing practices. Int J Prod Res 2012;50:1598–607. https://doi.org/10.1080/00207543.2011.560203.
[134] Ketokivi MA, Schroeder RG. Perceptual measures of performance: fact or fiction? J Oper Manag 2004;22:247–64. https://doi.org/10.1016/j.jom.2002.07.001.
[135] Rigdon EE. Rethinking partial least squares path modeling: in praise of simple methods. Long Range Plan 2012;45:341–58. https://doi.org/10.1016/j.lrp.2012.09.010.
[136] Haenlein M, Kaplan AM. A beginner's guide to partial least squares analysis. Underst Stat 2004;3:283–97.
[137] Chin WW. Partial least squares is to LISREL as principal components analysis is to common factor analysis. Technol Stud 1995;2:315–9.
[138] Henseler J, Dijkstra TK, Sarstedt M, Ringle CM, Diamantopoulos A, Straub DW, Ketchen DJ, Hair JF, Hult GTM, Calantone RJ. Common beliefs and reality about PLS comments on Rönkkö and Evermann (2013). Org Res Methods 2014;17:182–209. https://doi.org/10.1177/1094428114526928.
[139] Riou J, Guyon H, Falissard B. An introduction to the partial least squares approach to structural equation modelling: a method for exploratory psychiatric research. Int. J. Methods Psychiatr. Res. 2015. https://doi.org/10.1002/mpr.1497.
[140] Petter S. Haters Gonna Hate": PLS and information systems research. SIGMIS Database 2018;49:10–3. https://doi.org/10.1145/3229335.3229337.
[141] Hair JF, Hult GTM, Ringle CM, Sarstedt M, Thiele KO. Mirror, mirror on the wall: a comparative evaluation of composite-based structural equation modeling methods. J Acad Mark Sci 2017:1–17. https://doi.org/10.1007/s11747-017-0517-x.
[142] Rönkkö M, McIntosh CN, Antonakis J, Edwards JR. Partial least squares path modeling: time for some serious second thoughts. J Oper Manag 2016;47:9–27. https://doi.org/10.1016/j.jom.2016.05.002.
[143] Rönkkö M, Evermann J. A critical examination of common beliefs about partial least squares path modeling. Org Res Methods 2013;16:425–48. https://doi.org/10.1177/1094428112474693.
[144] Marcoulides GA, Chin WW, Saunders C. A critical look at partial least squares modeling. MIS Q 2009;33:171–5.
[145] Sarstedt M, Hair JF, Ringle CM, Thiele KO, Gudergan SP. Estimation issues with PLS and CBSEM: where the bias lies!. J Bus Res 2016;69:3998–4010. https://doi.org/10.1016/j.jbusres.2016.06.007.
[146] Hair JF, Sarstedt M, Ringle CM, Mena JA. An assessment of the use of partial least squares structural equation modeling in marketing research. J Acad Mark Sci 2012;40:414–33. https://doi.org/10.1007/s11747-011-0261-6.
[147] Hsu S-H, Chen W, Hsieh M. Robustness testing of PLS, LISREL, EQS and ANN-based SEM for measuring customer satisfaction. Total Qual Manag Bus Excell 2006;17:355–72. https://doi.org/10.1080/14783360500451465.
[148] Rigdon EE. Choosing PLS path modeling as analytical method in European management research: a realist perspective. Eur Manag J 2016;34:598–605. https://doi.org/10.1016/j.emj.2016.05.006.
[149] Peng DX, Lai F. Using partial least squares in operations management research: a practical guideline and summary of past research. J Oper Manag 2012;30:467–80. https://doi.org/10.1016/j.jom.2012.06.002.
[150] Richter NF, Cepeda G, Roldán JL, Ringle CM. European management research using partial least squares structural equation modeling (PLS-SEM). Eur Manag J 2016;34:589–97. https://doi.org/10.1016/j.emj.2016.08.001.
[151] Tenenhaus M. Component-based structural equation modelling. Total Qual Manag Bus Excell 2008;19:871–86. https://doi.org/10.1080/14783360802159543.
[152] Henseler J, Ringle C, Sinkovics R. The use of partial least squares path modeling in international marketing. Adv Int Mark 2009;20:277–320.
[153] Curtin R, Presser S, Singer E. The effects of response rate changes on the index of consumer sentiment. Public Opin Q 2000;64:413–28. https://doi.org/10.1086/318638.
[154] Sheehan KB. E-mail survey response rates: a review. J Comput-Mediat Commun 2001;6. https://doi.org/10.1111/j.1083-6101.2001.tb00117.x. 0–0.
[155] Visser PS, Krosnick JA, Marquette J, Curtin M. Mail surveys for election forecasting? An evaluation of the Columbus dispatch poll. Public Opin Q 1996;60:181–227. https://doi.org/10.1086/297748.