



# Literature Review: Lean Manufacturing Assessment During the Time Period (2008-2017)

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**Abstract:** The aim of this paper is to explore and evaluate previous work focusing on the relationship and links between Lean manufacturing and industrial work. This study reviews the literature on Lean Manufacturing Assessment (LMA) during the last decade; 2008–2017 and analyses the literature from different perspectives. This paper highlights various key words, scopes, objectives, case study, definitions, methodologies, tools and main results. A total of 126 research papers have been reviewed in this study to help the researchers in the evaluation of lean manufacturing practices to identify and benefit from these studies. This paper provides a quantitative descriptive analysis and qualitative thematic analysis to provide an analysis of impact of lean on performance. Consequently, this paper can be considered as a guide for researchers in LMA. It is expected to be a brief reference for future researchers that reduces effort and time consuming during their studies.

**Keywords:** Industrial, Lean Manufacturing, Assessment

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## 1. Introduction

This century is characterized by the rapid growth in all areas related to human life, such as education, health, industry and services. In line with this rapid growth is the lean applications, which include many applications that contribute to improving the performance in the field of services and industry, and this momentum produced many researches in the field of lean and its applications. In the past decade, several studies were conducted on lean manufacturing assessment LMA in general, given the wide range of lean application processes. These studies have assessed what has been achieved in the field of lean philosophy study, thus resulting in developing studies based on previous literature. Table 1 shows the previous studies on subjects directly related to the lean concept in general.

Based on Table 1, the number of papers reviewed, and the number of citation for each study, it seems that many studies have been conducted in the field of leans and these studies

included a difference in the type of firms, processes, size of firms, different tools, differences in methodology. Nevertheless, these studies emphasize the importance of lean application and its role in improving performance. Regarding the subject of this paper, previous studies indicate that there is momentum in studies that include different assessments in terms of objectives, key words, definitions, objectives, firms, methodologies and results. Therefore, this paper summarizes a review of the research papers published in the time period from 2008 to 2017 that are directly related to the evaluation process and applications of lean practices. The structure of this study is as follows. The first section contains studies on the evaluation processes in general, followed by the second section, which includes the methodology of the study. The third section involves studies in addition to the analysis of the content of these studies. The fourth section includes the repetitive analysis of previous studies and the conclusions are discussed in the last section.

**Table 1.** Literature Review in Previous Studies.

Main Themes	Reference	Time Period	No. of Papers	1/6/2018 Cited by
State of Lean Implementation in Health care	[1]	1977-2009	57	254
Lean thinking in healthcare	[2]	1990-2009	64	404
Six Sigma	[3]	1981-2010	87	124
Value stream mapping	[4]	1993-2010	49	117
Lean	[5]	1970-2009	148	217
Lean Six Sigma	[6]	2000-2011	116	61
Lean		200-2006	11	51
Sustainable Supply Chains	[8]	2000-2010	85	159
Lean Service	[9]	1980-2008	92	
Learning on Lean	[10]	1980-2009	86	22
Lean Manufacturing	[11]	2000-2011	48	52
Sustainability through Lean Construction Approach	[12]	1992-2012	18	29
The lean gap	[13]	1985-2012	38	47
Lean Manufacturing	[14]	1988-2013	249	248
Lean Management	[15]	1990-2013	66	185
lean manufacturing implementation	[16]	1983-2013	43	102
lean manufacturing	[17]	1990-2009	178	58
Lean Production	[18]	1988-2011	546	151
Lean implementation	[19]	1983-2014	148	47
Lean and green	[20]	1998-2014	59	113
Lean and Sustainable Manufacturing	[21]	2000-2014	58	21
Lean in healthcare	[22]	2003-2013	243	135
Lean management	[23]	2004-2014	49	10
Lean Assessment	[24]	1970-2015	98	20
lean manufacturing, Six Sigma and Sustainability	[25]	1990-2015	118	55
Lean Healthcare	[26]	1983-2015	107	28
Lean and Six Sigma	[27]	1999-2015	149	22
Lean Practices	[28]	1974-2015	83	20
Six Sigma and Lean	[29]	2000-2015	70	10
sustainability in supply chain management	[30]	2000-2015	190	36

## 2. Methodology of the Study

The methodology of this study is based on the fundamentals of content analysis referred to in many studies such as [14, 29, 31] which included the following research steps: collection of

materials, evaluating the appropriateness of subjects with each other and classification of what is selected in the classification lists (key words, scopes, objectives, and methodologies). Table 2 shows a brief explanation of the research methodology.

