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Lean Manufacturing Practices: A Structured Literature Review

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Abstract - **The goal of this study was be to provide structured literature review (SLR) and systematic insight of lean manufacturing practices, identifying gaps in knowledge and directing future research in the discipline of lean manufacturing. The study objectives were to: determine various research designs, research methods and data analysis methods that have been adopted to evaluate the practice of lean manufacturing; evaluate publishers, themes, university of author affiliation geographic locations, and industry engagement evolving all through the years and to establish research issues that will inspire research paradigm for future researchers in the discipline of lean manufacturing. This study identified and synthesized information from academic articles based on their data analysis techniques, research designs and methods, industry engagements, geographic locations, university of author affiliation, publishers and year of publication. Online database collection over the past 25 years focusing on lean manufacturing from 1996 to 2021 were explored with aid of the keywords "lean manufacturing"," lean manufacturing practices" and "lean manufacturing systems" in the title and/or abstract to provide a full list of journal articles. The review provided better understanding of the current state of research, dimensions and future directions of research in the lean manufacturing field. A total of 126 articles were retrieved based on this method and data was retrieved from a set of variables. In the last 25 years, there has been a gradual increase and concentration of researchers focusing on the lean manufacturing field. As globalization progresses, it is widely recognized that best practices need to be implemented because of scarcity of resources. This study revealed that 33.33% of the journals in this area of study were survey based and this trend in research indicates development of the multi-criterion decision-making and structural equation modelling methods. The study revealed that 86 articles were from between 2010 –2014 and 2016–2021 of the total summation of 126 articles published. This study paper was narrowed in reviewing academic journals from online academic archives, with the words "lean manufacturing", "lean manufacturing practices "and "lean manufacturing systems" in their title cam abstract. Similarly, high quality peer-reviewed journal articles were rated. Other scientific sources such as books and conference papers are not considered in this paper. This review provides a better understanding of the current state of affairs, trends and future research direction lean manufacturing field.**

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Index terms- **lean manufacturing, lean manufacturing practices and lean manufacturing systems**

I. INTRODUCTION

With intensified competition, sustainable development has pushed organizations to update their manufacturing systems to a smart level through adoption of lean manufacturing practices. Adoption of lean manufacturing improves organization's operational performance (Demeter and Losonci, 2011; Ramachandran &Alagumurthi, 2013). In the last 25 years, lean manufacturing has is defined as one of the main operations management tool (Samuel & Williams, 2016; Danese et al., 2018; Bellisario & Pavlov 2018; Hines et al., 2020).Afterthemid-1990s, the importance of lean manufacturing increased noticeably among practitioners (Alefari et al., 2017). Consequently, the study of lean manufacturing practices has developed rapidly. Lean manufacturing refers to a multidisciplinary dimension that involves production with reduced waste levels, by adopting operations management tools to yield competitive performance (Taj and Morosan 2011). Similarly LM is demonstrated a model involving where the human resources taking the function of thinkers and involving them facilitates traceable performance by boosting production capacity needed by companies to address the dynamic business landscape, aiming at focusing on sustainable future (Alves et al., 2012). In developing markets, with increasing customer demands, adoption lean manufacturing is a basic approach in most companies and organizations (Ramachandran and Alagumurthi,2012).

Because of the development and ambiguity of today's business landscape, lean manufacturing practices is key in ensuring smooth organizational operations (Nawanir et al., 2013; Valente et al., 2019; Rahman et al., 2010; Hernandez-Matias et al., 2019 & GodinhoFilho et al., 2016). Further, companies increasingly focus on adoption of lean manufacturing practices so as to foster robust manufacturing performance (Wickramasinghe and Wickramasinghe, 2017). This places lean manufacturing practices as a systematic management system with an orientation of minimizing waste from the product line (Scherrer-Rathje et al., 2009).

A (SLR) on lean manufacturing practices was conducted by majoring in this field of study, synthesizing appropriate evidence from academic journals articles, focusing on research designs, research methods, data analysis methods, industrial input and geographic locations. Similarly, statistics regarding university of author affiliation affiliations, publishers and year of publication and was analyzed. Data set spanning from

1995 to 2021 in databases with the keyword "lean manufacturing", "lean manufacturing practices" and "lean manufacturing systems" in respective title cam abstract, was considered for the study and its result generated a comprehensive list of lean manufacturing journal write-ups. An advanced bibliographic information of the journal articles considered for this study are in the appendix to proof study openness and by adopting an exclusive study. The published journal articles were classified and clustered in accordance with their respective research methodologies. Besides that, the journal articles were analyzed in a catalogue generated in Microsoft Excel.

Currently, there is a lack of classified literature review investigating by analyzing the dynamic literature in lean manufacturing (Jasti and Kodali 2014, 2015). Hence architecting for the importance for a robust and detailed review of literature in the key dimensions of lean manufacturing that have not yet been discovered is also suggested by (Marodin and Saurin, 2013 & Aguezzoul, 2014).

II. Research Objective

This study was anchored on the following research objectives;

a. To determine various research designs, research methods and data analysis methods that have adopted been adopted to evaluate the practice of lean manufacturing.
b. To evaluate publishers, themes, university of author affiliation geographic locations, and industry engagement evolving all through the years.
c. To establish research issues that will inspire research paradigm for future researchers in the field of lean manufacturing.

