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Lean manufacturing: literature review and research issues

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Abstract

Purpose – The advent of recession at the beginning of twenty-first century forced many organizations worldwide to reduce cost and to be more responsive to customer demands. Lean Manufacturing (LM) has been widely perceived by industry as an answer to these requirements because LM reduces waste without additional requirements of resources. This led to a spurt in LM research across the globe mostly through empirical and exploratory studies which resulted in a plethora of LM definitions with divergent scopes, objectives, performance indicators, tools/techniques/methodologies, and concepts/elements. The purpose of this paper is to review LM literature and report these divergent definitions, scopes, objectives, and tools/techniques/methodologies.

Design/methodology/approach – This paper highlights various definitions by various researchers and practitioners. A total of 209 research papers have been reviewed for the research contribution, research methodology adopted, tools/techniques/methodologies used, type of industry, author profile, country of research, and year of publication.

Findings – There are plethora of LM definitions with divergent objectives and scope. Theory verification through empirical and exploratory studies has been the focus of research in LM. Automotive industry has been the focus of LM research but LM has also been adopted by other types of industries also. One of the critical implementation factors of LM is simultaneous adoption of leanness in supply chain. LM has become an integrated system composed of highly integrated elements and a wide variety of management practices. There is lack of standard LM implementation process/framework.

Originality/value – The paper reviews 209 research papers for their research contribution, research methodology, author profile, type of industry, and tools/techniques/methodology used. Various characteristics of LM definitions are also reviewed.

Keywords Lean manufacturing, Lean production, Lean literature review

Paper type Literature review

1. Introduction

Twenty-first century manufacturing is characterized by customized products. This has led to the complex production planning and control systems making mass production of goods challenging. Many organizations, particularly automotive organizations, struggled in the new customer driven and globally competitive markets. These factors present a big challenge to organizations to look for new tools and methods to continue moving up the ladder in the changed market scenario. While some organizations continued to grow on the basis of economic constancy, others struggled because of their lack of understanding of the changed customer mind-sets and cost practices. To overcome this situation and to become more profitable, many manufacturers turned to "lean manufacturing" (LM). The goal of LM is to be highly responsive to customer demand by reducing waste. LM aims at producing products and services at the lowest cost and as fast as required by the customer.

The lean concept originated in Japan after the second world war when Japanese manufacturers realized that they could not afford the massive investment required to rebuild devastated facilities. Toyota produced automobiles with lesser inventory, human effort, investment, and defects and introduced a greater and ever growing

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variety of products. LM gives the manufacturers a competitive edge by reducing cost and improving productivity and quality. Various authors have documented quantitative benefits of lean implementation such as improvement in production lead time, processing time, cycle time, set up time, inventory, defects and scrap, and overall equipment effectiveness. The various qualitative benefits include improved employee morale, effective communication, job satisfaction, standardized housekeeping, team decision making, etc.

The generic term "LM" came into existence from the International Motor Vehicle Programme researchers of the Massachusetts Institute of Technology. The project was focussed to bridge the significant performance gap between Western and Japanese automotive industries. Womack *et al.* (1990) through their book *The Machine that Changed the World* popularized lean concept in manufacturing. In early 1990s LM concept was viewed as a counter-intuitive alternative to traditional Fordism manufacturing model (Womack *et al.*, 1990). The modern concept of LM/management can be traced to the Toyota Production System (TPS), pioneered by Japanese engineers Taiichi Ohno and Shigeo Shingo. Sugimori *et al.* (1977) portray TPS made of two components – Just-In-Time (JIT) production system and a respect-for-human system – with focus on active employee participation and elimination of wasted movements by workers. Monden (1983) introduced the JIT concepts to a broad audience in the USA emphasizing the importance of small lot sizes, mixed model production, multifunction workers, preventive maintenance, and JIT delivery by suppliers. TPS itself has undergone tremendous improvement during its journey over the last 40 years (Spear, 2004). The economic success of Japanese companies in the 1980s can also be attributed to the customized integrated application of TQM (Basu, 2001). Toyota was one of the leading Japanese companies which started statistical quality control in 1949 (Dahlgaard and Park, 2006). In a nutshell, it can be said that lean practices were implemented based on several ideologies that appeared prior to it such as JIT (Monden, 1983), Zero Inventories (Hall, 1983), Japanese Manufacturing Techniques (Schonberger, 1982), and TPS (Ohno, 1979; Monden, 1983).

LM over the time has seen a lot of transformations which have been discussed by contributors such as Womack *et al.* (1990), Womack and Jones (1996), Oliver *et al.* (1996), Delbridge (1998), Shah and Ward (2003), Delbridge *et al.* (2000), Bicheno (2004), Hines *et al.* (2004), Holweg (2007), Bhasin (2008), etc. Institutes like Cardiff Business School, SLOAN Management Institute at MIT, Cambridge-MIT Institute's Centre for Competitiveness and Innovation are pioneers in championing the LM knowledge. Many books have also been published by different authors such as Oliver *et al.* (1994), Womack and Jones (1996), Delbridge (1998, 2003), Pascal (2002), Liker (2004), Mann (2005), etc. to enrich the knowledge of lean after the seminal work done by Womack *et al.* (1990) in the book; *The Machine That Changed the World*. LM is generally described from two points of view, either from a philosophical perspective related to guiding principles and overarching goals (Womack and Jones, 1996; Spear and Bowen, 1999), or from the practical perspective of a set of management practices, tools, or techniques that can be observed directly (Shah and Ward, 2003).

The paper is structured as: Section 2 presents the reported definitions of LM. Section 3 presents a review of 209 research papers on LM. Sections 4 and 5 present the descriptive and critical analyses of the review respectively. Conclusions and future research issues are given in Section 6.

2. Various reported definitions of LM

This section presents a compilation of the various reported definitions of LM with connotation. Principles of lean thinking have been broadly accepted by many

production/operation managers and have been applied successfully across many disciplines. Some researchers and practitioners across the world have studied and commented on LM definitions. Intention is to compile the scholarly definitions of LM showing how the principles, objectives, and scope of LM have changed overtime (1988-2012). Pettersen (2009) compared the contemporary literature and concluded that there is no consensus on a definition of LM among the authors. The authors also seem to have different opinions on which characteristics should be associated with the lean concept. This paper presents lean definitions reflecting the changing goals, principles, and scope (Table I).

From the above definitions it is clear that lean may be a way (Storch and Lim, 1999; Howell, 1999), a process (Womack *et al.*, 1990), a set of principles (Womack *et al.*, 1990), a set of tools and techniques (Bicheno, 2004), an approach (NIST, 2000; Taj and Morosan, 2011), a concept (Naylor *et al.*, 1999), a philosophy (Liker, 1996; Cox and Blackstone, 1998; Singh, 1998; Comm and Mathaisel, 2000; Liker and Wu, 2000; Alukal, 2003; Holweg, 2007; Shah and Ward, 2007; De Treville and Antonakis, 2006), a practice (Framework of the LAI, MIT, 2000; Simpson and Power, 2005), a system (Womack and Jones, 1994; Cooper, 1996; Shah and ward, 2007; Hopp and Spearman, 2004), a program (Hallgren and Olhager, 2009), a manufacturing paradigm (Rothstein, 2004; Seth and Gupta, 2005), or *a model* (Alves *et al.*, 2012). Scope of LM includes product development (Krafcik, 1988), operations management (Narasimhan *et al.*, 2006), total supply chain (Womack *et al.*, 1990; Singh, 1998; Naylor *et al.*, 1999; Comm and Mathaisel, 2000; Cooney, 2002), human design element (Shah and Ward, 2003), manufacturing paradigm (Rothstein, 2004; Seth and Gupta, 2005), market demand, and environment changes (Alves *et al.*, 2012). Various goals for which LM is implemented are – to get large variety of products with fever defects (Krafcik, 1988), to integrate product development, supply chain management, and operation management (Womack *et al.*, 1990), to reduce cost/produce more with less (Hayes and Pisano, 1994), to reduce time to delivery (Liker's, 1996), to level the production schedule (Naylor *et al.*, 1999), to improve quality at low cost (Liker and Wu, 2000), to remove waste from system (Worley, 2004), to maximize capacity and minimize inventory (De Treville and Antonakis, 2006), to improve productivity and quality (Bhamu *et al.*, 2012), to achieve agility (Alves *et al.*, 2012), etc. It is clear that there is an absence of common definition of the concept. This lack of clarity is evident from multiplicity of descriptions and terms used with respect to LM (Shah and Ward, 2007). The ambiguity exists because LM evolved over a time (Womack *et al.*, 1990; Spear and Bowen, 1999; Hopp and Spearman, 2004; Shah and ward, 2007). Confusion of definition also exists due to substantive disagreement about what comprises LM and how it can be measured operationally (Shah and Ward, 2007).

3. LM literature review

After the seminal work *The Machine that Changed the World* (Womack *et al.*, 1990) lean has evolved much. Hines *et al.* (2004) discuss about this evolution of lean. They found that the distinction of lean thinking at the strategic level and lean production at the operational level is crucial to understand lean as a whole in order to apply the right tools and strategies to provide customer value. It is unanimously accepted that being lean is more beneficial. Some researchers have pointed out the limitations of the LM. Cooney (2002) opined that batch production still has an enduring value from a work design and manufacturing process perspectives. Bhasin and Burcher (2006) have found that the implementation or adaptation of lean is still facing problems and presented the underlying reasons surrounding low rates of successful lean initiatives.

Sl. no.	Author	Lean manufacturing definition
1.	Krafcik (1988)	Compared to mass production it uses less of everything-half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products
2.	Womack *et al.* (1990)	Lean is a dynamic process of change driven by a systematic set of principles and best practices aimed at continuous improvement. LM combines the best features of both mass and craft production
3.	Womack and Jones (1994)	Lean production can be defined as an alternative integrated production model because it combines distinctive tools, methods, and strategies in product development, supply management, and operations management into a coherent whole
4.	Hayes and Pisano (1994)	Briefly, it is called lean as it uses less, or the minimum, of everything required to produce a product or perform a service
5.	Womack and Jones (1996)	The term lean denotes a system that utilizes less, in terms of all inputs, to create the same outputs, as those created by a traditional mass production system while contributing increased varieties for the end customer
6.	Liker's (1996)	A philosophy that when implemented reduces the time from customer order to delivery by eliminating sources of waste in the production flow
7.	Cooper (1996)	Lean production is a system designed to compete on the assumption that sustained product advantage is unlikely, and therefore rather than avoid competition, face it head-on
8.	Dankbaar (1997)	Lean production makes optimal use of the skills of the workforce, by giving workers more than one task, by integrating direct and indirect work, and by encouraging continuous improvement activities. As a result, lean production is able to manufacture a larger variety of products, at lower costs and higher quality, with less of every input, compared to traditional mass production: less human effort, less space, less investment, and less development time
9.	Cox and Blackstone (1998)	Lean production is a philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities in the enterprise. It involves identifying and eliminating non-value adding activities in design, production, supply-chain management, and dealing with the customers. Lean producers employ teams of multi-skilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in potentially enormous variety
10.	Singh (1998)	Lean manufacturing is a philosophy, based on the Toyota Production System, and other Japanese management practices that strive to shorten the time line between the customer order and the shipment of the final product, by consistent elimination of waste

(*continued*)

Table I.
Definitions of lean manufacturing

Sl. no.	Author	Lean manufacturing definition
11.	Naylor *et al.* (1999)	Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule
12.	Storch and Lim (1999)	Lean production is an efficient way to satisfy customer needs while giving producers a competitive edge
13.	Howell (1999)	A new way to design and make things differentiated from mass and craft forms of production by the objectives and techniques applied on the shop floor, in design and along supply chains aiming to optimize performance of the production system against a standard of perfection to meet unique customer requirements
14.	Framework of the Lean Advancement Initiative (MIT, 2000)	[...] not being merely a set of practices usually found on the factory floor. Lean is rather a fundamental change in how the people within the organization think and what they value, thus transforming how they behave
15.	Comm and Mathaisel (2000)	Leanness is a philosophy intended to significantly reduce cost and cycle time throughout the entire value chain while continuing to improve product performance. This value chain is composed of a number of links. The links exist within government as well as within industry, and they exist between government and industry
16.	Liker and Wu (2000)	A philosophy of manufacturing that focusses on delivering the highest quality product on time and at the lowest cost
17.	Cooney (2002)	Lean takes a broad view of the production and distribution of manufactures, developing a production concept that encompasses the whole manufacturing chain from product design and development, through manufacturing and distribution
18.	Shah and Ward (2003)	Lean manufacturing can be best defined as an approach to deliver the upmost value to the customer by eliminating waste through process and human design elements. Lean manufacturing has become an integrated system composed of highly inter-related elements and a wide variety of management practices, including Just-in-Time (JIT), quality systems, work teams, cellular manufacturing, etc.
19.	Alukal (2003)	Lean is a manufacturing philosophy that shortens the lead time between a customer order and the shipment of the products or parts through the elimination of all forms of waste. Lean helpful firms reduce costs, cycle times and unnecessary, non-value added activities, resulting in a more competitive, agile, and market responsive company
20.	Hopp and Spearman (2004)	Lean production is an integrated system that accomplishes production of goods/services with minimal buffering costs
21.	Haque and Moore (2004)	Lean is by definition an enterprise initiative with a common format for all business processes with the single strategic goal of eliminating waste and improving the flow of value
22.	Rothstein (2004)	Lean production is more commonly considered as a broad production paradigm including an array of manufacturing systems containing some variety of lean practices, such as just-in-time inventory systems, teamwork, multi-tasking, employee involvement schemes, and policies for ensuring product quality throughout the production process