**Table 2.** Summary of Research Methodology.

Unit of Analysis	The sources include high ranked peer-reviewed papers in the LMA.
Type of Analysis	Qualitative.
Papers Selected	Scientific journals and conferences accessible through Google Scholar.
Time Period of Articles	2008-2017
Totals Numbers of Articles Before Exclusion	225
Totals Numbers of Articles After Exclusion	126

## 3. Collection of Materials

The general framework of this study is based on LMA studies, as LMA is considered a key basis for improving the performance of organizations in general, as indicated by many previous studies in the past decade the collection of data on the concept of lean in general. There are many studies that have been carried out in LMA in the previous decade, and these studies included the subject of LMA as a general subject and then dispersed in different parts. Tables 3-12 represent a wide range of these studies in LMA in general, and also include the number of citations for studies

related to this research field.

### 3.1. Time Period 2008

The study found that there were 28 studies that included lean assessment methodology in general. Within the methodology of this study, the number was limited to research that includes the word lean as a keyword in the title. Therefore, the number was reduced to 12 papers.

#### 3.1.1. Keywords Classification

Previous studies [32-34] included keywords (Lean Manufacturing and Manufacturing System [32], Lean manufacturing, Change agents and Regional development

agency [33], Leanness measure, Data envelopment analysis and Slacks-based measure [34]; Lean production, Decision making and Strategic choices [35], Lean Manufacturing and Workplace [36], Lean production, Performance measurement and Balanced scorecard [37], Lean, Leanness, Fuzzy-logic leanness, Systematic measures and Benchmarking [38], Lean Manufacturing Systems and Performance Measurement [39], Lean strategy, Automotive supplier industry, Relationship building and Path analysis [40], Lean Thinking [41], Lean accounting, Contingency Theory, Performance measures, Management Control, Lean Manufacturing; Control and Interdependencies [42], Lean Bundles and Operational Performance [43]). It is noted that these studies included key words referring to practices in general, and some indicate performance, types of institutions and type of data.

### 3.1.2. Objective and Firm Classification

The objectives of previous studies [32-43] are to indicate to different objectives, thus including (Current state of lean practice, Investigating the correlation, Decision-making strategies, Development of evaluation processes). Previous studies in Table 3. include several types of institutions firms, whereby the size of companies included small- and medium-sized enterprises.

### 3.1.3. Definitions, Methodology and Tools Classification

The studies [32-43] included a variety of methodologies: quantitative studies, qualitative studies, observations, and historical data, also the existence of fuzzy logic on a limited scale. One of the most important definitions in this time domain is that the definition of the Fuzzy logic for lean measurement: level of lean may include undetermined and uncertain degrees.

**Table 3.** Exploration and analysis, Lean Tools and Main Results in Publications 2008.

No.	Lean Tools	Main Results	References
1	Cell/flow-line/product, Flow of Material/Work in Processes, Delivery of Raw Materials, Kanban, Setup Time, Flexibility, Visual Factory, Defect Rate, On Time Delivery.	The results of assessments show that the petroleum industry is in lead among all industries, followed by computer, telecommunication/wireless, and electronics industries. The findings related to lean production system design-related questions show low scores in layout design, volume/mix flexibility, setup, visual factory, and point-of-use delivery. However, plants earned high scores in materials flow, scheduling/control, on-time delivery of finished goods, and overall defect rate.	[32]
2	Total productive maintenance, statistical process control, Lean Management, Kaizen, cellular manufacturing, synchronous manufacturing, Poka-Yoke, standardized working and work place organization	The results obtained from 15 companies show that the savings are eight times greater than total costs. It has been found that the commitment of management and the ability of the change agents are the key determinants of success.	[33]
3	Value stream, flow, pull, Kanban system, quick changeover, just-in-time	The decision-making process can be improved through historical data	[34]
4	Total quality management (TQM), Six-sigma (SS), Total productive maintenance (TPM), value stream mapping, Work-in-process,	An extensive analysis of PROMETHEE model revealed that LMS was the best for the given circumstances of the case.	[35]
5	Lean tools in general.	The model has proved effectiveness in improving the training process.	[36]
6	Lower WIP, higher quality, greater production flexibility.	The DMP model presented in this paper has generic appeal and can be applied to quite disparate organisations.	[37]
7	Just-in-time, Kaizen, and quality, Controls.	The results show that Ford's more than leaner GM's.	[38]
8	Total Quality Management	The proposed model is suitable for small and medium enterprises.	[39]
9	Just-in-time, Standardization, Value analysis.	The results show that building the external relationship is an important stage in making improvement.	[40]
10	Pull, Value Stream Mapping.	Effectiveness of redesigning care programs for hospitals.	[41]
11	Just-in-Time, Total Quality Management, Total Preventative Maintenance.	Suggestion insights from evidence on lean accounting.	[42]
12	Just-in-Time, Total Quality Management, Human Resource Management.	Results show that JIT and TQM have a direct and positive effect on the operational performance while HRM has a mediated effect on it.	[43]