III. Research questions

This study was anchored on the following research questions;

a. What are the various research designs, research methods and data analysis methods that have adopted been adopted to evaluate the practice of lean manufacturing?
b. How has publishers, themes, university of author affiliation geographic locations, and industry engagement evolving all through the years?
c. What is the inspire research paradigm for future researchers in the field of lean manufacturing?

IV. Scope of the Study

The study was focused on the literature review on adoption of lean manufacturing. Thus, the study sort to establish the interplay relationship of lean manufacturing in the aspect of research designs, research methods, data analysis techniques university of author affiliation, publishers, year of publication, industry engagements and geographic locations. Time frame that was be covered was from September 2021 to December 2021.

V. Significance of the Study

For the government, this study may provide a better insight into the adoption of lean manufacturing schemes. It helps to develop policies and regulations that will help improve the efficiency and effectiveness of the sector and reforms in the manufacturing sector can lead to GDP growth and thus job creation. Improvements in lean manufacturing can reduce trade flows and export costs, create export incentives, improve the prices of goods and services, and create reliable manufacturing sectors.

Manufacturers can benefit from this study because this study addressees better understanding of the underlying lean manufacturing practices that affect company performance and elimination of barriers that hinder lean production success. The study recommends that efficient and efficient lean manufacturing practices provide the basis for organizational growth, productivity gains, reduced production costs, delivery improvements, quality products and better customer satisfaction.

In the scientific world, this research will also benefit the academic community as it contributes to the growing literature on building lean. It has the potential to provide a lean manufacturing framework that can be used as a testing base for further research. In general, this study contributes to theoretical and practical improvements in the adoption, implementation and modernization of lean manufacturing practices in a variety of cultural and business environments.

VI. Research limitations/implications

This study was narrowed in reviewing academic journals from online academic archives, with the words "lean manufacturing", "lean manufacturing practices "and "lean manufacturing systems" in their title cam abstract. Similarly, high quality peer-reviewed journal articles were rated. Other scientific sources such as books and conference papers are not considered in this paper.

VII. Originality

This review provides a better understanding of the current state of affairs, trends and future research direction lean manufacturing field.

VIII. Research Philosophy

This study was anchored on assumptions that are philosophically constituted, scientifically approved and significant method(s) to facilitate its realization, (Bryman and Bell, 2007). Which entail the assumptions about the scientifically proved phenomena (ontological), human knowhow (epistemological) and the level of influence by the researcher based on the data analysis and generation of the research findings (axiological), (Saunders *et al*., 2009). Assumptions developed a link among the data collection tool, adoption of the methodology, techniques of data collection and generation of findings and recommendations. In relation to social sciences, Dudoviskiy (2016) demonstrates various scholarly philosophies; interpretivism realism, pragmatism and positivism. Collins and Hussey, (2009) interpretivism and

positivism are completely two different approaches that cannot be adopted at the same time in a scientific fact finding mission.

Positivist research paradigm was adopted for this study. It is of the understanding that information obtained by observation by adopting measurement is authentic, (Saunders *et al.*, 2009). Besides, positivism is of the view that a researcher is limited to data collection and interpretation by an objective approach with findings observable and quantifiable, (Collins and Hussy, 2009). This study is researcher interference free and the study is not providing for a window for human interests. The study purely relies on quantifiable observations which results to statistical analysis, (Dudovskiv, 2016). Positivism paradigm based studies are entirely facts oriented and treats the world as external and objective state, (Wilson, 2009. The adopted methodology is quantitative, involving vastly structured research question testing and statistical tools in this philosophy, (Novikov & Novikov, 2019).

IX. Methodology

With review of literature, the adopted methodology was qualitative research design focusing on lean manufacturing practices spanning from 1996 to 2021 with the aid of the keyword "lean manufacturing", "lean manufacturing practices" and "lean manufacturing systems" in their title cam abstract was considered for this study.

X. Prelude to Literature Review

Prelude to LR is a starting point of any logical review of the existing available literature (Denyer and Tranfield, 2009). Literature review is a logic, simple and traceable method to determine, quantify and understand the existing-related field of study (Winter and Knemeyer, 2013; Seuring and Muller, 2008 and Fink, 1998). A systematic approach to literature evaluation is considered as a means of identifying and analyzing data, with the aim of finding clear conclusions, and identifying the gap for future research opportunities in the field of study (Denyer and Tranfield, 2009 & Jafari 2015). With this understanding, a (SLR) was be implemented to develop an understanding, determine emerging practices and defining future research paradigms. Literature validation, symbolizes an effective relationship dur9ing analysis of data systematically.

XI. Steps Followed for Reviewing the Literature

This study was based on a five-step SLR approach (see Figure 1), (Saenz and Koufteros,2015; Malaviya and Kant, 2015; Seuring and Muller & 2008 Soni and Kodali, 2011):

- ✓ Step 1.Articles spanning in a 25 year period, from 1996 to 2021.
- ✓ Step 2. Data harvesting was based in five databases: Taylors and Francis; Springer; Emerald; Science direct and JSTO.
- ✓ Step 3. An advanced search with keywords "lean manufacturing", "lean manufacturing practices" and "lean manufacturing systems" was administered based on the title cam abstract in the five databases. This method was also recommended by (Malaviya and Kant, 2015 & Soni and Kodali, 2011).
- ✓ Step 4. the journal articles were then analyzed in a catalogue generated in Microsoft Excel as a data analysis tool to determine the gradual change in the past 25 years.
- ✓ Step 5. Is the last step, which was based on three outcomes; research gaps, significant of the findings and directions for future researchers in the field of lean manufacturing.