Table I. (*continued*)

Sl. no.	Author	Lean manufacturing definition
23.	Worley (2004)	Lean manufacturing is defined as the systematic removal of waste by all members of the organization from all areas of the value stream
24.	Simpson and Power (2005)	Lean is a practice with the objective to generate a system that is efficient and well organized and devoted to continuous improvement and the elimination of all forms of waste
25.	Seth and Gupta (2005)	Lean production refers to a manufacturing paradigm based on the fundamental goal of continuously minimizing waste to maximize flow
26.	Taj and Berro (2006)	Lean means "manufacturing without waste." The lean approach is focussed on systematically reducing waste (Muda) in the value stream
27.	Narasimhan *et al.* (2006)	Production is lean if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations
28.	De Treville and Antonakis (2006)	Integrated manufacturing system intended to maximize capacity utilization and minimize buffer inventories through minimizing system variability
29.	Shah and Ward (2007)	Lean is a management philosophy focussed on identifying and eliminating waste throughout a product's entire value stream, extending not only within the organization, but also along its entire supply chain network
30.	Holweg (2007)	Lean manufacturing extends the scope of the Toyota production philosophy by providing an enterprise-wide term that draws together the five elements – product development process, supplier management process, customer management process, and policy focussing process
31.	Hallgren and Olhager, 2009	Lean manufacturing is a program aimed mainly at increasing the efficiency of operations
32.	Taj and Morosan (2011)	A multi-dimensional approach that consists of production with minimum amount of waste (JIT), continuous and uninterrupted flow (Cellular Layout), well-maintained equipment (TPM), well-established quality system (TQM), and well-trained and empowered work force (HRM) that has positive impact on operations/competitive performance (quality, cost, fast response, and flexibility)
33.	Alves *et al.* 2012	Lean production is evidenced as a model where the persons assume a role of thinkers and their involvement promotes the continuous improvement and gives companies the agility they need to face the market demands and environment changes of today and tomorrow

Table I.

Shah and Ward (2003) identified 22 lean implementation elements and classified these into four bundles (categories) – just in time (JIT), total productive maintenance (TPM), total quality management (TQM), and human resource management (HRM). Papadopoulou and Ozbayrak (2005) classified the lean literature into six categories – production floor management; product/process-oriented; production planning, scheduling, and control; lean implementation; work-force management; and supply chain management. Moyano-Fuentes and Sacristan-Diaz (2012) reviewed lean production literature and categorized the literature into four areas of internal aspects (shop floor), value chain, work organization, and impact of geographical

context. However, none of the literature reviews papers on LM presents the type of research methodologies, global proliferation of lean research, type of industries where lean is implemented. This section presents the review of 209 scholarly articles during 1988-2012 from 75 international journals and eight conferences (Table II) identifying the research contribution, research methodology, and type of industry where lean is

(A) Journal	Number of references	%
International Journal of Production Research	33	15.79
International Journal of Operations & Production Management	28	13.40
Journal of Manufacturing Technology Management	15	07.17
Production Planning & Control	8	03.83
Integrated Manufacturing Systems	6	02.87
Journal of Operations Management	5	02.39
International Journal of Advanced Manufacturing Technology	5	02.39
International Journal of Quality & Reliability Management	5	02.39
Production Planning & Control: The Management of Operations	4	01.91
International Journal of Production Economics	4	01.91
The TQM Magazine	4	01.91
International Journal of Productivity and Performance Management	4	01.91
International Journal of Logistics: Research & Applications	3	01.44
International Journal of Physical Distribution & Logistics Management	3	01.44
Supply Chain Management: An International Journal	3	01.44
Total Quality Management	3	01.44
Others (two references of each journal)[a]	18	08.61
Others (one reference of each journal)[b]	50	23.93
(B) International Conferences	08	03.83
Total	209	100

Notes: [a]Benchmarking: *An International Journal*, *Business Process Management Journal*, *International Journal of Agile Management systems*, *Journal of Industrial Engineering and Management*, *Lean Construction Journal*, *Management Decision*, *Measuring Business Excellence*, *Total Quality Management & Business Excellence*, *Engineering, Construction and Architectural Management*; [b]*Journal of Psychosomatic Research*, *European Journal of Social Sciences*, *European Journal of Operational Research*, *African Journal of Business Management*, *Asia Pacific Journal of Marketing and Logistics*, *Asian Social Science*, *Assembly Automation*, *British Food Journal*, *Cityscape: A Journal of Policy Development and Research*, *Computers in Industry*, *European Journal of Business and Management*, *European Journal of Scientific Research*, *Indian Foundry Journal*, *Industrial Management & Data Systems*, *Industrial Marketing Management*, *International Journal of Management Practice*, *International Journal of Business and Management*, *International Journal of Flexible Manufacturing Systems*, *International Journal of Lean Six Sigma*, *International Journal of Manufacturing Technology and Management*, *International Journal of Service Industry Management*, *International Journal of Simulation and Process Modeling*, *Journal of Achievements in Materials and Manufacturing Engineering*, *Journal of Advanced Manufacturing Systems*, *Journal of Applied Sciences*, *Journal of Combinatorial Chemistry*, *Journal of Construction Engineering and Management*, *Journal of Intelligent Manufacturing*, *Journal of Management History*, *Journal of Manufacturing Systems*, *Journal of Medical Biochemistry*, *Logistics Information Management*, *Managing Service Quality*, *Manufacturing and service operations management*, *Neural Computing & Application*, *Online Journal of Workforce Education and Development*, *Procedia Computer Science*, *Quality and Reliability Engineering International*, *Quality Safety Health Care*, *Robotics and Computer-Integrated Manufacturing*, *The International Journal of Logistics Management*, *The Leadership & organization Development Journal*, *The TQM Journal*, *World Development*, *IEEE Explore*, *Sloan Management Review*, *Prometheus: Critical Studies in Innovation*, *International Journal of Systems Science; Work, Employment & Society*, *Human Resource Management Journal*

Table II.
Distribution of the reviewed paper in various journals and conferences

applied as shown in Table III. The research papers are presented year wise with profile of the author and country of the authors for descriptive analysis. The critical analysis of the review is presented in Section 5.

Review methodology

These days, the most economic and effective way to carry out research is through the use internet and databases. However, there is so much proliferation of information – effective and non-effective, authenticated and non-authenticated, reliable and non-reliable, and most importantly useful and non-useful. Therefore, Google Scholar is used to start the search for quality research papers. Initially "lean manufacturing," "Toyota production system," "just in time manufacturing," and "lean literature review" were used as the search keywords. Some papers were downloaded but soon it was realized that most of the papers, but not all, related to TPS and JIT manufacturing are not connected to LM. Thereafter, keyword "lean literature review" was used and 45 papers were downloaded. These papers were studied to understand the various research issues being explored by the researchers in LM. It was observed that many of these papers, although provided literature review on LM, also provided case studies on lean implementation. The various researchers implemented LM in case study organizations and some also provided the lean frameworks (conceptual, implementation, strategic, operational, etc.). Seven lean implementation frameworks were studied. It was found that there is no standard LM implementation framework and the crux of this is the lack of dedicated LM implementation tools, techniques, or methodologies. All the reported tools used in LM implementation are stand alone matured tools like 5S, six sigma, TPM, CMS, JIT, VSM, kaizen, etc. So, it was decided to review papers for lean tools, techniques, and methodologies. While reviewing the available papers it was observed that many quality cross-references were missed and a little probing revealed that many of these papers are using the word "lean production" instead of "lean manufacturing." Therefore, these two keywords were again used to get more papers for review. This resulted in 32 papers with term LM and 34 papers with term lean production.

More papers, found through the cross-references, have been reviewed due to their influential role in the development of lean. Ten of these papers are about lean principles, two about lean management, six about leagile manufacturing, 18 about lean six sigma, five about lean supply chain management, two about continuous improvement, and rest 48 about lean tools and techniques. It is pertinent to mention that many papers discuss multiple issues but each paper is categorized in the most suitable category depending upon whether the term is in title, abstract, or body of the paper. Overall 209 papers have been reviewed from over 75 international journals and eight conferences over the period of 1988-2012. But, this set of 209 papers does not include all papers which were used in review of LM definitions. In this empirical research, literature review papers, conceptual papers, descriptive papers, exploratory papers, and empirical papers including case studies, surveys, best practices were included.

There are many limitations to the search methodology. One important limitation was the availability of the papers to the authors. Primary databases searched for the papers were Emerald, Taylor & Francis, Elsevier, IEEE, and Springer publishing groups. Authors wish to make clear that all the papers reviewed may not have these two keywords and all the papers having these two words may have not been reviewed. Many papers were reviewed from cross-references because these contained the required information.

Table III.
Lean manufacturing literature review

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
1.	Krafcik	A	USA	1988	Introduces the term "Lean" in order to describe a production system that uses less resources of everything compared to mass production	Descriptive	–
2.	Delbridge and Oliver	A	UK	1991	Analyze the application of lean in Japanese automotive manufacturers and wide range of performance gap between Western and Japanese assembler through stock turnover data	Empirical	Japanese and Western automotive industries
3.	Barber	P	UK	1992	Provides improvements in quality, productivity, and stock turns through lean implementation in an automotive industry	Exploratory longitudinal	Automotive industry
4.	Badham	A	Australia	1992	Provides an outline of the positive European challenge to lean production models and their implications for global manufacturing	Descriptive	–
5.	Ellegard *et al.*	AP	Sweden	1992	Empirical analysis of mass, lean, and reflective production system in Swedish automotive assembly industry	Empirical	Automotive industry
6.	Jacobs and Meerkov	AP	USA	1993	Analyze the due-time performance index in lean and mass manufacturing environments	Conceptual	–
7.	Frank and Kiupel	A	Germany	1993	Discusses the process supervision of alarm system, based on fuzzy logic in lean production to reduce the redundancy in the decision making	Conceptual	–
8.	Berggren	A	Sweden	1993	Discusses the lean production developments in the auto industry and states that lean production is certainly not the ultimate station of industrial development	Descriptive	–
9.	Wickens	P	UK	1993	Discusses the lean production system, its critics and the future	Descriptive	–
10.	Barker	A	UK	1994	Total time-based value added analysis which aids the design of lean manufacturing systems	Exploratory longitudinal	Electrical switchgear

(*continued*)

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
11.	Prickett	A	UK	1994	Major considerations in the design and implementation of a cell-based manufacturing system	Exploratory cross-section	Fabrication
12.	Sohal and Egglestone	AP	Australia	1994	Empirical investigation of LM implementation in Australian manufacturing companies	Empirical	Automotive, metal processing, rubber, etc.
13.	Ramarapu *et al.*	A	USA	1995	A comparative analysis and review of JIT implementation where elimination of waste and production strategy are the most specific factors	Comparative	–
14.	Karlsson and Åhlström	A	Sweden and UK	1995	The role of the remuneration system in lean production implementation process	Exploratory longitudinal	Mechanical and electronic office equipments
15.	Niepce and Molleman	A	The Netherlands	1996	Analysis of human factors in LM through an empirical study in automotive organization within socio-technical system	Exploratory longitudinal	Automotive
16.	Boyer	A	USA	1996	Assessment of the managerial commitment to lean production to increase the productivity	Empirical	Metal working
17.	Burcher *et al.*	AP	UK	1996	Methodology to assist repetitive batch manufacturers in the adoption of certain aspects of the lean production principles for reduction of inventory	Conceptual	–
18.	Forza	A	Italy	1996	Development of an empirical framework for linkages between human resource management and lean production practices	Empirical	Electronics, auto supplier, machinery, etc.
19.	Kannan and Ghosh	A	USA	1996	Virtual cellular manufacturing for small batch production to increase productivity	Conceptual	–
20.	Karlsson and Åhlström	A	Sweden and UK	1996	Model to assess the changes to introduce lean production principles	Exploratory longitudinal	Mechanical and electronic office equipments

(*continued*)

Table III.