## 3.2. Time Period 2009

The study found that there were 25 studies that included lean assessment methodology in general, and within the methodology of this study, the number was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number was reduced to 8 papers.

### 3.2.1. Keywords Classification

Previous studies [44-51] included keywords (Non-financial performance measures, Lean manufacturing, Structural

equation modeling [44], Manufacturing systems, Benchmarking, Best practice, Lean production, Just in time [45], Lean production, Agile production, Operations management. [46]; Flexible manufacturing systems, Lean production, Best practice. [47], Lean Management, Multiple Case Study, Lean Service [48], Lean manufacturing, key practice areas [49], Lean manufacturing, just in time [50], Worker assignment; lean manufacturing; cross-training; multi-skilling; skill chaining [51]. It is noted that these studies referred to specific practices as Just-In Time.

### 3.2.2. Objective and Firm Classification

The previous studies [44-51] indicate to different objectives, including (Current state of lean practice, Identifying the practices that managers use to improve the overall manufacturing flexibility and including several types of institutions firms, such as electronic companies and financial services, whereas the companies included small- and medium-sized enterprises.

### 3.2.3. Definitions, Methodology and Tools Classification

The studies [44-51] included a variety of methodologies: quantitative studies, qualitative studies, observations and historical data, also the existence of fuzzy logic on a limited scale. One of the most important definitions in this time domain is that the definition of the Structural equation model (SEM) is estimated using data provided by companies.

**Table 4.** Exploration and Analysis, Lean Tools and Main Results in Publications 2009.

Lean Tools	Main Results	References
Just-in-Time, Total Quality Management	Results provide substantial evidence that utilization of non-financial manufacturing performance measures mediates the relationship between lean manufacturing and financial performance.	[44]
Counties Improvement, Just-in-Time, Total Quality Management, Value Stream Mapping	Review of studies in benchmarking field.	[45]
Just-in-Time, Flexibility	Identify practices that contribute to improving work through agility and softness.	[46]
Techniques, and major groups involved in improving Flexibility	The results identified the practices as the best practices that managers can use to improve processes.	[47]
General Practices	Lean first, then Automate.	[48]
General Practices	Select 14 key area: work processes, scheduling, inventory, equipment, layout, material handling, employees, quality, product design, suppliers, tools and techniques, customers, ergonomics and safety, and management and culture.	[49]
General Practices	Determined 65 leans practices.	[50]
General Practices	Developing a model that contributes to improving training to use and apply lean skills.	[51]

### 3.3. Time Period 2010

The study found that there were 33 studies that included lean assessment methodology in general, and within the methodology of this study, the number was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number was reduced to 16 papers.

#### 3.3.1. Keywords Classification

Previous studies [52-67] included keywords (Material handling, Lean manufacturing, Case study, Value stream mapping; Diamond drill bit components [52], Lean manufacturing, Lean maturity, manufacturing companies, methodology [53], Supply chain management, Lean production, Integration [54], assessment, authentic problems, facilitator; games, problem-based learning, problem soft skills, realism, review, simulations, skills, soft lean manufacturing, solving skills, Toyota Production System [55], Lean, Value Stream Mapping, Small Medium Enterprise, Current State, Future State [56], Lean manufacturing, green manufacturing, case-study, discrete event simulation, optimization [57], Lean manufacturing, Medium Size Manufacturing Enterprises, Kaizen [58], Lean manufacturing, Value Stream Mapping, Tak time and capacity [59], Lean production, Manufacturing systems, Fuzzy control, Quality management [60], United Kingdom, Public sector organizations, Business process re-engineering [61], Lean implementation, lean manufacturing, simulation, Toyota Production System [62],

Lean Kitting assembly, Fuzzy Based Simulation (FBS), work in process inventory, floor space required, operator walking distance [63], Lean paradigm, green paradigm; performance measurement, supply chain management; SCM [64], Lean model Second generation wavelet packet, transforms, Fisher criterion [65], Emergence department administration, Lean principles, length of stay, time to physician, wait time [66], Lean manufacturing, organizational change, automotive industry [67].