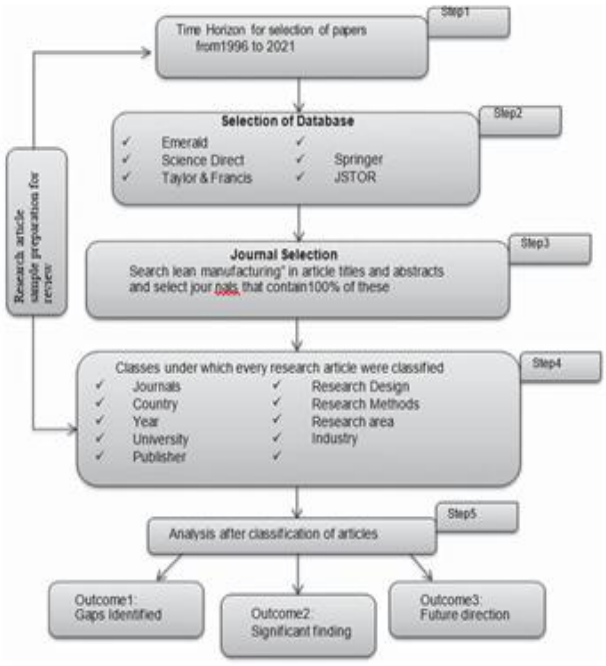

Figure1: Sources: Adapted from Seuring and Muller (2008), Soni and Kodali (2011) and Malaviya and Kant (2015)

XII. Inclusive and Exclusive Criteria

Beside the steps adopted an inclusive and excusive criteria in table 1 was incorporated to define the boundaries for a structured literature review.

Table 1: Inclusive and Excusive Criteria

Inclusive	Excusive
Articles published between 1996 and 2021	Any scholarly articles published before 1996 and after 2021
Data harvesting from five databases: Taylors and Francis; Springer; Emerald; Science direct and JSTO.	Non-scholarly databases
Scholarly journal articles	Text books, book series, book chapters, gray literature and online sites.

Inclusive	Exclusive
Scholarly published journals articles in the field of Lean manufacturing, production, principles, practices/tools/ techniques	Journal articles studying stand-alone Lean principle or tool/ technique or bundle of practices, lean-Green management and Lean-Agile manufacturing
Academic publications focusing on research gaps	Publications not focusing on research gaps
Journals written in English language	Journals written in any other language but English

Source: Researcher, 2022

XIII. Review and Discussion

It entails a snapshot of the LR guided by the proposed a five-step SLR approach to attain the objective of this study. The review outcomes are demonstrated in figures and tables to validate and legitimize the sources for the data analysis.

XIV. Journals Distribution

64 journals were considered for this study as demonstrated in table 2. Moreover, table 2 represents range of published articles and shows a properly-defined framework of the highest and lowest articles published. Table 2 also shows that International Journal of Lean Six Sigma and International Journal of Production Research published the highest numbers of articles (10), International Journal of Advanced Manufacturing Technology (8), Journal of Manufacturing Technology Management and Journal of Cleaner Production (7), International Journal of Operations & Production Management (6), Journal of Manufacturing Systems and Production Planning & Control (4), Journal of Operations Management, International Journal of Production Economics and SAE International Journal of Materials and Manufacturing (3), International Journal of Productivity and Performance Management, International Journal of Quality & Reliability Management, Journal of Modelling in Management, Journal of Modelling in Management, Procedia Manufacturing, Measuring Business Excellence, Measuring Business Excellence and Cogent Engineering (2). More journals were also published in to lean manufacturing as shown in Table 2. This indicates the affiliation of quality journals in the direction of the modern literature in the field of the lean manufacturing and supports the practitioners and scholars in this field of study.

XV. Distribution by Year

Figure 2 indicates that 126 published journal articles were reviewed in the previous 25 years, which depicts an ascending fashion of the various publications journal articles on lean manufacturing, culminating to notable increase in the number of published articles (86) over the last 10 years throughout the intervals of 2010–2014 & 2016 to 2021. This depicts a significant awareness and focus amongst scholars in the field of lean manufacturing. To the contrary, an intense decrease in published articles between 2015 is significant and there is no defined causation.

XVI. Distribution by Universities

Geographic university affiliation primarily based on number of peer-reviewed articles as shown in table 3. A grand total of 102 institutions/facilities/universities have lead authors who investigated and researched lean manufacturing practices. Moreover, table 3 indicates the utmost universities affiliated to lean manufacturing field. Their participation varies from 2 to 6 published articles. The table also shows that Birla Institute of Technology & Science, Pilani, (India) has the highest articles affiliated to LM. Therefore, it is the lead centre in the field of LM, followed by National Institute of Technology, (India) & Western Michigan University, Muskegon, MI, (USA).One the other hand, 100 universities/college/institutions were related only once or twice of the published journal articles.

A similar intensified analysis will gradually aid experts and scholars in figuring out the most active academic institutions worldwide in the field of LM.

XVII. Distribution by Publishing Source

Five major publishers were acknowledged: JSTOR, Springer, Emerald, Science Direct & Taylor and Francis as shown in Figure 3. Figure 3 indicates that majority of the published articles were from Emerald published with 37 articles on Lean manufacturing practices, Taylor and Francis with 29 articles, Science Direct with 24 articles Springer with 17 articles and JSTOR with 23 articles. The adopted databases are reputable with rich literature in the field of lean manufacturing practices, and published significant research consumed by both experts and scholars.