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
21.	Åhlström and Karlsson	A	Sweden and UK	1996	The role of the management accounting system in the lean adoption process	Exploratory longitudinal	Mechanical and electronic office equipments
22.	Katayama and Bennett	A	Japan and UK	1996	The role of LP to overcome the contemporary pressure on Japanese companies	Empirical	Automotive, electronics, refrigerator manufacturing
23.	Sohal	A	Australia	1996	Improvements in product development through lean adoption in Australian windscreen wiper company	Empirical	Windscreen wiper systems
24.	Hines and Rich	A	UK	1997	Outline value stream mapping tools and decision-making process in LM	Empirical	FMCG food product retailer
25.	Jina *et al.*	P	UK	1997	Integration of supplier relationships, marketing and planning, and customer enquiry in a high product variety and low volume sector by applying lean principles	Descriptive	Aerospace and specialist machinery
26.	Åhlström	A	UK	1998	Supports core and supporting principles in parallel and sequence in the implementation of lean production	Conceptual	–
27.	Hines *et al.*	AP	U.K.	1998	Description of VSM approach with its weaknesses. Also a new approach is proposed which involves a strategic review of supply chain activities	Descriptive	–
28.	Bowen and Youngdahl	A	USA	1998	Discusses the transfer of "lean" manufacturing logic into service operations to form the "lean" service	Descriptive	Service
29.	Singh	P	India	1998	LM principles and benefits in context of changing manufacturing paradigms	Descriptive	–
30.	Hines *et al.*	A	UK	1999	VSM approach for supplier integration in a distribution industry together with process benchmarking	Exploratory longitudinal	Electrical and Electronic
31.	Soderquist and Motwani	A	France	1999	Lean quality management in a French automotive supplier industry to gain competitive advantage	Exploratory longitudinal	Automotive

(*continued*)

Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
32.	Howell	P	USA	1999	Applicability of lean production in construction industry to maximize the performance for the customers	Descriptive	Construction
33.	Storch and Lim	A	Korea	1999	Potential application of flow, group technology and value stream lean principles in shipbuilding industry to gain better outputs	Descriptive	Shipbuilding
34.	Robertson and Jones	P	UK	1999	Lean production and agile manufacturing concepts in telecommunications industry	Descriptive	Tele-communications
35.	Biazzo and Panizzolo	A	Italy	2000	Assessment of the lean production in work organizations from workers perspectives	Descriptive	–
36.	Van-Hoek	A	UK	2000	Postponement and information decoupling as relevant contributions for making the agile supply chain a reality with lean capabilities	Conceptual	–
37.	Comm and Mathaisel	A	USA	2000	Eight step paradigms to assess and benchmark lean philosophy in an aerospace company for quality improvement and survival	Descriptive	Aerospace
38.	Bamber and Dale	AP	UK	2000	The effects of management approach, employee attitude, education and training in adopting Kawasaki Lean Production System in an aerospace company	Exploratory longitudinal	Aerospace
39.	Mathaisel and Comm	A	USA	2000	The relevance and value of the lean concepts to increase the productivity in the US defense aerospace industry	Exploratory cross-section	Aerospace
40.	Christopher	A	UK	2000	Comparisons and applications of "leanness" and "agility" as the business survival strategies for industries	Descriptive/ comparative	–
41.	Mason-Jones *et al.*	A	UK	2000	Material flow control principles for selection of lean, agile or leagile strategies as per marketplace need to gain the optimal supply chain performances	Empirical	Precision products, carpet making and electronic

(*continued*)

Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
42.	Sanchez and Parez	A	Spain	2001	Analysis of lean production indicators through integrated lean check-list to assess manufacturing changes	Empirical	Automotive and industrial machinery
43.	Gulyani	P	India	2001	Analysis of transportation system for dynamic gains from lean production and supply chain management	Exploratory longitudinal	Automotive
44.	Pheng and Chuan	A	Singapore	2001	Survey of main contractors in Singapore for adopting the JIT with agile in precast concrete construction operations to cope with schedule fluctuations	Exploratory cross-section	Construction
45.	Arkader	A	Brazil	2001	Formulation of a lean supply path for buyer-supplier relation in the Brazilian auto-firm with organizational, firm specific and environment barriers	Empirical	Automotive
46.	McCullen and Towill	A	UK	2001	Empirical study of agility and lean supply chain integration to reduce the sources of variability and the bullwhip effect, respectively	Empirical	Precision mechanical engineering machinery
47.	Won *et al.*	A	USA	2001	Comparison of two approaches to develop frameworks of the TPS for successful manufacturing system design	Comparative	–
48.	McDonald *et al.*	A	USA	2002	Simulation as a part of VSM tool in a manufacturing product line to facilitates process visualization and reduce the time required in process	Exploratory longitudinal	Industrial motors
49.	Yusuf and Adeleye	A	UK	2002	Threats to lean and the drivers of agile manufacturing through a survey of UK manufacturing firms with a comparative study of these two strategies	Comparative and exploratory cross-section	Food, automotive, aircraft, etc.
50.	Cooney	A	Australia	2002	Lean applicability in batch production in the Australian automotive industry	Descriptive/ empirical	Automotive

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
51.	Aitken *et al.*	AP	UK	2002	Description of models of agile and lean, involving the workers, suppliers and sub-contractors	Descriptive/ exploratory longitudinal	Electrical
52.	Kalsaas	A	Norway	2002	Analysis the subcontractor case of VSM in an Japanese automotive industry by restructuring the production of product families to improve the throughput time	Empirical	Automotive
53.	Shah and Ward	A	USA	2003	Empirically examine the effects of plant size, plant age, and unionization status on lean implementation	Empirical	Chemical, primary metal, chemical, etc.
54.	Motwani	A	USA	2003	Examine the critical factors involved in the implementation of lean tools in an automotive industry through a framework	Exploratory longitudinal	Automotive
55.	McCarthy and Tsinopoulos	A	UK	2003	Introduces a strategic management framework based on the configurationally theory and an evolutionary classification method focussing on the agile concepts	Conceptual	–
56.	Wu	AP	Taiwan/USA	2003	Empirically examine the connection between lean production and various aspects of the logistics system with a comparison between lean V/S non-lean suppliers	Empirical/ comparative	Automotive
57.	Pavnaskar *et al.*	A	USA	2003	Propose a classification scheme to serve as a link between manufacturing waste problems and lean manufacturing tools, and metrics	Conceptual	–
58.	Berry *et al.*	A	Denmark	2003	Establish links between strategic groups' specifically low prices and aesthetic design, and lean manufacturing factors and operational performance	Empirical	Chemical, metal, electronics, etc.
59.	Bruce *et al.*	A	UK	2004	Applications of lean, agile and leagile approaches in the supply chain management of textile and apparel industry to achieve quick response and reduced lead times	Exploratory cross-section	Textile

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
60.	Hines *et al.*	AP	UK	2004	Literature review of lean, expansion beyond the auto industry over time and propose a lean framework at strategic and operation level	Descriptive	–
61.	Agrawal and Hurriyet	A	Australia	2004	Discusses the past, present and future of manufacturing technologies from craft to organic era through lean with the contribution to the growth of supply chain	Descriptive	–
62.	Hopp and Spearman	A	USA	2004	The academic and practitioner literature on pull and lean where specifically pull is a mechanism for limiting WIP and lean is about minimizing the cost of buffering variability	Descriptive	–
63.	Emiliani and Stec	AP	USA	2004	Use of Value-Stream maps for determining the beliefs, behaviors, and competencies possessed by business leaders to improve leadership effectiveness	Conceptual/ exploratory longitudinal	Stamped and welded metal brackets and service
64.	Doolen and Hacker	A	USA	2005	Lean practices assessment in electronic manufacturers where implementation depends on the economic, operational, or organizational factors	Exploratory cross-section	Electronics
65.	Arnheiter and Maleyeff	A	USA	2005	Comparative study of the misconceptions, concepts and techniques of lean, Six-Sigma and lean Six-Sigma	Comparative	–
66.	Furterer and Elshennawy	A	USA	2005	Implementation of TQM, lean and Six Sigma in local government to improve the quality and timeliness of providing services	Exploratory longitudinal	Local government
67.	Huang and Liu	A	China	2005	Development of an algorithmic simulation model and application with VSM in the job shop and flow shop to decrease WIP, inventory and logistics cost	Exploratory longitudinal	Oval-gear flow meter
68.	Modarress *et al.*	A	USA	2005	Method to set kaizen costing to develop financial measurement metrics in lean production system through a case of airplane company	Exploratory longitudinal	Aerospace

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
69.	Salem *et al.*	A	USA	2005	The evaluation of lean construction tools in medium size construction firms to improve last planner, visualization, daily huddle meetings, and first run studies	Exploratory longitudinal	Construction
70.	Seth and Gupta	A	India	2005	Application of VSM in an auto industry to achieve improvement in productivity, production per person and reduction in WIP at supplier end	Exploratory longitudinal	Automotive
71.	Simons and Zokaei	A	UK	2005	Review literature on the applications of logistics and operations management concepts with the application of lean into the red meat industry	Exploratory longitudinal	Food
72.	Comm and Mathaisel	A	China	2005	Application of LM principles and simulation in a labor-intensive textile firm in China to improve the production efficiency	Exploratory longitudinal	Textile
73.	Simpson and Power	A	Australia	2005	Discusses empirically the supplier relationship, lean manufacturing and environment management practices	Conceptual/ exploratory cross-section	Automotive
74.	Taj	A	China	2005	Lean assessment tool to help Chinese hi-tech industries in identifying the areas of productivity lag and opportunities for improvement	Empirical	Electronics, telecommunication and IT
75.	Taylor	A	UK	2005	Application of lean/value chain analysis in agro-food sector to improve supply chain performance, profitability and relationships	Exploratory cross-section	Agro-Food
76.	Papadopoulou and Ozbayrak	A	UK	2005	Literature review of leanness to highlight the evolutional orbit, misconceptions, social aspects and universality	Descriptive	–
77.	Bhasin and Burcher	A	UK	2006	The conceptual discussion of the success and failure of lean implementation	Conceptual	–
78.	Conti *et al.*	A	UK/USA	2006	Assess the effects of LP on physical and mental job stress through a multi-industry empirical study by using Karasek job stress model	Empirical	Automotive, process, metal working, etc.,

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
79.	Andersson *et al.*	A	Sweden	2006	Describe the similarities and differences between the TQM, Six Sigma and lean with an evaluation and criticism of each concept	Comparative/ descriptive	–
80.	Bendell	A	UK	2006	Comparative literature review of six sigma and the lean approaches with the description of a model of business process improvement	Descriptive/ comparative	–
81.	Emiliani	A	USA	2006	The role and importance of Connecticut business and business leaders in discovery and dissemination of lean management in America	Descriptive	–
82.	Kumar *et al.*	A	India	2006	Integrating lean tools within six sigma methodology to achieve dramatic results in cost, quality and time by focussing on process performance in an Indian SME	Exploratory longitudinal	Die casting SME
83.	Parry and Turner	A	UK	2006	The use of lean visual process management tools in aerospace companies to help drive operations and processes in real time	Exploratory cross-section	Aerospace
84.	Weller *et al.*	A	USA	2006	Application of VSM in drug discovery and parallel synthesis to improve the timeliness	Exploratory longitudinal	Drugs
85.	Worley and Doolen	A	USA	2006	Analysis of the role of communication and management support in driving leanness in an electronic industry	Exploratory longitudinal	Electronics
86.	Taj and Berro	A	USA	2006	Application of principles of constrained management and lean manufacturing in an auto-assembly plant to improve the productivity	Exploratory longitudinal	Automotive
87.	Achanga *et al.*	A	UK	2006	Analysis of the critical success factors such as leadership, management, finance, organizational culture and skill and expertise for lean implementation in SMEs	Exploratory cross-section	Manufacturing SMEs

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Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
88.	Bonavia and Marin	A	Spain	2006	Use of LP practices in the Spanish ceramic tile industry, and empirically setting their relationship with plant size and effect on the operation performance	Empirical	Ceramic tile
89.	Braglia *et al.*	A	Italy	2006	Application of "Improved Value Stream Mapping" for a complex Bill of Material case environment to find the critical production path for reducing the WIP level	Exploratory longitudinal	Electro-domestic equipments
90.	Narasimhan *et al.*	A	USA	2006	Literature review and empirical validation of leanness and agility as manufacturing paradigms to improve performance capabilities in manufacturing plants	Empirical	Computers, machine tools, food, etc.
91.	Hines *et al.*	A	UK	2006	Six-step theoretical holistic framework for guiding applied research within the field of new lean product lifecycle management	Conceptual	–
92.	Shen and Han	A	China	2006	Analyzes the benefits of VSM in Electrical Manufacturing Services of China with agile information flow and ERP to achieve sustainable and profitable growth	Conceptual/ exploratory longitudinal	Electrical and electronic
93.	Maguad	A	USA	2006	Literature review comprising the origins, development, and trends of the modern quality movement philosophies, principles, set of ideas and methods	Descriptive	–
94.	Krishnamurthy and Yauch	A	USA	2007	Analyze a theoretical model of leagile manufacturing with a case study in a single corporation with multiple business units	Exploratory cross-section	Forging and die casting, machining, etc.