#### 3.3.2. Objective and Firm Classification

The previous studies [52-67] refer to different objectives, including (Current state of lean practice, Identifying the practices that managers use to improve the overall manufacturing flexibility and including several types of institutions firms, such as electronic companies petroleum drill bit manufacturing, hospitals and services sectors, whereas the companies included small- and medium-sized enterprises.

#### 3.3.3. Definitions, Methodology and Tools Classification

The studies [52-67] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data and a mathematical model. One of the most important definitions in this time domain is the definition of the Lean Kitting assembly as: "a specific collection of components and/or sub-assemblies together and combine with other kits to support one or more assembly operations for a given product".

**Table 5.** Exploration and Analysis, Lean Tools and Main Results in Publications 2010.

Lean Tools	Main Results	References
Value stream mapping	The process of lean application contributes to the disposal of waste in drills factories by reducing assembly and disposal of distances.	[52]
Just in Time, Perfect quality, Continuous improvement,	Lean is considered an integrated system to improve the performance.	[53]

Lean Tools	Main Results	References
Visual management.	The study showed the positive effect of adopting a lean methodology on the performance in companies.	[54]
Just in Time	Simulations contribute to the strengthening of learning and training on lean assessment but do not give actual results to the lean level in companies in fact.	[55]
5S	The results indicate that there is a positive effect of lean in reducing time-related wastes and the number of operators according to the case study.	[56]
Value stream mapping	The lean can have a significant impact on improving the operational processes.	[57]
Value stream mapping	The results indicate that SMEs have a high potential to employ lean practices to improve the performance, raise production values, and eliminate waste.	[58]
Just in Time		
Value stream mapping, Just in Time	The results showed a high potential for improving the performance.	[59]
Total productive Maintenance, Total Quality Management, Value Stream Mapping and Visual Control.	The model includes uncertainty in the presence of waste.	[60]
Visual management, Value stream mapping, 5S and Line balancing	The results indicate the effectiveness of lean practices in improving the service sector.	[61]
Value stream mapping	Use simulations in training, education, and fact analysis.	[62]
Operator walking distance and WIP	Employing fuzzy logic in the decision-making process in improving the performance.	[63]
Lean practices	Study the relation between lean and green supply chain.	[64]
Lean	Lean model can reduce the time consumption.	[65]
Just in Time, Value stream Mapping, Workplace Organization	Lean practices have contributed to improving the flow of patients in the emergency department and increasing their level of satisfaction.	[66]
Lean practices	The study showed that there is an impact of the organizational change in the process of transition to lean.	[67]

### 3.4. Time Period 2011

The study found that there were 24 studies that included lean assessment methodology in general, and within the methodology of this study, the number was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number is limited to 14 papers.

#### 3.4.1. Keywords Classification

Previous studies [68-81] included keywords: Lean Performance, Fuzzy Logic and continuous improvement [68], International study Lean manufacturing Environmental management practices Environmental performance Empirical study [69], Lean manufacturing; leanness assessment, fuzzy methods, leanness index [70], lean manufacturing, leanness assessment, fuzzy logic, decision support system [71], Lean, manufacturing, practices, small, medium, enterprises [72], Cycle time, Inventory management, 5-whys, 5S, Value stream mapping, Cellular manufacturing [73], Material handling and Lean [74], Lean Manufacturing, Lean Thinking, Total Quality Management [75], Lean manufacturing, implementation, case studies, electrical and electronics, Malaysia [76], Cellular manufacturing, Lean production, Performance measurement [77], Lean tools, Waste, Mass production, Tak time, Lead time. Value chain, Value-added activity, Non-value-added activity

[78], Lean, Simulation [79], Manufacturing systems, Analytic hierarchy process, Lean manufacturing, Concept selection, Multi-criterion decision making [80], Lean Manufacturing, Value Stream Mapping, Unified Modelling Language, Analytic Hierarchy Process. [81]. It is noted that there is an increase in the number of practices in the keywords.

#### 3.4.2. Objective and Firm Classification

The objectives of previous studies [68-81] included Studying the effect of lean on the performance, Assessing the lean using a fuzzy approach including several types of institutions firms, such as electronic companies petroleum drill bit manufacturing, hospitals, pharmaceutical industries and services sectors, whereas the size of companies included small- and medium-sized enterprises.