XVIII. Classification Based on Country

The evaluation of lean production practices studies categorized country facilitate experts and scholars with necessary statistics on the geographical distribution of LM practices. 126 published journal articles were distributed across 33 countries around the world as shown in figure 4. Out of 126 published journal articles, figure 4 also points out that USA scholars contributed the majority comprising of 33 publications and India 23 publications. Other than USA and India, several countries like Brazil, UK, Indonesia, Malaysia,

Australia, Canada, England, France, Italy, Netherlands, Spain and Sweden are part of the majority countries addressing lean manufacturing practices studies.

Egypt, Greece, Iran, Belgium, China, Colombia, Ireland, Jordan, Kuwait, Mexico, Norway, Pakstan, Palestine, Singapore, Sri Lanka, Taiwan, Turkey, Iran and Austria are categorized as nations were the statistics on published articles on lean manufacturing is relatively low as indicated in figure 4.

Table 2: Journal publications per data base

Data Base	Name of journals	Number of articles	%
Emerald		**37**	**29.37**
	Benchmarking: An International Journal	1	0.79
	Engineering, Construction and Architectural_Management	1	0.79
	Human-Resource-Management-International-Digest	1	0.79
	Industrial Management & Data Systems	1	0.79
	International Journal of Lean Six Sigma	10	7.94
	International Journal of Operations & Production Management	6	4.76
	International Journal of Productivity and Performance Management	2	1.59
	International Journal of Quality & Reliability Management	2	1.59
	Journal of Advances in Management Research	1	0.79
	Journal of Manufacturing Technology Management	7	5.56
	Journal of Modelling in Management	2	1.59
	Leadership & Organization Development Journal	1	0.79
	Measuring Business Excellence	2	1.59
Science Direct		24	19.05
	The Journal of Emergency Medicine	1	0.79
	Procedia Manufacturing	2	1.59
	Journal of the American Dietetic Association	1	0.79
	Journal of Operations Management	3	2.38
	Journal of Manufacturing Systems	4	3.17
	Journal of Engineering and Technology Management	1	0.79
	Journal of Cleaner Production	7	5.56
	Journal of Business Research	1	0.79
	International Journal of Production Economics	3	2.38
	European Management Journal	1	0.79
Springer		**22**	**17.46**
	Environmental Science and Pollution Research	1	0.79
	European Journal of Wood and Wood Products	1	0.79
	Global Journal of Flexible Systems Management	2	1.59
	Human Relations	1	0.79
	International Journal of Global Business and Competitiveness	1	0.79
	JOM	1	0.79
	Journal of Business Ethics	1	0.79
	Journal of The Institution of Engineers (India): Series C	1	0.79
	Journal of the Operational Research Society	1	0.79
	Letters in Spatial and Resource Sciences	1	0.79
	Production Engineering	1	0.79
	The Annals of Regional Science	1	0.79
	The International Journal of Advanced Manufacturing Technology	8	6.35
	The Journal of Management and Governance	1	0.79
Taylor & Francis		**29**	**23.02**

Data Base	Name of journals	Number of articles	%
	Asia Pacific Business Review	1	0.79
	Cogent Engineering	2	1.59
	Combustion Science and Technology	1	0.79
	Engineering Management Journal	1	0.79
	Industry and Innovation	1	0.79
	Intelligent Technologies and Engineering Systems	1	0.79
	International Journal of Logistics Research and Applications	1	0.79
	International Journal of Management Science and Engineering Management	1	0.79
	International Journal of Production Research	10	7.94
	International Wood Products Journal	1	0.79
	Journal of Enterprise Transformation	1	0.79
	Journal of the Operational Research Society	1	0.79
	Materials Today: Proceedings	1	0.79
	Production & Manufacturing Research	1	0.79
	Production Planning & Control	4	3.17
	Total Quality Management	1	0.79
JSTOR		**14**	**11.11**
	Journal of the Operational Research Society	1	0.79
	Cityscape	1	0.79
	Transportation Journal	1	0.79
	Human Organization	2	1.59
	SAE International Journal of Materials and Manufacturing	3	2.38
	International Labor and Working-Class History	1	0.79
	MIR: Management International Review	1	0.79
	Journal of Economic Geography	1	0.79
	German Journal of Human Resource Management: Zeitschrift für Personalforschung	1	0.79
	Transportation Science	1	0.79
	Academy of Management Perspectives	1	0.79