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
95.	Abdulmalek and Rajgopal	A	USA	2007	Analyze the VSM via Simulation in a process sector (steel mill) to see the significant benefits in reduction of production lead time and lower WIP inventory	Exploratory longitudinal	Large integrated steel mill
96.	Alhourani and Seifoddin	A	USA	2007	New concepts of similarity coefficient and the algorithms required in the designing of a cellular manufacturing system to reduce the material handling cost and WIP	Conceptual	–
97.	Black	A	USA	2007	The four design rules for TPS implementation to reduce the sources of variation in time, while waste and delay in the system are systematically removed	Conceptual	–
98.	Fraser *et al.*	A	Australia	2007	Development and evaluation through a case study of multi-phase model consists technical and human aspects, for cellular manufacturing implementation	Exploratory longitudinal	Electrical and electronics
99.	Lander and Liker	A	USA	2007	Application of VSM in a low volume highly customized artistic clay tile company to gain stability, good control and profit	Exploratory cross-section	Clay tile
100.	Lee	A	USA	2007	Artificial intelligence heuristics evaluation for a simultaneous Kanban controlling and scheduling system to minimize the total production control	Conceptual	–
101.	Lee and Jo	A	South Korea	2007	Analysis of spread of TPS through Korea through focussing on the experience of Hyundai Motor Company for gaining better manufacturing utilization, product quality, etc.	Exploratory longitudinal	Automotive
102.	Lian and Landeghem	A	Belgium	2007	Analyze a VSM-based simulation generator to generate current and future VSM quickly and automatically to see the effects of lean from push to pull system	Exploratory longitudinal	Poultry and pig raising equipments

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
103.	Miltenburg	A	Canada	2007	Examine the best algorithms for finding an optimal schedule and analyses for mixed model JIT production in which *takt* time and cycle time are design variables	Conceptual	–
104.	Oliver *et al.*	A	UK	2007	Examine the interplay in lean product development practices, product attributes and market performance for premium autos and audio products	Exploratory cross-section	Automotive and high-end audio equipment
105.	Reichhart and Holweg	A	UK	2007	Explore the wider conflicts between distribution and LP along through literature review and an automotive case study	Empirical	Automotive
106.	Swamidass	A	USA	2007	Empirical investigation of the effect of TPS on high and low performing US manufacturing firms during 1981-1998 on the ratio of total inventory/sales	Empirical	Computers, machinery metal fabrication, etc.
107.	Takahashi *et al.*	AP	Japan	2007	Comparison of the performances of Kanban control system with theory of constraints by using Markov analysis in JIT production system	Comparative	–
108.	Towill	A	UK	2007	The four level prism model of TPS which assists visualization of the system processes for performance improvement	Conceptual	–
109.	Yavuz and Akcali	A	USA	2007	Review the current analytical literature of production smoothing in mixed-product JIT manufacturing with the description of the practical and modeling issues	Descriptive	–
110.	Jensen and Jensen	AP	Denmark	2007	Discuss start-up phase of implementing lean tools in two SMEs and suggests that 5S tool is good for small and VSM for medium size company	Exploratory longitudinal	Pumps, valves, and agricultural equipments
111.	Rivera and Chen	A	USA	2007	Propose the cost-time profile tool and the cost-time investment concept to evaluate the cost and performance improvements in LM implementation	Conceptual	–

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
112.	Shah and Ward	A	USA	2007	Literature review to find the confusion and inconsistency in LP along with empirical validation of operational measurements in manufacturing firms	Conceptual/ empirical	Electrical, metals, rubber (from SIC code 20-39)
113.	Johansen and Walter	AP	German	2007	Survey for German construction companies to disclose the understanding of lean principles, perceptions of lean and trends in lean	Empirical	Construction
114.	Bayo-Moriones *et al.*	A	Spain	2008	Analysis the role of organizational size and age contexts with AMT, quality management, and work organization practices in JIT implementation	Exploratory cross-section	Food, textile, chemical, etc.
115.	Naslund	A	USA	2008	Comparison of the goals, approaches, tools, history and critical success factors of lean with JIT, six sigma and TQM through literature review	Comparative	–
116.	Seth *et al.*	AP	India	2008	Analysis of various wastes in the supply chain of the Indian edible cottonseed oil industry using VSM approach to improve productivity and capacity utilization	Exploratory longitudinal	Cottonseed edible oil
117.	Brown *et al.*	AP	UK	2008	Compare quality (TQM and six-sigma) and productivity improvement strategies (lean and TOC) along with their implementation investigations in medical sector	Comparative/ empirical	Medical
118.	Lasa *et al.*	A	Spain	2008	Application of VSM in a Spanish plastic parts industry to obtain the highest performance with redesigning of productive system	Exploratory longitudinal	Plastic casing for mobile phones
119.	Shah *et al.*	A	USA	2008	Analyze empirically the combined implementation of lean-six sigma approach in manufacturing plants to see the significant performance benefits	Empirical	SIC code ranging from 20 (food) to 39 (Miscellaneous manufacturing)
120.	Sahoo *et al.*	A	India	2008	Application of lean philosophy, Taguchi's method, and design of experiments in an Indian forging company to improve the performance	Exploratory longitudinal	Forging

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
121.	Jørgensen and Emmitt	AP	UK and Denmark	2008	Review extensive literature on lean construction field for researchers, as a valuable resource which is less mature in comparison to lean production	Descriptive	–
122.	Jayaram *et al.*	A	USA	2008	Examine the relationships in relationship building, lean design, lean manufacturing and firm performance through an automotive supplier case study	Exploratory cross-section	Automotive
123.	Olivella *et al.*	A	Spain	2008	Analysis of work organization practices such as standardization, discipline and control, multi skilling and adaptability, etc. in LP through literature review	Conceptual	–
124.	Pham *et al.*	A	UK	2008	A "Fit" manufacturing paradigm which integrates the manufacturing efficiencies achieved through lean and agility for sustainability in the casting industry	Conceptual/ empirical	Casting
125.	Bhasin	A	UK	2008	Propose dynamic multi-dimensional performance framework which focusses on the intangible and intellectual assets to examine the organizational success in LP	Conceptual	–
126.	Serrano *et al.*	A	Spain	2008	Evaluate the real applicability of VSM to redesign of disconnected flow lines based on manufacturing environments with a diversity of logical problems	Exploratory cross-section	Kit furniture, water heater, forging, etc.
127.	Grewal	A	India	2008	Adoption of VSM in an Indian small bicycle manufacturing firm to achieve reduction in lead time, cycle time and inventory level	Exploratory longitudinal	Bicycle
128.	Piercy and Rich	A	UK	2009	Lean application in a pure service sector to minimize the waiting time in response, cost position with minimal investment and improved quality	Exploratory cross-section	Call service center (Pure service)
129.	Wong *et al.*	AP	Malaysia	2009	Empirical investigation of the actual implementation of lean manufacturing in the Malaysia electrical and electronics industry	Empirical	Electrical and electronics

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
130.	Braglia *et al.*	A	Italy	2009	Presents two alternative approaches based on statistics and fuzzy algebra to include variability analysis in VSM to support practitioners of industries	Conceptual/ exploratory longitudinal	Motor cycle helmet
131.	Gupta and Snyder	A	USA	2009	Review the journal articles with the comparative outlines of TOC, MRP, and JIT manufacturing philosophies	Comparative	–
132.	Cooper	A	USA	2009	Development of the lean manufacturing curriculum implementation model in university in conjunction with competency-based learning activities	Conceptual	Academic institution
133.	Yu *et al.*	A	Canada	2009	Presents data collection, value stream selection, current practice analysis, and specific changes proposed for LP model with a case of construction sector	Exploratory longitudinal	Construction
134.	Fullerton and Wempe	A	USA	2009	Analyze empirically the utilization and impact of non-financial manufacturing performance measures on the LM implementation in the US manufacturing firms	Empirical	SIC codes 20-39 (chemical, industrial machinery, electronics etc.)
135.	Lasa *et al.*	AP	Spain	2009	Analyses the key factors necessary to exploit the full potential of lean concepts and redesign the productive systems of six manufacturing companies using VSM	Exploratory cross-section	Kit furniture, water heater, forging, etc.
136.	Hallgren and Olhager	AP	Sweden	2009	Empirically investigates the leanness and agility in different manufacturing firms with discussions of internal and external drivers, and the performance outcomes	Empirical	Electronics and automotive
137.	Boyle and Scherrer-Rathje	A	Canada and Switzerland	2009	Empirically identify the best practices, tools, and techniques for improving the flexibility in manufacturing organizations	Empirical	Textile, leather and allied products, plastics, etc.

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
138.	Stump and Badurdeen	A	USA	2012	Proposes integration of the strategies POLCA, TOC and FMS, and agile with lean principles in Mass Customization environments with an applicability framework	Conceptual and exploratory longitudinal	Boat
139.	Riezebos *et al.*	A	UK	2009	Review the role of IT in achieving the principles of lean production with special references to production planning and control and computer aided production	Descriptive	–
140.	Wee and Wu	AP	Taiwan	2009	Summarizes the suggestions and ideas for industries to implement lean and demonstrates lean supply chain to reduce cost and improve quality using VSM	Exploratory longitudinal	Automotive
141.	Álvarez *et al.*	A	Spain	2009	Application of the Kanban, Milkrun, and VSM techniques in the automotive assembly line to reduce inventories, transportation and idle times	Exploratory longitudinal	Automotive
142.	Puvanasvaran *et al.*	A	Malaysia	2009	Evaluate the degree of leanness and the roles played by communication process in lean through a case study of a Malaysian aerospace manufacturing company	Empirical	Aerospace
143.	Pettersen	A	Sweden	2009	Investigates the definitions of lean production, methods, and goals associated with the LP concept through the review of contemporary articles	Conceptual	–
144.	Anand and Kodali	A	India	2009(a)	Application of VSM and simulation in a brake lining manufacturing firm having high volume and variety of products to improve the productivity and quality	Exploratory longitudinal	Automotive
145.	Anand and Kodali	A	India	2009 (b)	Application of ANP methodology based on the impacts on the functions of the operations department for selecting LM system in an automotive industry	Exploratory longitudinal	Automotive
146.	Christopher *et al.*	A	UK and New-Zealand	2009	Propose a logical framework for implementation of a scheme for value stream classification and evaluates through a range of industries	Conceptual	–

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
147.	Dentz *et al.*	AP	USA	2009	Application of VSM to identify wastes and target processes for improving labor efficiency and quality in factory home building operations	Exploratory cross-section	Construction
148.	Silva *et al.*	AP	Brazil	2009	Continuous improvement in quality system of a Brazilian automotive parts industry through the CIM, DFMA and LSS methodologies	Empirical	Automotive
149.	Singh *et al.*	A	India	2009	Discussion of the survival strategy to overcome recession by means of lean principles and philosophies followed by interaction with industrial personnel	Exploratory longitudinal	Automotive, IT, Service, etc.
150.	Singh and Sharma	A	India	2009	Application of VSM in an Indian railway sophisticated components manufacturing firm to reduce the lead time, processing time, WIP inventory and manpower	Exploratory longitudinal	Diesel traction fleet processed component
151.	Bergmiller and McCright	A	USA	2009	Discuss the parallel models for Lean and Green systems which include management systems, identification and reduction of waste to achieve business goals	Comparative	–
152.	Villa	P	Italy	2010	Highlights some key concepts of lean, six sigma and automation, and their fit in laboratory organization for improving performance by eliminating the wastes	Exploratory longitudinal	Healthcare laboratory
153.	Rashid *et al.*	A	Malaysia	2010	Assess the lean manufacturing in Malaysian Food SME using VSM to reduce the lead time and number of operators	Exploratory longitudinal	Food
154.	Kemper *et al.*	A	The Netherland	2010	Presents a clear, precise and consistent framework for flowcharts and value-stream flow diagrams in process improvement	Conceptual	–

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
155.	Pepper and Spedding	A	Australia	2010	Examine the literature of integration of lean principles with Six Sigma methodology and provides a conceptual successful integration model	Descriptive	–
156.	Miller *et al.*	AP	USA	2010	Integrates lean and green manufacturing with simulation in a small furniture company to make a positive impact on the environment, society and its finance	Exploratory cross-section	Small furniture
157.	Anand and Kodali	A	India	2010 (a)	Compares the existing literature on LM frameworks and proposes a new conceptual framework to overcome some of the shortcoming of existing frameworks	Comparative/ conceptual	–
158.	Perez *et al.*	A	Spain and UK	2010	Analyze the cultural capability in lean supply and application of lean model in the Catalan pork supply chain to see the impact on the characteristics and the performance	Conceptual and empirical	Pork sector
159.	Chen and Meng	A	China	2010 (a)	Propose a VSM-based production system for Chinese enterprises to help them deploy lean production systematically to increase the competitive ability	Descriptive	–
160.	Saurin *et al.*	A	Brazil	2011	Introduces a framework for assessing the use of LP practices in manufacturing cells of an automotive parts supplier industry	Exploratory longitudinal	Automotive
161.	Vinodh *et al.*	A	India	2010	Application of VSM for enabling leanness in an Indian camshaft manufacturing industry with the improvements in lead time, total cycle time and on time delivery	Exploratory longitudinal	Cam shaft
162.	Singh *et al.*	A	India	2010	Discusses the concept of leanness and development of leanness index for an Indian automotive industry based on judgments of experts	Conceptual	Automotive

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
163.	Al-Tahat	A	Jordan	2010	Investigates the performance of traditional methods and fully automated pattern making processes using VSM to improve process and decision making	Exploratory longitudinal	Foundry
164.	Mollenkop *et al.*	A	USA	2010	Examine the relationships among the green, lean, and global supply chain strategies through existing literature	Conceptual	–
165.	Chen *et al.*	A	USA	2010	Describe the benefits and pitfalls associated with lean philosophy by considering the different organizational elements with some recommendations to new adopters of lean	Descriptive	–
166.	Pool *et al*	A	The Netherland	2011	Application of lean approach in semi-process industry by introducing the cyclic schedules to improve production quality and supply-chain coordination	Exploratory longitudinal	Semi-process (liquid coffee)
167.	Snee	P	USA	2010	Assessment of the development of lean six-sigma over the years through identifying the critical issues and emerging trends for improving the business performances	Conceptual	–
168.	Demeter and Matyusz	A	Hungary	2010	Empirically analyze the impact of lean practices on inventory turnover and the effect of contingency factors to improve the inventory turnover performance	Empirical	Fabricated products, machinery, transport, etc.
169.	Delgado *et al.*	AP	Portugal	2010	Implementation of lean six-sigma in a financial services company to improve processes, product quality and efficiency, and lowering the operational costs	Exploratory longitudinal	Financial services
170.	Chen and Meng	A	China	2010 (b)	Reviews the status of lean; analyze LP in Chinese mainland, and the importance of culture reforms in the organizations to implement lean	Descriptive	–

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
171.	Anand and Kodali	A	India	2010 (b)	Review the LM implementation frameworks and propose a new conceptual framework which consist several levels with associated lean tools/techniques/ practices	Conceptual	–
172.	Grove *et al.*	A	UK	2011	Application of VSM to map out essential tasks for the health visiting services which also includes stakeholders to remove waste processes	Exploratory longitudinal	Health care visiting services
173.	Taj and Morosan	A	China	2011	Empirical investigation of the impact of lean operation practices and the production system design on the performance factors of the Chinese manufacturing plants	Empirical	Electronics, garments, chemical, etc.
174.	Hodge *et al.*	A	USA	2011	Exploratory analysis of the appropriate lean principles in the textile industries and finds VSM is an initial tool from the developed lean implementation model	Exploratory cross-section	Textile
175.	Eswaramoorthi *et al.*	A	India	2011	Survey to identify the status of lean practices and major reasons of snail-paced lean implementation in the Indian machine tool manufacturing	Exploratory cross-section	Machine tool
176.	Staats *et al.*	AP	India	2011	Empirically examine the applicability of LP system in Indian software services firm and the identification of significance of lean in a knowledge-based industry	Empirical	Software services firm
177.	Eroglu and Hofer	A	USA	2011	Examine the inventory leanness for improvements in the US manufacturing firm's performance as it varies substantially across industries	Empirical	Paper mill, automotive, pharmaceutical, etc.