#### 3.4.3. Definitions, Methodology and Tools Classification

The studies [68-81] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data and a mathematical model. One of the most important definitions in this time domain is that the definition of the Manufacturing Cells is characterized by the creation of a workflow in which the tasks are required and workers are closely connected in terms of time, space, and information.

Table 6. Exploration and analysis, Lean Tools and Main Results in Publications 2011.

Lean Tools	Main Results	References
Just in Time	The model contributed to more accurate results of the evaluation.	[68]
Just in Time, Quality management	The results of the positive impact of the lean on the administrative environment of firms.	[69]
Just in Time, Value Stream Mapping and Total Quality Management	Develop a cyclic model for measuring lean using a fuzzy model.	[70]
Total Quality Management, Total Productive Maintenance, kanban, kaizen and Poka Yoke	Develop a cyclic model for measuring lean using a fuzzy model.	[71]
Set up time reduction, Visual control, Cell layout, Standard operation,	Identify the most important lean practices.	[72]

Lean Tools	Main Results	References
Kanban, Continuous flow, Uniform workload, Small lot size, Continuous improvement, Training and Teamwork.		
Work in Process, Value Stream Mapping	The proposed practices have contributed to the reduction of waste in the pharmaceutical industry specifically through value stream mapping.	[73]
Value Stream Mapping, Kanban, Contentious Improvement, Visual System and 5S	The results were positive in reducing time and labor.	[74]
Total Quality Management and Lean Thinking	The study showed the similarities between total quality and lean practices.	[75]
Just in Time, Kanban, Kaizen, Six Sigma, 5S, Value Stream Mapping,	Results show that people need to have lean skills to ensure the quality and success of their application.	[76]
Teamwork and leadership, Continuous improvement, Standardized work, Pull production, Total Productive Maintenance, Visual, Management of production control, Visual management, Layout size and shape and Visibility and information exchange	The study showed that there was a positive effect of lean practices on manufacturing cells.	[77]
Just in Time, Quality Systems, Work Teams, Cellular Manufacturing, Supplier Management	Results showed that lean applications were still at their early stages.	[78]
Cycle time, Work in Processes and Labor Utilization	Studies showed a strong correlation between practices used.	[79]
Lean Management System	The prepared model shows positive results in improving the decision-making process.	[80]
Value Stream Mapping	The prepared model shows positive results in improving the decision-making process.	[81]

### 3.5. Time Period 2012

The study found that there were 27 studies that included lean assessment methodology in general. Within the methodology of this study, the number was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number was decreased to 16 papers.

#### 3.5.1. Keywords Classification

Previous studies [82-97] included keywords: India, Manufacturing industries, Lean production, Lean manufacturing, Manufacturing, Manufacturing performance, Manufacturing operations [82], lean manufacturing; manufacturing systems; structural equation modeling; organizational performance [83], Lean manufacturing Leanness, Fuzzy logic [84], Lean manufacturing, Parameters, Manufacturing industry, Survey, Lean production, Process efficiency [85], Lean production Analytical hierarchy process, Artificial neural network, Adaptive analytical hierarchy process approach [86], lean manufacturing; India; operational and quality improvement; survey [87], Lean Product development, Lean implementation measurement, New Product Development process [88], Malaysia, Manufacturing industries, Supply chain management, Lean production, Product quality management, performance, Structural equation modeling [89], Fuzzy logic; Impact assessment; Lean manufacturing; SMEs [90], Variability; Lean Manufacturing; Assessment [91], Lean /Ideology/Culture Tools/Journey [92], Lean manufacturing, Leanness, IF-THEN Rules, Leanness enablers, Gap analysis [93], India, Manufacturing industries, Lean production, Decision support systems, Lean manufacturing, Leanness assessment, Fuzzy method [94], Lean management, Lean production, Continuous improvement, Off-site manufacturing, Manufacturing industries [95], Performance improvements; Waste; Lean

Manufacturing; Mathematical model [96], Lean production, Inventory management, Financial performance [97]. It is noted that studies have become limited to specific areas, such as the focus on the process of production, inventory, and performance.

#### 3.5.2. Objective and Firm Classification

The objectives of previous studies [82-97] included Improving the decision-making process by determining the lean level within the application of hierarchical analysis, an exploratory study of the lean state of India's industries, developing a valuation model enables companies to understand the basic practices, rapid and accurate assessment of lean level, a broader understanding of how lean application in malaysia depends on supply chain management, developing a system of consulting companies towards the use and application of lean, developing a new methodology for lean assessment through variability source mapping, exploring lean in large companies, developing the assessment process within the ambiguous logic, the development of the decision-making system in lean applications. Several types of institutions firms were included, such as electronic companies petroleum drill bit manufacturing, hospitals, pharmaceutical industries and services sectors, and the size of companies included small- and medium-sized enterprises.