Source: Researcher, 2022

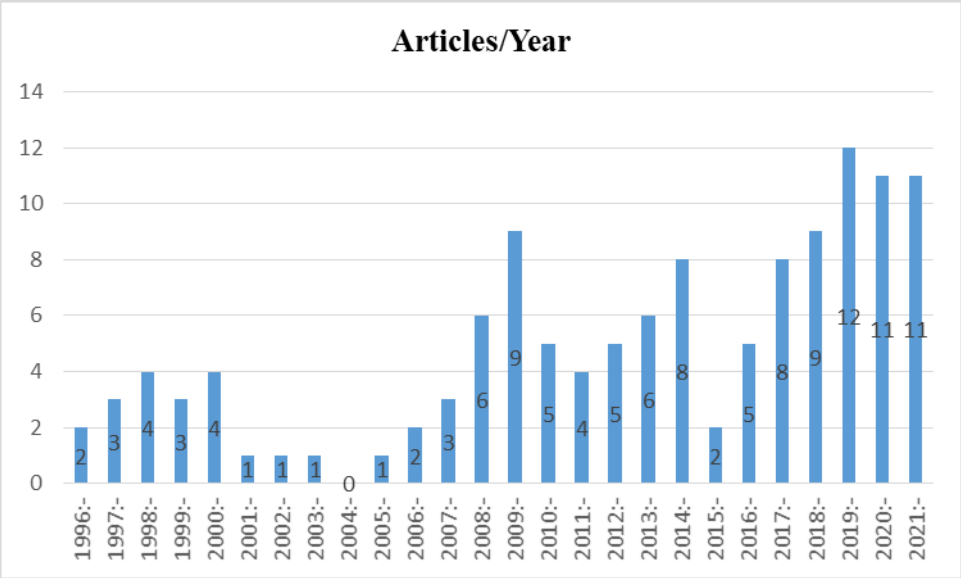

Figure 2: Articles per publication year

Source: Researcher, 2022

Table 3: Geographic university affiliation

S/No	Name of university	No. of affiliations	%
1.	Birla Institute of Technology & Science, Pilani, India	6	4.76
2.	National Institute of Technology, India	3	2.38
3.	Western Michigan University, Muskegon, MI, USA	3	2.38
4.	Kettering University Michigan	2	1.59
5.	Utah State University, Logan, Utah, USA,	2	1.59
6.	University of Minnesota, United States	2	1.59
7.	Panipat Institute of Engineering & Technology, Samalkha, India	2	1.59
8.	Punjabi University Patiala, Punjab, India	2	1.59
9.	RMIT University, Australia	2	1.59
10.	Royal Institute of Technology in Stockholm, Sweden	2	1.59
11.	Sebelas Maret University, Indonesia	2	1.59
12.	Universidade Federal do Rio Grande do Sul,Porto Alegre, Brazil	2	1.59
13.	Universitas Andalas, Padang, Indonesia	2	1.59
14.	Universiti Utara Malaysia, Sintok, Malaysia	2	1.59
15.	University of Derby, England	2	1.59
16.	University of Detroit Mercy, Detroit, Michigan, USA	2	1.59
17.	University of Iowa, Iowa City, Iowa	2	1.59
18.	University of Patras, Agrinio, Greece	2	1.59
19.	M.Kumarasamy College of Engineering, Karur, India	1	0.79
20.	University of Manchester Institute of Science and Technology , UK	1	0.79
21.	National Cheng Kung University, Tainan 701, Taiwan	1	0.79
22.	Ambala College of Engineering and Applied Research, Devsthali, Ambala, India	1	0.79
23.	An-Najah National University, Palestine	1	0.79
24.	Benha University, Benha, Egyp	1	0.79
25.	Buein Zahra Technical University, Iran	1	0.79
26.	Chatham University, Pennsylvania.	1	0.79
27.	College of Engineering Pune, India	1	0.79
28.	Cranfield University, Cranfield, UK	1	0.79

S/No	Name of university	No. of affiliations	%
29.	Dalhousie University in Halifax, Canada	1	0.79
30.	Federal University of Amazonas, Brazil	1	0.79
31.	Federal University of Santa Catarina, Florianopolis, Brazi	1	0.79
32.	Federal University of São Carlos, São Carlos, Brazil	1	0.79
33.	National Louisiana Tech University, Ruston, Louisiana 71272, USA	1	0.79
34.	Ghent University, Belgium	1	0.79
35.	Government College of Art & Craft, Kolkata- India	1	0.79
36.	Government College University Faisalabad, Pakstan	1	0.79
37.	Grenoble School of Management, France	1	0.79
38.	Guru Nanak Dev Engineering College, Punjab, India	1	0.79
39.	Indian Institute of Technology Kharagpur, Kharagpur, India	1	0.79
40.	Institute of Management Technology (IMT), Nagpur, India	1	0.79
41.	Instituto Tecnológico de Aeronáutica, Brazil	1	0.79
42.	Jaipuria Institute of Management Jaipur, Jaipur, India	1	0.79
43.	Johns Hopkins University, Maryland	1	0.79
44.	Kansas State University, Manhattan, KS, USA	1	0.79
45.	Kuwait University, Kuwait	1	0.79
46.	London Business School, UK	1	0.79
47.	Loughborough University, Loughborough, LE11 3TU, UK.	1	0.79
48.	Louisiana State University, Louisiana	1	0.79
49.	Massachusetts Institute of Technology USA	1	0.79
50.	McMaster University, Canada	1	0.79
51.	Methodist University of Piracicaba, Brazil	1	0.79
52.	National Autonomous University of Mexico, Mexico	1	0.79
53.	National University of Singapore,	1	0.79
54.	Nebrija University, Spain	1	0.79
55.	Nile University, Cairo, Egypt	1	0.79
56.	Northumbria University, UK	1	0.79
57.	Norwegian University of Science and Technology, Norway	1	0.79
58.	Nyenrode Business Universiteit, Netherlands	1	0.79
59.	Oriental University, Indore, Indore, India	1	0.79
60.	Queen's University, Canada	1	0.79
61.	Seattle University, Seattle- United States	1	0.79
62.	Selcuk University, Konya-Turkey	1	0.79
63.	The Hashemite University, Zarqa, Jordan	1	0.79
64.	The Sao Paulo State University, Brazil	1	0.79
65.	The University of Manchester, England	1	0.79
66.	The University of Melbourne, Austraria	1	0.79
67.	The University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606, USA	1	0.79
68.	The University of Warwick, International Manufacturing Centre, Coventry, UK,	1	0.79
69.	Tianjin University, Tianjin, China	1	0.79
70.	Universidad Nacional de Colombia	1	0.79
71.	Universidade Católica do Parana, Brazil	1	0.79
72.	Universidade Federal de Santa Catarina, Florianópolis, Brazil	1	0.79
73.	Universiti Teknologi Malaysia, Malaysia	1	0.79
74.	Universiti Teknologi MARA, Shah Alam, Malaysia	1	0.79
75.	University Ca' Foscari of Venice, San Trovaso,Italy	1	0.79
76.	University College Dublin, Dublin, Ireland	1	0.79
77.	University of Angers, France	1	0.79