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
178.	Antony	A	UK	2011	Comparison in between Six-Sigma and lean, based on the views of a few academicians and practitioners	Comparative	–
179.	Roy	P	India	2011	Documents a structured approach to overcome practical difficulties in implementing lean management practices in Indian SMEs	Descriptive	–
180.	Yang and Lu	A	Taiwan	2011	Application of lean in conjunction with multiple-attribute decision-making approach and simulation to solve pacemaker location problems in a case company	Empirical	Thin film transistor-crystal display manufacturer
181.	Singh *et al.*	A	India	2011	Review literature of VSM and apply this tool in small manufacturing Indian industry to reduce lead time, processing time and WIP inventory	Exploratory longitudinal	Piston pin SME
182.	Shahin	A	Iran	2011	Propose a conceptual model for enhancing productivity through Group Technology and lean production system, and analyze it for automotive industry	Conceptual/ empirical	Automotive
183.	Wong and Wong	A	Malaysia	2011	Empirical study of the approach of adopting lean, the tools and techniques, the problems and lessons learnt in the Malaysian electrical and electronic industry	Empirical	Electrical and electronics
184.	Losonci *et al.*	A	Hungary	2011	Investigates the employee perceptions during a successful lean transformation in an automotive industry	Exploratory longitudinal	Automotive
185.	Jiménez *et al.*	A	Spain	2011	Applicability of lean tools mainly VSM in wine sector to reduce production lead time and raw material reduction	Exploratory longitudinal	Wine

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Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
186.	Anand and Kodali	A	India	2011	Application of VSM and simulation during the design of lean manufacturing system in PVC door and window manufacturing industry to gain significant improvements in performance	Exploratory longitudinal	PVC Door and window
187.	Vinodh and Joy	A	India	2011	Empirical analysis to measure the lean manufacturing practices prevailing in Indian SMEs through structural equation modeling technique	Empirical	Indian manufacturing SMEs
188.	Cottyn *et al.*	A	Belgium	2011	Introduces an alignment method between manufacturing execution system and lean objectives to prevent the system becoming obsolete with a case example analysis	Conceptual/ exploratory longitudinal	Small furniture
189.	Ramesh and Kodali	A	India	2011	Proposes a decision framework for choosing VSM tool in conjunction with AHP-preemptive goal programming for maximizing performances in the shortest timeframe	Conceptual/ exploratory longitudinal	Automotive
190.	Behrouzi and Wong	A	Malaysia	2011	Presents an innovative approach to evaluate the lean performance systematically by using fuzzy membership functions	Conceptual	–
191.	Gnanaraj *et al.*	A	India	2011	Sensitize through a model the management of SMEs to successfully implement lean Six Sigma in the organizations to improve the delivery time and quality	Exploratory longitudinal	Automotive SME

(*continued*)

Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
192.	Tan *et al.*	A	UK	2012	Proposes a framework and process to assist firms in managing lean capabilities through flexible/ temporary workforce to improve the efficiency and effectiveness	Conceptual/ exploratory longitudinal	Cookware manufacturers
193.	Vimal and Vinodh	A	India	2012	Propose leanness assessment and evaluation model based on fuzzy IF-THEN mechanism, and apply it in a case company also	Conceptual/ empirical	Relay
194.	Atkinson and Mukaetova-Ladinska	A	UK	2012	Describe the lean thinking approach in an ongoing nurse-led liaison service for older adults resulted in improving access to mental health services for elderly medically ill inpatients	Descriptive	Health services
195.	Gupta *et al.*	A	India	2012	Application of lean Six-Sigma methodology in an Indian tyre manufacturing company to reduce the percentage of defective tyres from total monthly production	Exploratory longitudinal	Tyre
196.	Assarlind *et al.*	AP	Sweden	2012	Discusses the multifaceted views on lean Six-Sigma applications	Empirical	Large Swedish manufacturing company
197.	Psychogios *et al.*	A	Greece	2012	Develops a multi-factor application approach for lean Six Sigma in the telecommunications industry along with exploring the critical success factors	Exploratory cross-section	Telecommunication
198.	Powell *et al.*	A	Norway and The Netherlands	2012	Analysis of a capability maturity model to assess the functionality offered by ERP systems to support pull production in small- and medium-sized enterprises	Exploratory cross-section	Agricultural machinery, electronics, hinges, etc. SMEs
199.	Psychogios and Tsironis	A	Greece	2012	Investigate the critical factors influencing the application of lean Six Sigma in an airline company and proposes an integrated framework for the same	Exploratory longitudinal	Airline

(*continued*)

Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
200.	Meiling *et al.*	A	Sweden	2011	Evaluate the lean management principles in off-site manufacturing firms having a sustainable approach of continuous improvement evolving processes, people and long-term thinking	Empirical	Timber-framed module prefabrication SMEs
201.	Hilton and Sohal	A	Australia	2012	Identify the factors for success in deploying lean six-sigma and proposes a conceptual model for the same	Conceptual	–
202.	Subha and Jaisankar	A	India	2012	Elucidate the balanced adoption of lean manufacturing practices for achieving operational benefits	Empirical	Motors, pumps, valves, and auto components
203.	Soni and Kodali	A	India	2012	Evaluate reliability and validity of lean, agile and leagile supply chain constructs in Indian manufacturing industry and proposes a model	Empirical	Automotive, textile, machinery, etc.
204.	Bortolotti and Romano	A	Italy	2012	Analyses lean implementation and process automation through an information based framework in a banking group to improve efficiency and customer satisfaction	Empirical	Pure service sector (Banking)
205.	Agus and Hajinoor	A	Malaysia	2012	Explores lean production supply chain management in Malaysian manufacturing industry toward enhancing product quality and business performance	Empirical	Non-food Malaysian manufacturing
206.	Suarez-Barraza *et al.*	A	Mexico, Spain, Sweden	2012	Analyses the extensive literature which includes applications, conceptual models and categories of lean service	Descriptive	Services

(*continued*)

Table III.

Sl. no.	Author(s)	Profile of Author(s)	Country	Year	Contribution to research	Methodology	Type of industry
207.	Panizzolo *et al.*	A	Italy, India	2012	Investigates the adoption of current state of lean practices in the Indian SMEs to drive significant improvement in manufacturing performance	Empirical	Disposal needles, bearing balls, iron handicraft and brakes and clutches. Indian SMEs
208.	Ming-Te *et al.*	A	Taiwan	2013	Set up lean service performance model and employee characteristic analysis for enhancing production and service performance and human resource utilization	Empirical	Food service
209.	Robinson *et al.*	A	UK	2012	Demonstrates theoretical and empirical perspective of discrete-event simulation and lean approaches to improve processes and service delivery of healthcare	Empirical	Healthcare

Note: A, academician; P, practitioner; AP, academician and practitioner (both)

The different research methodologies used by various researchers are divided into six types – conceptual, descriptive, empirical, exploratory cross-sectional, and exploratory longitudinal (Dangayach and Deshmukh, 2001). The meaning of these research methodologies is given below:

- Conceptual: basic or fundamental concepts of LM.
- Descriptive: explanation or description of LM content or process, performance measurement issues.
- Empirical: data for study has been taken from existing database, review, case study, taxonomy, or typological approaches.
- Comparative: comparison between two or more practices or solutions and the evaluation of the best practice or a solution.
- Exploratory cross-sectional: objective of study is to become more familiar through survey, in which information is collected at one point of time.
- Exploratory longitudinal: survey methodology, where data collection is done at two or more points over time in the same organization.

Various industries have been classified as per International Standard Industrial Classification (ISIC) of all economic activities, Rev.4, Department of Economic and Social Affairs (Statistics Division), United Nations (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=27).

4. Descriptive analysis of the data

Some of the observations, results, and discussion based on the literature review are presented in this section.

4.1 Research methodology

Results shown in Table III show that around one-fourth of papers are conceptual or descriptive in nature discussing the fundamental concepts or description of LM process including performance measurement issues. Three-fourth of papers deal with the theory verification based on empirical or survey methodologies. Table IV reveals that exploratory cross-section studies are less reported as compared to longitudinal and other approaches. This is a very healthy sign in LM research compared with research in other areas where more research is based on exploratory cross-section studies. There are few studies based on the combination of various research methodologies.

4.2 Distribution of research papers over regional basis

As shown in Figure 1, around half the papers are published by authors from USA and UK. Indian authors have also published around 13 percent of the papers. Most of these papers are based on the empirical study of Indian automotive industry. There are authors from many European nations. This demographic representation of authors shows that the LM research and application is spread all over the globe. Surprisingly, the number of articles published by the Japanese is less. One of the reasons for this may be that the Japanese prefer the term Toyota production over LM.

4.3 Distribution of author profile

Most of the research in LM is done by academicians using industry data. In total, 173 authors (82.78 percent) are basically academicians and only ten authors (4.78 percent)

Sl. no.	Type of methodology	No. of references	%
1.	Exploratory longitudinal	55	26.31
2.	Empirical	45	21.53
3.	Descriptive	29	13.87
4.	Conceptual	28	13.40
5.	Exploratory cross-section	22	10.53
6.	Comparative	11	05.26
7.	Conceptual and exploratory longitudinal	7	03.35
8.	Conceptual and empirical	5	02.39
9.	Empirical and comparative	2	00.96
10.	Comparative and exploratory cross-section	1	00.48
11.	Comparative and conceptual	1	00.48
12.	Descriptive and exploratory longitudinal	1	00.48
13.	Conceptual and exploratory cross-section	1	00.48
14.	Descriptive and empirical	1	00.48
	Total	209	100

Table IV.
Research methodologies in LM literature

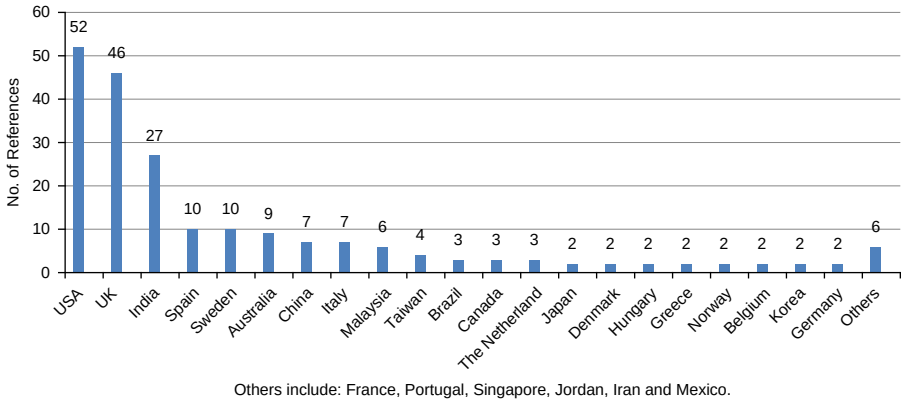

Figure 1.
Number of research papers published by researchers from different countries (as per first author)

are practitioners. In total, 26 authors (12.44 percent) are both academician as well as practitioners as shown in Figure 2.

4.4 Distribution of papers over time

Figure 3 presents the year wise distribution of all 209 articles from 1988 to April 2012. It can be inferred from the data that the research in LM has picked up from the

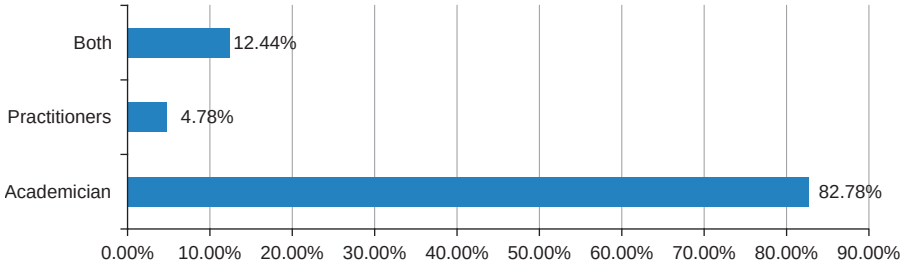

Figure 2.
Distribution of author profile

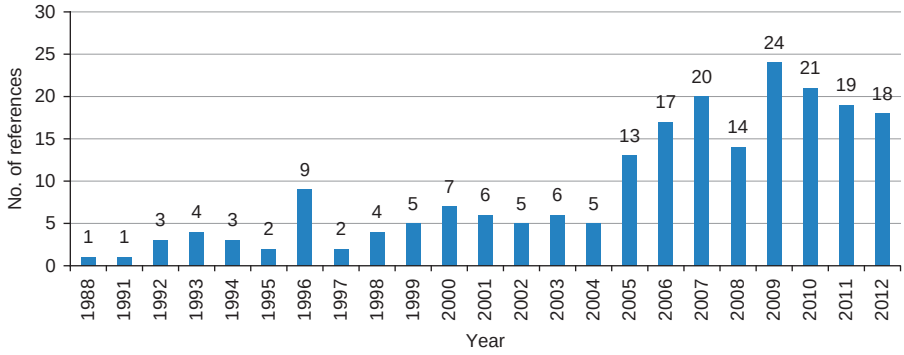

Figure 3.
Year wise distribution of reviewed papers

beginning of the twenty-first century assuming that the research takes few years to compile and publish. One of the reasons for this is the recession in market during this time. The recession forced the organizations and researchers to come out with solutions to decrease the production cost. LM was widely seen to cut cost through waste reduction. Due to the high interest in the subject from early 1990, *International Journal of Operations & Production Management* brought out a special edition on lean production (Vol. 16, No. 2, 1996). These days, there are many international journals on LM.

4.5 Distribution of papers by type of industry

Table V below shows the LM contribution in different industries complied as per ISIC of all economic activities, Rev. 4.

It shows that the maximum numbers of publications are related to transportation sector (automotive and aerospace industry). This sector has seen fierce competition and almost stagnant demand in USA and European countries for almost a decade. At the same time there has been an increase in demand from the emerging economies like China and India. This forced almost all top industries in automotive sector to woo these emerging markets. However, the customers in the emerging markets are very sensitive to price and operative costs which made the automotive sector to look forward to lean implementation to reduce cost. However, the LM implementation started in automobile industry and soon its application was adopted by other industries including textile, construction, service, food, medical, electrical and electronics, ceramic industry, furniture, services, etc. LM has been adopted by all types of manufacturing systems – product layout, process layout, and fixed layout; batch production and mass productions; discrete production to continuous production. It has found applications from manufacturing to service sector; mass production to high variety and small volumes production; labor-intensive industries to technology intensive industries; construction industry to assembly industry; medical health care to communication industry. LM can be applied easily, but there is no single good solution to achieving higher performance, and that the context of operations is of the utmost importance (Lowe *et al.*, 1997; Shah and Ward, 2003).

5. Critical analysis of the review

5.1 Application of lean in small and medium enterprises (SMEs)

SMEs play a tremendous role in manufacturing sector all over the world in term of production volume and employment generation. Globalization and emerging

Table V.
Distribution of references by industry sector

Section	Industry	References
Section C – Manufacturing	Electrical, computer, electronic and optical production	Barker (1994), Hines *et al.* (1999), McDonald *et al.* (2002), Aitken *et al.* (2002), Doolen and Hacker (2005), Worley and Doolen (2006), Shen and Han (2006), Fraser *et al.* (2007), Wong *et al.* (2009), Hallgren and Olhager (2009), Yang and Lu (2011), Wong and Wong (2011), Vimal and Vinodh (2012)
	Fabricated metal production and basic metals	Prickett (1994), Boyer (1996), Emiliani and Stec (2004), Sahoo *et al.* (2008), Pham *et al.* (2008)
	Machinery and equipment n.e.c[a]	Karlsson and Åhlström (1995, 1996), Åhlström and Karlsson (1996), McCullen and Towill (2001), Demeter and Matyusz (2010), Abdulmalek and Rajgopal (2007), Lian and Landeghem (2007), Jensen and Jensen (2007), Krishnamurthy and Yauch (2007), Al-Tahat (2010), Eswaramoorthi *et al.* (2011)
	Motor vehicles, trailers and semitrailers	Niepce and Molleman (1996), Sohal (1996), Soderquist and Motwani (1999), Sanchez and Parez (2001), Gulyani (2001), Arkader (2001), Cooney (2002), Kalsaas (2002), Motwani (2003), Wu (2003), Huang and Liu (2005), Seth and Gupta (2005), Simpson and Power (2005), Conti *et al.* (2006), Kumar *et al.* (2006), Taj and Berro (2006), Lee and Jo (2007), Oliver *et al.* (2007), Reichhart and Holweg (2007), Jayaram *et al.* (2008), Grewal (2008), Braglia *et al.* (2009), Hallgren and Olhager (2009), Wee and Wu (2009), Álvarez *et al.* (2009), Anand and Kodali (2009a, b), Silva *et al.* (2009), Saurin *et al.* (2011), Vinodh *et al.* (2010), Singh *et al.* (2011), Shahin (2011), Losonci *et al.* (2011), Ramesh and Kodali (2011), Gnanaraj *et al.* (2011)
	Other transport equipment[b]	Jina *et al.* (1997), Storch and Lim (1999), Comm and Mathaisel (2000), Bamber and Dale (2000), Mathaisel and Comm (2000), Modarress *et al.* (2005), Parry and Turner (2006), Stump and Badurdeen (2012), Puvanasvaran *et al.* (2009), Singh and Sharma (2009), Singh *et al.* (2011), Psychogios and Tsironis (2012)
	Textile	Bruce *et al.* (2004), Comm and Mathaisel (2005), Hodge *et al.* (2011)
	Food production, Manufacture of beverages	Taylor (2005), Simons and Zokaei (2005), Seth *et al.* (2008), Rashid *et al.* (2010), Perez *et al.* (2010), Pool *et al.* (2011), Ming-Te *et al.* (2013), Jiménez *et al.* (2011)
	Other manufacturing[c]	Weller *et al.* (2006), Bonavia and Marin (2006), Lander and Liker (2007), Braglia *et al.* (2006), Tan *et al.* (2012)
	Human health and social work activities sector	Brown *et al.* (2008), Villa (2010), Grove *et al.* (2011), Atkinson and Mukaetova-Ladinska (2012), Robinson *et al.* (2012)

(*continued*)

Section	Industry	References
	Plastic products	Lasa *et al.* (2008), Anand and Kodali (2011), Gupta *et al.* (2012)
	Furniture	Miller *et al.* (2010), Cottyn *et al.* (2011), Meiling *et al.* (2011)
Section (J)	Information and communication	Taj (2005), Robertson and Jones (1999), Staats *et al.* (2011), Psychogios *et al.* (2012)
Section (O) and (N)	Administration[d]	Furterer and Elshennawy (2005), Bowen and Youngdahl (1998), Emiliani and Stec (2004), Piercy and Rich (2009)
Section (K)	Financial and insurance activities	Delgado *et al.* (2010), Bortolotti and Romano (2012)
Section (P)	Education	Cooper (2009)
Section (F)	Construction	Howell (1999), Pheng and Chuan (2001), Salem *et al.* (2005), Johansen and Walter (2007), Yu *et al.* (2009), Dentz *et al.* (2009)

Notes: [a]Machinery for metallurgy, machinery for food, beverages and tobacco processing, agricultural and forestry machinery, metal-forming machinery and machine tools; [b]along with manufacture of air and spacecraft and related machinery, transport and storage (H); [c]pharmaceuticals, medicinal chemical and botanical products, other non-metallic mineral products, domestic appliances; [d]public administration and defense; compulsory social security, administrative and support service activities

Table V.

technologies have an enormous impact on SMEs around the world. SMEs are trying hard to include new methodologies/principles like lean to achieve performance improvement. Unfortunately, the idea of applying LM has not been adopted by a large number of SMEs due to the fear of implementation cost and the subsequent benefits of lean. Some critical factors for implementation of lean within SMEs include: leadership and management, finance, skill and expertise, performance evaluation system, and culture of the recipient organization (Achanga *et al.*, 2006; Pingyu and Yu, 2010). Panizzolo *et al.* (2012) explored the LM penetration in the Indian SMEs and found that lean implementation strategy drive significant improvement in manufacturing performance. Some of the observations for failure of LM implementation in SMEs are: use of wrong tool, use of one tool to solve all the problems, lack of understanding, and poor decision-making environment. External support from government, suppliers, customers, and outside consultants could enhance the successful implementation of lean in SMEs (Rose *et al.*, 2010). Large manufacturers are more likely to implement LM practices than small ones (Lowe *et al.*, 1997; White *et al.*, 1999; Shah and Ward, 2003). But companies which have used lean tools like TQM, 5S, JIT, etc., observed significant improvements in lead time, delivery cycles, productivity and quality levels, rejection rates, and customer satisfaction (Sohal and Egglestone, 1994; Lowe *et al.*, 1997).

5.2 Application of lean in logistics and supply chain management

Apart from the internal elements and factors, transformation to lean and successful survival also brings into picture the other players in the supply chain namely suppliers, distributors, distribution network, and logistics. Lean supply chain management is a driver toward enhancing product quality and business performance (Christopher and Towill, 2000; Agus and Hajinoor, 2012; Moyano-Fuentes and Sacristan-Diaz, 2012). Given the same organizational constraints and resources, lean suppliers gain significant competitive advantages over non-lean suppliers in production systems, distribution systems, information communications, containerization, transportation, customer-supplier relations, and on-time delivery performance (Wu, 2003). Poor logistics, supplier integration, frequent changes in customer demand, and volatile demand are some of the challenges to be overcome in implementing lean concepts in supply chain management. Poor transportation creates external diseconomies by introducing inefficiencies and unreliability in the supply chain, making it seriously difficult for the manufacturers and assemblers to implement lean production (Gulyani, 2001). Supplier integration is an important issue to be preceded to LM commitment (Jayaram *et al.*, 2008; Hines *et al.*, 1999). Reichhart and Holweg (2007) elucidated the problems and difficulties involved in applying lean concepts to the distribution system. The slow adoption of lean thinking in distribution is due to an inherent conflict between LM techniques and the need to link the production pull signal to variable demand in the marketplace.

5.3 Lack of LM implementation process/framework

During recent years, the application of LM in different types of industries is growing rapidly. Some of the organizations have reported huge benefits, while many industries have not obtained the desired results. One of the reasons for this is improper understanding of LM by both the management and employees of an organization (Anand and Kodali, 2010a). None of the available frameworks/models on LM provide a stepwise guideline or process to implement LM. Some of these frameworks are devoid of lean concepts. Unfortunately many of these frameworks have large number of elements different to each framework. This is perhaps the most undesirable effect of

empirical/exploratory study in LM. There is a strong need to converge these divergent views to some standard framework.

There is no standard LM implementation process/framework. LM has become an integrated system composed of highly integrated elements and a wide variety of management practices (Delbridge, 2003). Though there are sequences in which lean principles are implemented (Womack and Jones, 1996; Åhlström, 1998; Motwani, 2003; Hines *et al.*, 2004; Anand and Kodali, 2010a, b), management nevertheless also need to devote effort and resources (Åhlström, 1998). The lean objectives of waste elimination and zero defects can be achieved through increasing the awareness of lean, identifying and mitigating the lean barriers, changing the organization culture, changing the role of team leaders, delayering the organization, forming a multifunctional teams, increasing the employees commitment level through proper pay and reward system, integrating the whole supply chain from supplier to customer, involving the necessity of innovation and adaptation in the organization, and by using a set of lean principles along with vertical information systems in the organization.

Most the literature has focussed on implementation of the lean tools and techniques/practices in the manufacturing sector (Womack and Jones, 1996; Rother and Shook, 1998; Pascal, 2002; Singh *et al.*, 2010); however, the effectiveness and sustainability of these lean principles has been highly variable (Motely, 2004). Some of the literature has explored/focussed on leadership practices/cultural issues/workers issues/workplace environment rather than lean tools (Oliver *et al.*, 1996; Lowe *et al.*, 1997; Delbridge, 1998; Delbridge *et al.*, 2000; Delbridge and Whitfield, 2001; Spear, 2004; Shah and Ward, 2007) as these issues play key role in the sustainable success of lean journey. A greater role should be given to middle management in performance improvement and strategy formulation (Manville *et al.*, 2012). The viability of LM also depends on the effects it has on the company's external and internal environments (Katayama and Bennett, 1996). The critical issues identified from the review are grouped in pre-implementation, implementation, and post-implementation phases as given below.

LM pre-implementation issues. Successful adoption of lean in any type of industry depends on how well the organization started the implementation plan. The various plans can be grouped into pre-implementation, implementation, and post-implementation phases.

Any organization before implementing LM, must create lean awareness programs for all the employees at different hierarchical levels in the organizations. The objectives of the LM should be cleared to all employees particularly to the front line workers and supervisors. Authors have observed during the implementation of LM at two organizations that shop floor employees have many misconceptions about the objectives of LM and it was very difficult to get the precise operational data from workers. When the objectives were not clear, wrong data were provided to have higher cycle time. It is pertinent to identify lean drivers and barriers for the specific organization. Top management commitment is to be ensured for removing barriers and leveraging the drivers. Develop a full plan of implementation and post-implementation tasks. Some of these prerequisites cannot be taught or forced, but should be developed and nurtured through proper training (Anand and Kodali, 2010a). This phase creates a platform for lean implementation and at the same time eliminates the skepticism surrounding its implementation and benefits. In addition to the seven wastes and unused creativity (Liker, 2004), communication, within organization and with vendors and customers, is another important pre-implementation issue to be addressed. It is essential to sustain this effort and realize the benefits of a long-term commitment to create a quality culture.

Customer focus (Womack and Jones, 1996) is central to lean philosophy. Customer focus revolves around the notion of "defining value from customer perspective," which requires frequent and regular communication with customers. In-house and external education and training programs are important for learning the various tools/techniques/methodologies. Special hands-on training should be conducted for supervisory level in waste identification and categorization.