S/No	Name of university	No. of affiliations	%
78.	University of Bordeaux, France	1	0.79
79.	University of Bradford Management Centre, UK	1	0.79
80.	University of Campinas, Brazil	1	0.79
81.	University of Colombo, Colombo, Sri Lanka	1	0.79
82.	University of Ferrara, Via Savonarola, 9, 44121 Ferrara, Italy	1	0.79
83.	University of Groningen, 9747 AE Groningen, The Netherlands	1	0.79
84.	University of Kentucky, USA	1	0.79
85.	University of Louisiana, United States	1	0.79
86.	University of Louisville, Kentucky	1	0.79
87.	University of Madras and Institution of Engineers (India)	1	0.79
88.	University of Maryland	1	0.79
89.	University of Memphis, Tennessee.	1	0.79
90.	University of Michigan-Dearborn, Dearborn, MI 48126-2638, United States	1	0.79
91.	University of Nijmegen, Netherlands	1	0.79
92.	University of Padova, Padova, Italy,	1	0.79
93.	University of Sulaimani,Kurdistan Region	1	0.79
94.	University of Tennessee, Knoxville, TN, United States	1	0.79
95.	University of the Basque, Spain	1	0.79
96.	University of Washington, Seattle, USA	1	0.79
97.	University of Zaragoza, Spain	1	0.79
98.	Uppsala University, Sweden	1	0.79
99.	Vienna University of Economics and Business Administration, Austria	1	0.79
100.	Virtek Laser Systems North America	1	0.79
101.	Western Michigan University, Muskegon, MI, USA	1	0.79
102.	Yazd University, Yazd, Iran	1	0.79
	Grand total	126	100

Source: Researcher, 2022

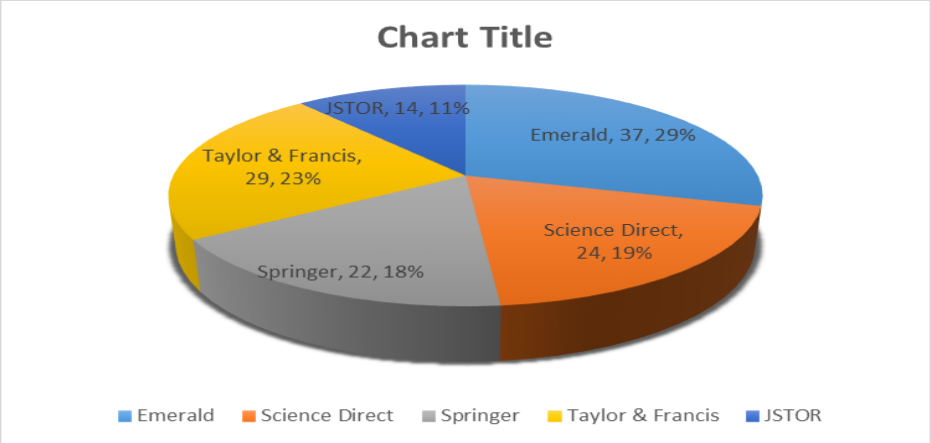

Figure 3: Publishing database
Source: Researcher, 2022

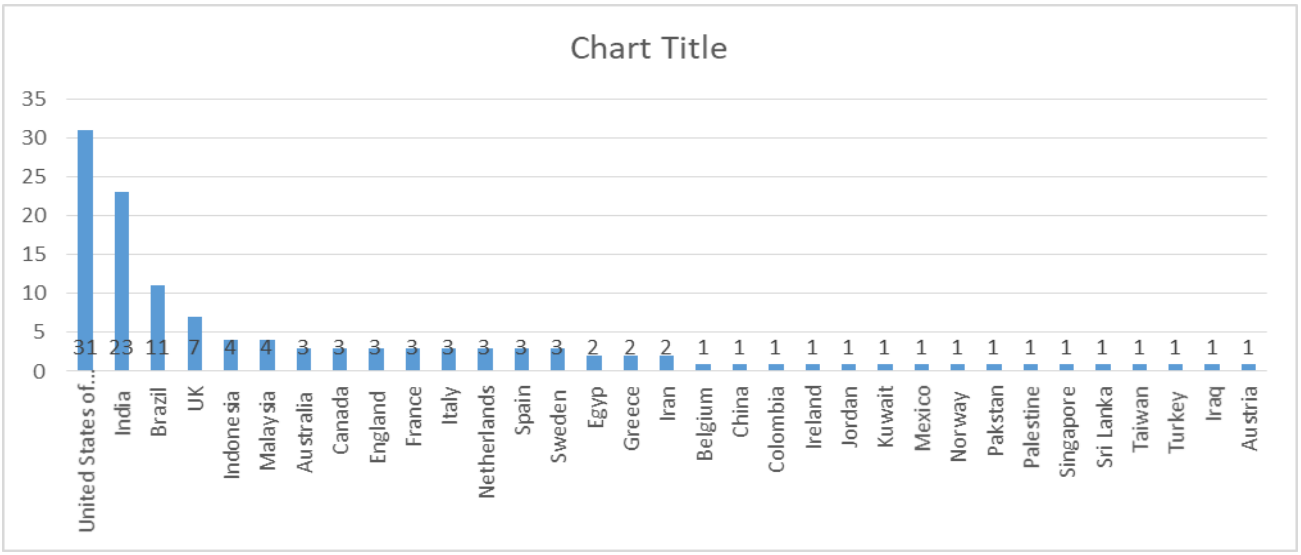

Figure 4: Published articles per country
Source: Researcher, 2022

XIX. CLASSIFICATION PER INDUSTRY

Industry level of incorporation in LM related studies is portrayed in figure 5, with electrical/electronic having majority of the published articles as compared to other industries in this field followed by fabricated metal, energy, pharmaceuticals, agricultural and agribusiness, food & beverage, textile, health. Other sectors in the industry involved with LM studies included chemicals, education, communication & construction, as shown in Figure 5.

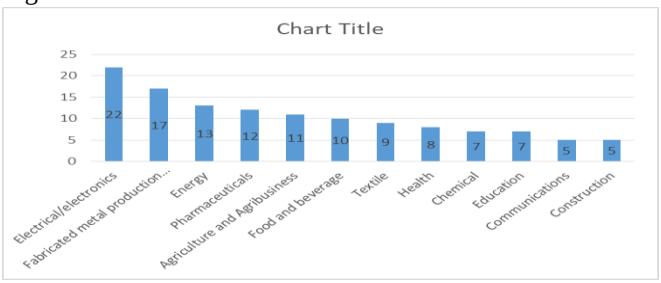

Figure 5: Publication distribution per Industry

Source: Researcher, 2022

XX. RESEARCH DESIGN

Articles in lean manufacturing were classified into five main research designs as shown in table 4: (mathematical model and fuzzy logic) desk quantitative, (multi/mix method approach) empirical triangulation, (case study & action research) empirical qualitative, (survey research) empirical quantitative and (conceptual models & developing schemes for future research) desk qualitative. The highest adopted research design was empirical quantitative with a review if 42 42 articles, followed by empirical qualitative with 38 articles, desk quantitative with 18 and desk qualitative with 22 articles. Multi/mix methods was adopted by the 6 articles which was the lowest as shown in table 4.

Table 4: Research designs adopted for lean manufacturing

Research design	Number of Papers	%
Empirical quantitative Survey:- (questionnaire)	42	33.33
Empirical qualitative:- (Case study and action research)	38	30.16
Desk quantitative:- (Mathematical model & fuzzy logic)	18	14.29
Desk qualitative:- (Conceptual models and developing schemes for future research)	22	17.46
Empirical triangulation:- (Multi/mix methods)	6	4.76
Total	**126**	**100.00**

Source: Researcher, 2022

XXI. RESEARCH METHODS

The analysis and cross-examination of the independent articles revealed that all of articles under consideration adopted either of the following research methods: surveys; interviews; mathematical & conceptual modelling; case study and simulations. Majority of the articles published were based on survey methods with 42 articles, case studies 35 articles, conceptual models 22 articles, mathematical modelling 12 articles and interviews with 4 articles as shown in table 5.

Table 5: Research methods adopted for lean manufacturing practices

Research methods	No. of papers	%
Survey	42	33.33
Case study	35	27.78
Conceptual model	22	17.46
Mathematical model	12	9.52
Interviews	4	3.17
Survey cam Interviews	3	2.38
Case study cam Mathematical model	6	4.76
Simulation	2	1.59

Source: Researcher, 2022

XXII. TECHNIQUES FOR DATA ANALYSIS

Individual published articles were also review to determine the techniques adopted for data analysis as shown in figure 6. The techniques adopted for data analysis include: structural equation modelling; comparative analysis; factor analysis; cluster analysis; correlation & regression analysis, conceptual; analysis of variance, multi-criterion decision-making methods; linear programming and other methods. The adoption of structural equation modelling (SEM) is used to signify the relationship in a certain structure (Vinodh and Joy 2012), while multi-criterion decision-making methods (MCDM) are adopted; to demonstrate the various models and to conceptualize their causal effects related (Alves and Alves 2015).

Majority of the articles reviewed adopted comparative analysis at 16% of the articles, with SEM at 14%, conceptual analysis at 13% , MCDM analysis at 10% and regression analysis at 8% of the reviewed articles as shown in figure 6. Others recorded low percentages which include: correlation analysis; factor analysis & ANOVA methods with 7% each and linear programming analysis of variance (NOVA) with 3%, while comparative analyses; chance-constrained; chance-constrained data envelopment analysis; cluster analysis and integrated mixed integer programming model were adopted at a level of 2%. Vensim PLE, epsilon-constraint method pattern matching logic , MDM and interpretive structural modelling and were utilized at 1% of the reviewed articles as shown in figure 6. 9% of the reviewed articles adopted other techniques in data analysis regardless of the wide scope of the research techniques acknowledged.