LM implementation issues. The implementation level focusses on identification and elimination of all forms of wastes throughout supply chain with proper application of lean tools and techniques. To improve performance, lean should lead to collective improvement in all the activities of supply chain – supplier, organization, and customer (Hines *et al.*, 2004; Womack *et al.*, 1990). Effective customer-supplier relationships are widely recognized as crucial to the successful implementation of LM principles to achieve high level of efficiency and effectiveness in the system. On-time delivery by suppliers allows a firm to keep low inventories and shorten response time to customers. Lean supply is associated with level scheduling and optimization to improve quality, service, and lead time (Christopher and Towill, 2000; Wu, 2003). Key aspects of SIPOC (Suppliers, Input, Process, Output, Customer) sub-system should be identified and in each sub-system identify the various types of wastes, standards, and benchmarks to compare. LM implementation involves the implementation and evaluation of lean (application of lean tools/techniques, machine and process stability, quality improvement, inventory control, and evaluation). Outsourcing (maintenance, housekeeping, security, food services, mail, copy services, etc.), collaboration (meet the need of doing more with less), and technology (knowledge sharing, idea generation, cost saving information, ERP) to improve the performance of the system are the key aspects in the production process.

LM post-implementation issues. Mohanty *et al.* (2007) observed that many of the companies that reported initial gains from lean implementation often found that improvements remain localized, and the companies were unable to have continuous improvements. One of the reasons for this can be attributed to lack of proper post-implementation planning. The post-implementation phase completes the lean implementation process. This phase involves observing the outcomes and analyzing the entire process. After implementing lean, the organization needs to be patient in order to observe the positive results. The organization should call for review of the entire process in order to create opportunities for continuous improvement. This level emphasizes the outcomes/results of the lean implementation in term of achievement of goals leading to profitable growth of the organization or benefits arising from LM implementation. Fullerton *et al.* (2003) found a positive relationship between company profitability and the degree of implementation of waste reduction practices. Continuous improvement involves an extended journey, gradually building up skills, and capabilities within the organization to find the new problems/wastes in the system and solving them with the help of different tools and techniques. Post-implementation issues relate to the review of employees for recognition and awards (moral award, position increment, bonuses, recognition by peers, penalty, work environment improvement) and customer for finding customer satisfaction level through customer complaint information, customer complaint analysis, customer services, and customers information system.

The general methodology for lean implementation in an organization, with critical input and output information, is shown in Figure 4. This is a general methodology and depending upon the level of implementation, some steps need not be followed. For example, if the organization wish to implement LM in steps and the need is felt

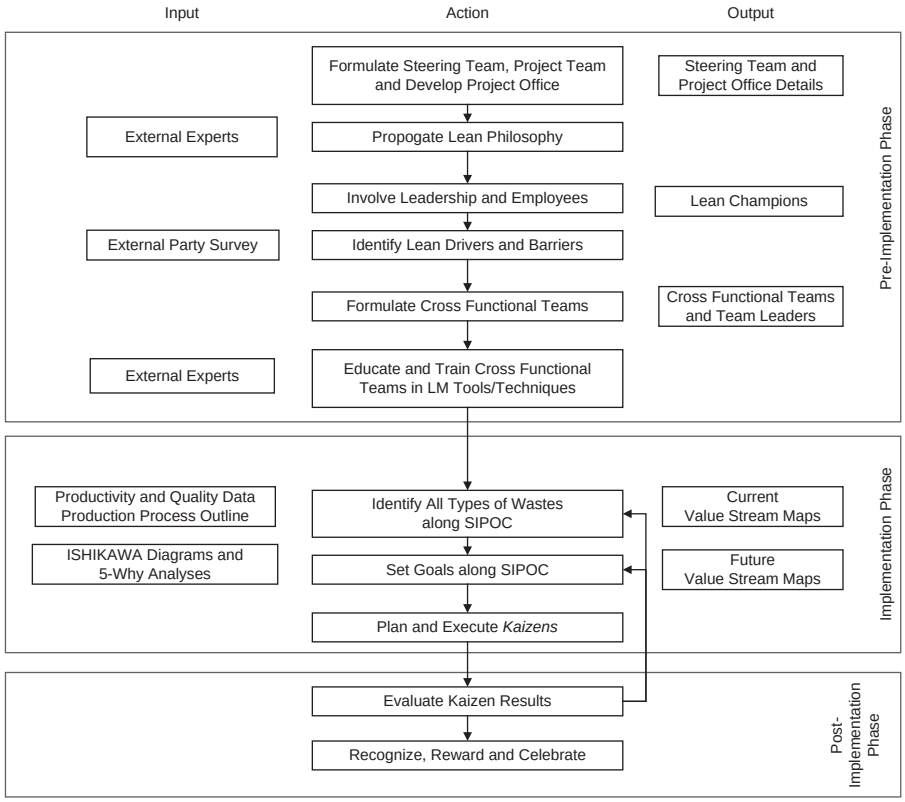

Figure 4.
Lean implementation methodology

at the middle level management, then it can directly start from cross-functional team formation to get the desired results.

5.4 Cultural, work organizational, and HRM issues in LM implementation

The relationship between the LM implementation and organization culture is very sensitive. Different countries have different customs, labor density, degrees of development, industrialization, education, traffic situation, land price, etc. Companies have to take these issues into consideration when applying lean production. Cultural support for lean collaboration is recommended as a precursor to the application of the lean principles (Perez *et al.*, 2010; Chen and Meng, 2010a). Cultural differences pertain mainly to internal resistance and openness to change (Delgado *et al.*, 2010). Success of LM depends largely on the work organization practices. For example, in 1990s Toyota adopted skill-based practices from a seniority-based scheme. Some important work organization practices common to the factories that successfully adopted lean production are: standardization, discipline and control, continuous training and learning, team-based organization, participation and empowerment, multi-skilling and adaptability, common values, compensation and reward system to support lean production, belief, commitment, communication, work methods, etc. (Emiliani and Stec, 2004; Olivella *et al.*, 2008). The early research in LM has pointed out the role of management support, remuneration system, accounting system, etc. (Karlsson and Åhlström (1995, 1996); Boyer, 1996; Worley and Doolen, 2006). Conti *et al.* (2006) used Karasek job stress model to link lean

shop floor practices to expected worker stress and found that the stress is significant only at managerial level in designing and operating a lean system and not at the shop floor level. Globalization has brought increased competition in labor market and many firms today are employing contractual workers in order to help them stay lean and flexible. Firms should manage and train temporary workers to improve the efficiency and effectiveness of the implementation of lean improvement initiatives (Tan *et al.*, 2012).

The organization culture is the base for all involvement activities. Culture is a result as well as an enabler for sustainable and successful lean operations (Liker, 2004; Hines *et al.*, 2008). It is important to involve production team members in checking, reporting, and if possible correcting hidden failures and minor stoppages. These activities boost employee confidence to face future challenges, strengthen an employee's ability to work in teams, provide opportunities to display leadership skills, and enable to solve problems logically. According to Storch and Lim (1999), effective operation of the lean philosophy requires clear communication, not only among operational units, but also among all segments of the value stream. Before implementing lean it is important for everyone to be satisfied with the goals and decisions. Any kind of change requires education and training to adopt it and it is no different in case of lean implementation. In a lean production environment, education and training is required to develop multi-skilled workers. Various factors related to human resource aid in implementing lean philosophy in an organization as shown in Table VI. An important motivational factor is proper remuneration system. This system plays an important role in the lean implementation (Karlsson and Åhlström, 1995). Some of the incentives may be: productivity bonus, if the worker has helped in reducing the standard cycle time of the process; quality bonus, for zero defects in the specified time period; time accuracy bonus, if all orders are delivered on time; etc.

5.5 LM tools, techniques, and methodologies

Since the beginning of the new century many organizations are trying to be lean. This has led to the development/identification of many LM tools, techniques, and methodologies and every day new ones are being proposed. LM has become an integrated system composed of highly inter-related elements and a wide variety of management practices, including 5S, JIT, quality systems, work teams, cellular manufacturing, TPM, Kanban, etc. There are plethora of different tools and techniques for different purposes and waste elimination (Green and Dick, 2001). However, the LM tools and techniques have multiple names; some of them overlap with other tools and techniques, and particular tools/techniques might even have a different method of implementation proposed by different researchers (Pavnaskar *et al.*, 2003). Many of these tools and techniques are used in conjunction with each other to achieve the optimum results. Table VII presents a review of the literary contributions to identify the tools, techniques, and methodologies used in LM.

Table VI.
HR-related important factors for successful LM implementation

Culture (societal and organizational)	Dealing with constraints
Commitment	Performance feedback
Recruiting, hiring, and training	Policy focus and deployment
Communication	Employee development
HR systems	Quality leadership
Diffusing knowledge into decision making	Multifunctional teams
	Roles and responsibilities

Table VII.
Lean tools, techniques, and methodologies used in research

Lean tools/techniques/ methodologies	References
VSM	Hines *et al.* (1998, 1999), McDonald *et al.* (2002), Kalsaas (2002), Emiliani and Stec (2004), Huang and Liu (2005), Modarress *et al.* (2005), Seth and Gupta (2005), Comm and Mathaisel (2005), Taylor (2005), Kumar *et al.* (2006), Parry and Turner (2006), Weller *et al.* (2006), Worley and Doolen (2006), Braglia *et al.* (2006), Shen and Han (2006), Abdulmalek and Rajgopal (2007), Lander and Liker (2007), Lian and Landeghem (2007), Johansen and Walter (2007), Krishnamurthy and Yauch (2007), Seth *et al.* (2008), Lasa *et al.* (2008), Sahoo *et al.* (2008), Serrano *et al.* (2008), Grewal (2008), Wong *et al.* (2009), Braglia *et al.* (2009), Yu *et al.* (2009), Lasa *et al.* (2009), Boyle and Scherrer-Rathje (2009), Stump and Badurdeen (2012), Wee and Wu (2009), Álvarez *et al.* (2009), Puvanasvaran *et al.* (2009), Anand and Kodali (2009b), Dentz *et al.* (2009), Singh and Sharma (2009), Piercy and Rich (2009), Villa (2010), Rashid *et al.* (2010), Miller *et al.* (2010), Chen and Meng (2010a, b), Vinodh *et al.* (2010), Al-Tahat (2010), Grove *et al.* (2011), Hodge *et al.* (2011), Yang and Lu (2011), Singh *et al.* (2011), Jiménez *et al.* (2011), Anand and Kodali (2011), Bhamu *et al.* 2013
Kanban/Pull	Barker (1994), Sohal and Egglestone (1994), Karlsson and Åhlström (1996), Niepce and Molleman (1996), Hines *et al.* (1998), Pheng and Chuan (2001), McDonald *et al.* (2002), Naylor (2000), Wu (2003), Berry *et al.* (2003), Furterer and Elshennawy (2005), Huang and Liu (2005), Taylor (2005), Conti *et al.* (2006), Weller *et al.* (2006), Worley and Doolen (2006), Taj and Berro (2006), Bonavia and Marin (2006), Braglia *et al.* (2006), Abdulmalek and Rajgopal (2007), Lander and Liker (2007), Lian and Landeghem (2007), Jensen and Jensen (2007), Shah and Ward (2007), Lasa *et al.* (2008), Serrano *et al.* (2008), Bayo-Moriones *et al.* (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Puvanasvaran *et al.* (2009), Villa (2010), Rashid *et al.* (2010), Perez *et al.* (2010), Saurin *et al.* (2011), Pool *et al.* (2011), Hodge *et al.* (2011), Singh *et al.* (2011)
JIT	Barker (1994), Prickett (1994), Sohal and Egglestone (1994), Boyer (1996), Forza (1996), Karlsson and Åhlström (1996), Katayama and Bennett (1996), Sohal (1996), Niepce and Molleman (1996), Storch and Lim (1999), White *et al.* (1999), Naylor (2000), Sanchez and Parez (2001), Gulyani (2001), Pheng and Chuan (2001), Yusuf and Adeleye (2002), Kalsaas (2002), Shah and Ward (2003), Wu (2003), Berry *et al.* (2003), Comm and Mathaisel (2005), Chen *et al.* (2005), Conti *et al.* (2006), Taj and Berro (2006), Abdulmalek and Rajgopal (2007), Swamidass (2007), Shah and Ward (2007), Johansen and Walter (2007), Bayo-Moriones *et al.* (2008), Brown *et al.* (2008), Shah *et al.* (2008), Jayaram *et al.* (2008), Wong *et al.* (2009), Fullerton and Wempe (2009)
TPM	Katayama and Bennett (1996), Niepce and Molleman (1996), Hines *et al.* (1998), Shah and Ward (2003, 2007), Berry *et al.* (2003), Huang and Liu (2005), Conti *et al.* (2006), Kumar *et al.* (2006), Bonavia and Marin (2006), Abdulmalek and Rajgopal (2007), Black (2007), Sahoo *et al.* (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Puvanasvaran *et al.* (2009), Villa (2010), Perez *et al.* (2010), Chen and Meng (2010b), Saurin *et al.* (2011), Hodge *et al.* (2011), Jiménez *et al.* (2011)

(*continued*)

Table VII.