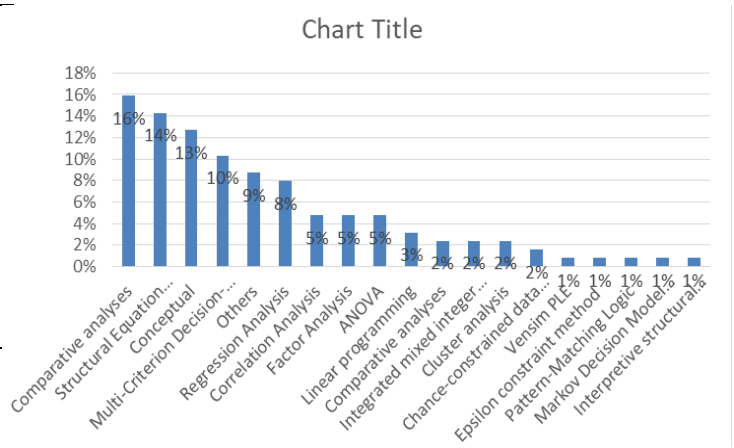

Figure 6: Data-analysis techniques
Source: Researcher, 2022

XXIII. CONCLUSION

This article significantly contributes to the current literature in lean manufacturing practices literature, by providing an overview of the research into lean manufacturing in a span of 25 years analyzing indicators like; their data analysis techniques, research designs and methods, industry engagements, geographic locations, university of author affiliation, publishers and year of publication.. In addition, this review uncovered trends, opportunities and future directions in the field of Lean Manufacturing guided with the three research questions addressed earlier. As a rejoinder to first research question, a structured review of 126 articles research provides a comprehensive review of 126 articles were retrieved from 1996 to 2021, originating from 64 different peer-reviewed journals, determining different research designs and research methods and research data analysis techniques. While address the second research question, this article explored different dimensions which was limited to most active publishers and institutions in the field of lean manufacturing research, their countries origin and affiliated industries, research designs, research methods and research techniques. With the responses attained in relation to the two research, the third research question was addressed by portraying the knowledge gaps and motivating effect for future direction of research in the

field of lean manufacturing.

XXIV. Significant Findings

1. The pertinent outcome is that only eleven review articles published were affiliated to LM field whereas they did not use indicators adopted in this study:
   - ✓ The first article is based on valid and reliable concepts for lean manufacturing by analyzing the live of implementation so as to address the paradigms of improvement.
   - ✓ The second article concentrates reviewing and conceptualizing a classified model for lean manufacturing (LM) adoption.
   - ✓ The third and fourth articles demonstrates a futuristic literature review by identifying the originality index of the lean manufacturing (LM) studies conducted across the globe worldwide.
   - ✓ Fifth, sixth, seventh and eight focused on empirical research in lean manufacturing
   - ✓ Ninth addressed analytically and systematically reviewing the literature in pathways of LM in the industries of wood and furniture.
   - ✓ tenth article is focused on determining the adoptability and sensitization of the lean production
   - ✓ Eleventh article addressed the MCDM and double-objective mathematical model in the product/service production line by adoption of lean manufacturing practices.
2. The International Journal of Lean Six Sigma and International Journal of Production Research published the highest numbers of papers have the highest number of publication each with 10 articles, International Journal of Advanced Manufacturing Technology (8), Journal of Manufacturing Technology Management and Journal of Cleaner Production (7), International Journal of Operations & Production Management (6), Journal of Manufacturing Systems and Production Planning & Control (4), Journal of Operations Management, International Journal of Production Economics and SAE International Journal of Materials and Manufacturing (3).
3. Countries such as the USA and India, hold the highest number of research associations in lean manufacturing.
4. Empirical quantitative methods such as surveys were used in 33.33% of the articles. This SLR relates to other reviews of lean manufacturing articles that focus on empirical methods including quantitative, qualitative and mixed methods (36.51%). This shows a variance of 3.8%.
5. The study revealed data analysis techniques that were adopted in the articles which incorporated comparative analysis and SEM.
6. Application of SEM & MCDM methods is on the rise, while, conceptual methodology is gradually decreasing among scholars affiliated to the field of lean manufacturing.

XXV. Fundamental Gaps Identified

- ✓ Case study & survey and conceptual were the main adopted methods in the reviewed articles while mathematical model, interviews, empirical triangulation (mixed methods) and simulation had a limited number of articles published .
- ✓ Empirical triangulation was adopted in 6 published articles out of the 126 reviewed articles. As a result, empirical triangulation was not effectively utilized and future studies should adopt this research design.
- ✓ Although large numbers were recorded in relation to LM, the current LR portrays lack of classical research in LM.
- ✓ Majority of the lean manufacturing articles published were developed countries related hence calling for extensive research in countries that are countries.
- ✓ Finally, research lean manufacturing is expected to determine the relationships of production lines, organizational culture & the impact it makes on quality of products produced or services rendered, cost of production and timely production.

XXVI. Future Research

This article has demonstrated a classical state of lean manufacturing from varied dimensions. The study proposes the following themes to guide future research paradigms in this field of study:

- ✓ This article was based on the current scope of LM while focusing on research methods, various data sources & techniques of analysis. On the other hand, the adopted literature review was limited to reviewing articles published from Emerald, Science Direct, Taylor and Francis, JSTOR and Springer. Hence necessitating for emphasis on lean manufacturing in relation to other numerous reputable books & journals future research.
- ✓ The review can be advanced by incorporation conference papers, masters & doctoral thesis among other academic archives.
- ✓ This review is curtailed to articles published with keywords “lean manufacturing”, “lean manufacturing practices “and “lean manufacturing systems” embodied in their title cam abstract.
- ✓ Administering a comprehensive study among developing and developed countries with view of global production, international markets & service delivery dimensions, dynamic customer demands with vast competition and sustainable lean manufacturing practices calls for future research.

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