Lean tools/techniques/ methodologies	References
5S	Hines *et al.* (1998), Salem *et al.* (2005), Kumar *et al.* (2006), Parry and Turner (2006), Worley and Doolen (2006), Bonavia and Marin (2006), Abdulmalek and Rajgopal (2007), Jensen and Jensen (2007), Johansen and Walter (2007), Krishnamurthy and Yauch (2007), Grewal (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Stump and Badurdeen (2012), Puvanasvaran *et al.* (2009), Silva *et al.* (2009), Villa (2010), Rashid *et al.* (2010), Chen and Meng (2010b), Vinodh *et al.* (2010), Hodge *et al.* (2011), Jiménez *et al.* (2011), Anand and Kodali (2011)
Cellular manufacturing/GT	Barker (1994), Prickett (1994), Delbridge (1998), Naylor (2000), Huang and Liu (2005), Modarress *et al.* (2005), Bonavia and Marin (2006), Abdulmalek and Rajgopal (2007), Alhourani and Seifoddin (2007), Fraser *et al.* (2007), Shah and Ward (2007), Shah *et al.* (2008), Jayaram *et al.* (2008), Wong *et al.* (2009), Fullerton and Wempe (2009), Boyle and Scherrer-Rathje (2009), Puvanasvaran *et al.* (2009), Saurin *et al.* (2011), Hodge *et al.* (2011), Shahin (2011)
Continuous improvement	Barker (1994), Karlsson and Åhlström (1996), Sanchez and Parez (2001), Wu (2003), Berry *et al.* (2003), Simons and Zokaei (2005), Comm and Mathaisel (2005), Conti *et al.* (2006), Swamidass (2007), Shah and Ward (2007), Johansen and Walter (2007), Brown *et al.* (2008), Lasa *et al.* (2008), Shah *et al.* (2008), Puvanasvaran *et al.* (2009), Silva *et al.* (2009), Chen and Meng (2010b), Saurin *et al.* (2011)
TQM	Spencer (1994), Waldman (1994), Boyer (1996), Forza (1996), Katayama and Bennett (1996), Niepce and Molleman (1996), Yusuf and Adeleye (2002), Shah and Ward (2003), Berry *et al.* (2003), Furterer and Elshennawy (2005), Conti *et al.* (2006), Abdulmalek and Rajgopal (2007), Johansen and Walter (2007), Brown *et al.* (2008), Wong *et al.* (2009), Fullerton and Wempe (2009), Boyle and Scherrer-Rathje (2009), Pettersen (2009)
Kaizen	Sohal and Egglestone (1994), Katayama and Bennett (1996), McDonald *et al.* (2002), Modarress *et al.* (2005), Worley and Doolen (2006), Taj and Berro (2006), Braglia *et al.* (2006), Jensen and Jensen (2007), Grewal (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Dentz *et al.* (2009), Silva *et al.* (2009), Hodge *et al.* (2011), Roy (2011), Anand and Kodali (2011)
SMED	Hines *et al.* (1998), Berry *et al.* (2003), Huang and Liu (2005), Worley and Doolen (2006), Jensen and Jensen (2007), Krishnamurthy and Yauch (2007), Grewal (2008), Bayo-Moriones *et al.* (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Stump and Badurdeen (2012), Chen and Meng (2010b), Hodge *et al.* (2011), Singh *et al.* (2011)
Multifunctional teams/employee involvement	Karlsson and Åhlström (1995, 1996), Sohal (1996), Sanchez and Parez (2001), Pheng and Chuan (2001), Comm and Mathaisel (2005), Weller *et al.* (2006), Bonavia and Marin (2006), Shah and Ward (2007), Johansen and Walter (2007), Shah *et al.* (2008), Fullerton and Wempe (2009), Chen and Meng (2010b), Saurin *et al.* (2011)
Production smoothing (Heijunka)	Hines *et al.* (1998), Storch and Lim (1999), McDonald *et al.* (2002), Yusuf and Adeleye (2002), Wu (2003), Weller *et al.* (2006), Braglia *et al.* (2006), Lander and Liker (2007), Yavuz and Akcali (2007), Jensen and Jensen (2007), Lasa *et al.* (2008), Serrano *et al.* (2008), Wong *et al.* (2009), Saurin *et al.* (2011), Pool *et al.* (2011)

(*continued*)

Lean tools/techniques/ methodologies	References
Visual control (Andon)	Hines *et al.* (1998), Furterer and Elshennawy (2005), Salem *et al.* (2005), Parry and Turner (2006), Bonavia and Marin (2006), Johansen and Walter (2007), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Rashid *et al.* (2010), Chen and Meng (2010b), Saurin *et al.* (2011), Hodge *et al.* (2011), Jiménez *et al.* (2011)
Supplier relationship	Hines *et al.* (1999), Sanchez and Parez (2001), Pheng and Chuan (2001), Berry *et al.* (2003), Seth and Gupta (2005), Comm and Mathaisel (2005), Simpson and Power (2005), Conti *et al.* (2006), Taj and Berro (2006), Johansen and Walter (2007), Jayaram *et al.* (2008)
Poke Yoke	Hines *et al.* (1998), Conti *et al.* (2006), Krishnamurthy and Yauch (2007), Shah *et al.* (2008), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Pettersen (2009), Chen and Meng (2010b), Vinodh *et al.* (2010), Hodge *et al.* (2011)
Standardized work	Furterer and Elshennawy (2005), Simons and Zokaei (2005), Lander and Liker (2007), Wong *et al.* (2009), Boyle and Scherrer-Rathje (2009), Rashid *et al.* (2010), Saurin *et al.* (2011)
Simulation	McDonald *et al.* (2002), Huang and Liu (2005), Comm and Mathaisel (2005), Abdulmalek and Rajgopal (2007), Lian and Landeghem (2007), Yu *et al.* (2009), Pool *et al.* (2011), Yang and Lu (2011), Anand and Kodali (2011), Robinson *et al.* (2012)
Automation (Jidoka)	Hines *et al.* (1998), Lander and Liker (2007), Wong *et al.* (2009), Stump and Badurdeen (2012), Pettersen (2009), Villa (2010), Saurin *et al.* (2011)

Table VII.

Table VII shows that VSM has the maximum appearances followed by Kanban/Pull production, JIT, 5S, TPM, cellular manufacturing, kaizen, TQM, SMED, etc. There are numerous practices that can be applied under LM. This is one reason why one finds different individual practices though the focus on LM is the same (e.g. Sohal and Egglestone, 1994; Oliver *et al.*, 1996; White *et al.*, 1999).

5.6 Integration of LM with other systems/philosophies

During the review of papers, it has been observed that most of the papers try to develop a system to deliver the products/services to the customer using *takt* time. Many of the tools/techniques are used in conjunction with each other to further enhance the performance of the system. From strategic point of view, any concept that provides customer value can be in line with a lean strategy. In fact, there is a range of complimentary approaches like ERP, MRP, SPC, agility, Theory of Constraints (TOC), etc. that can and have been used in conjunction with lean (Hines *et al.*, 2004). Winata and Mia (2004) investigated the linkages between JIT, Information Technology for Communication, and broad scope Management Accounting Systems information. Dettmer (2001) presented the differences and similarities between LM and TOC and the ways to integrate them. Systematic application of lean practices and Information Technology system, particularly ERP system can improve the efficiency of the organization even in SMEs (Powell *et al.*, 2012). Miller *et al.* (2010) integrated lean tools and sustainability concepts with discrete event simulation modeling in a small furniture production company to make a positive impact on the environment, society, and its own financial success.

Lean sigma combines the variability reduction tools and techniques from six sigma with the waste and non-value added elimination tools and techniques from LM to generate savings to the bottom-line of an organization (Kumar *et al.*, 2006; Furterer and Elshennawy, 2005). Combining lean practices with six sigma has gained immense popularity in recent years (Shah *et al.*, 2008). A structured and clever cross-fertilization of lean six sigma methodology can be used in a wide range of projects at various levels to tackle specific problems (Assarlind *et al.*, 2012; Gupta *et al.*, 2012; Hilton and Sohal, 2012).

Lean and agile manufacturing are often described as two distinct manufacturing philosophies with different set of goals. Lean basically emphasizes reduction in wastage of resources and an agile system aims to be more flexible and adaptive to changes in the environment and thus has the potential to use more resources (Christopher and Towill, 2000). Despite the differences in end objective, some researchers present lean and agile as strategies that are mutually supportive in the organization (Katayama and Bennett, 1999; Naylor *et al.*, 1999; Robertson and Jones, 1999). Other researchers have advanced the idea of lean and agile manufacturing strategies coexisting through "leagile" manufacturing applied within a manufacturing system or supply chain. Both lean and agile initiatives significantly affect quality conformance, delivery speed, and delivery reliability (Hallgren and Olhager, 2009)

5.7 LM performance measurement system

Undeniably, there are certain guidelines which organizations need to contemplate in their efforts to implement an effective performance measurement system for LM. Frequently, organizations use generic measures with little consideration of their relevance to LM (Bhasin, 2008). The challenge is to choose the right measures for the appropriate level of the organization (Booth, 1996). If inappropriately planned, the

measures can run counter to the strategy and thus encourage the wrong type of behavior in the lean journey. Bhasin (2008) provided a LM performance template including performance metrics related to finance, customer/market, process, people, and future. However, some of the information required to use the template is hard to get and the information required is also exhaustive. Vimal and Vinodh (2012) computed leanness level using IF-THEN rules. However, there is a need to develop few critical metrics to justify LM adoption before, during, and after implementation.

6. Conclusions and future research issues

This paper compiles various reported definitions of LM reflecting the changing goals, principles, and scope of LM. This paper also presents a review of 209 research papers on LM/lean production during 1988-2012. The review focusses on research contribution, research methodologies, type of industry, and author profile. Following conclusions can be drawn from the review:

- Theory verification through empirical and exploratory studies has been the focus of research in LM. More research is based on exploratory longitudinal studies rather than exploratory cross-section studies. Research on LM is conducted across the globe. There are papers from the developed, emerging, and under developed countries. However, USA and UK lead the research with more publications.
- The research in LM has picked up from early twenty-first century. Automotive industry has been the focus of LM research but LM has been adopted by other type of industries also. However, the adoption of LM in SMEs is not widespread. Because of the fear of high implementation cost and uncertain future benefits. Some sort of external support is required to enhance adoption of LM in SMEs. Success of LM depends largely on the cultural and work practices prevalent in organizations.
- LM has been adopted by all types of manufacturing systems – product layout, process layout, and fixed layout; batch production and mass productions; discrete production to continuous production. LM has found applications from manufacturing to service sector; mass production to high variety and small volumes production; labor-intensive industries to technology intensive industries; construction industry to assembly industry; medical health care to communication industry.
- One of the critical implementation factors of LM is simultaneous adoption of leanness in supply chain. One of the reasons for the slow adoption of LM under variable demand scenario is to link the production pull signal to the variable demand.
- LM adoption led to more stress at managerial level rather than the shop floor level people.
- There is lack of standard LM implementation process/framework. LM has become an integrated system composed of highly integrated elements and a wide variety of management practices. Various issues during pre-implementation, implementation, and post-implementation phases of LM have been identified in this paper. It is expected that this identification of various issues would help the managers to effectively develop their implementation plan.
- Some chronicle changes observed in LM research is given in Table VIII.

Table VIII.
Some chronicle changes in LM

	Phase I, before 1994	Phase I, 1994-1999	Phase II, 2000-2005	Phase III, 2006 +
Focus area	Cost reduction and productivity improvement	Customer satisfaction in terms of quality, cost, and delivery	Value system, lean consumption, and lean expands up to enterprise level	Value creation and innovation
Knowledge propagation	Origin and development of the philosophy	Lean dissemination begins at larger level (MIT IMVP Study)	Lean propagates in to product development, marketing, sales, service, accounting, etc.	Performance phase. Development of new principles
Type of methodology	Mainly descriptive and conceptual studies	Mainly conceptual and descriptive studies. Start of empirical studies	Mainly empirical and exploratory studies	Mainly exploratory longitudinal studies

Limitations and Future research issues

- Some quality papers on LM may have been left out of this review because of the limitations in the search methodology. There are large number of papers on the LM and its tools/techniques/methodologies and it was practically impossible for the authors to get these papers as well as review all the papers.
- The research on LM through empirical and exploratory studies has led to many frameworks with divergent views. Use of a wide variety of management practices has led to different views devoid of concepts. There is a strong and urgent need to converge these divergent views to some standard framework/process. Development of stepwise guideline/process for LM implementation like TPM, TQM, or six sigma is strongly required.
- Within the framework of this research, several issues are pertinent to the exploration of practical and theoretical aspects of the implications of employee engagement in LM environments. With respect to this research, it has been noted that many empirical studies have been conducted that survey the opinions of senior levels of leadership, yet few studies exist that explore the dichotomy of blue-collar manufacturing employees and front-line supervisors (Delbridge, 2003; Manville *et al.*, 2012).
- The use of wide variety of management practices in LM implementation has led to a wide variety of generic performance indicators. There is a need to develop LM standard/critical metrics for its evaluation before implementation, during implementation, and after implementation.
- Various researchers in LM have used more than 18 tools/techniques/methodologies. Most of these tools/techniques/methodologies are standalone methods developed and used previously. Further research is required to distinguish the standard tools/techniques/methodologies for LM. Similarly, there are other systems like six sigma, agile manufacturing, and green manufacturing which have some elements of LM. More research is also required to distinguish the common and different elements of LM, agile manufacturing, six sigma, and green manufacturing.

The genesis of divergent views on LM perhaps lies in its divergent definitions, objectives, and scope. The researchers have developed LM as a way, process, set of principles, approach, concept, philosophy, system, program, and paradigm. The most urgent need is to standardize the LM definition, converge LM scope, and to synthesize the LM objectives to converge to a few critical objectives.

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