#### 3.5.3. Definitions, Methodology and Tools Classification

The studies [82-97] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data and a mathematical model. One of the most important definitions in this time domain is that the definition of the Value stream mapping (VSM) is a lean manufacturing technical methodology that helps interpret the flow of materials and information currently needed to transfer goods or services to the end consumer.

**Table 7.** Exploration and Analysis, Lean Tools and Main Results in Publications 2012.

Lean Tools	Main Results	References
Total productive maintenance, Employee's productivity and Total Productivity Management	The study indicates to lean dimensions on operational performance.	[82]
Lean Manufacturing	The results indicated that the proposed model improves the objectives of the manufacturing process (cost, quality, flexibility)	[83]
Lean Practices	The results suggest that the evaluation and fuzzy logic analysis give more comprehensive results.	[84]
Just in time, Zero Defect, Pull, Continuous improvement	Develop a proposed model to improve the effectiveness of lean application.	[85]
Continuous improvement, Zero Defect, Pull, Standardized Workplace, Lean Practices	The results showed the effectiveness of the model.	[86]
Lean Manufacturing	Improving the level of operational performance does not depend only on lean.	[87]
Lean Manufacturing	Develop a road map that contributes to the lean tracking of each stage of the production process and identify the difficulties faced by the lean application.	[88]
Continuous improvement, Setup time reduction, Product reliability and Product performance	Results show a strong correlation between lean and quality management.	[89]
Lean Manufacturing	Research study has provided a novel system for assessing the impact of lean manufacturing within SMEs.	[90]
Main Value Stream	The results showed that the proposed model contributed to the identification of objects that have no value in production processes.	[91]
Kanban systems, Cellular manufacturing, Total productive maintenance, Process mapping, continuous improvement and 5S	The study points to be deemed to be embracing Lean as an ideology.	[92]
Lean Manufacturing	Effectiveness of the proposed model	[93]
Just in Time	The proposed model contributes to the determination of lean areas accurately.	[94]
Continuous improvement Total Quality Management	The study shows important aspects of management where improvement can be applied.	[95]
Standard Processes, Visual management, Continuous Improvement, Pull Systems.	Develop a methodology to support the identification of lean strategies.	[96]
Total Quality Management, Just in Time	Development of lean production theory	[97]

### 3.6. Time Period 2013

The study found that there were 29 studies that included lean assessment methodology in general. Within the methodology of this study, the number was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number of paper was reduced to 11.

#### 3.6.1. Keywords Classification

Previous studies [98-109] included keywords: Production planning, Simulation, Sustainable development [98], lean manufacturing, lean production, leanness, lean indicators, lean assessment, lean model [99], Just-in-time; lean manufacturing; kanban system; inventory management; operations strategies [100], Environmental management, Lean manufacturing, Human resource management, Operational performance, Automotive sector [101], Leanness, Lean implementation methodology, Continuous performance measurement, Lean strategies, Lean production, Performance management [102], Accounting Management, Lean [103], Lean Manufacturing, Performance [104], Performance measurement, Lean production, Assessment instrument, Lean service [105], Lean manufacturing, Lean enterprise, Lean Transformation, Lean principles and practices, Lean Assessment, Lean stakeholder value, Analytic network process [106], Lean manufacturing, Interpretive structural modeling, Leanness index, Tire

manufacturing, [107], Product development, New products, Lean production, New product development, Lean manufacturing, Concurrent engineering [108], lean manufacturing, competitive skills, business performance [109]. It is noted that studies have become limited to specific areas more than other years, such as the focus on the process of production, inventory and performance, human resource, and accounting management.

#### 3.6.2. Objective and Firm Classification

The objectives of previous studies [98-109] included integration of lean and green strategies into the industrial system, describing a preliminary study in developing a conceptual model to measure leanness in manufacturing industry and purposing the relationship between competitive skills and lean manufacturing. It included several types of institutions firms.

#### 3.6.3. Definitions, Methodology and Tools Classification

The studies [98-109] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data. One of the most important definitions in this time domain is that the definition of the Lean and Green is: the ability of operations to support the environmental management.

**Table 8.** *Exploration and Analysis, Lean Tools and Main Results in Publications 2013.*

Lean Tools	Main Results	Reference
Lean, Green, Quality rate improvement	The integration of lean and green strategies reduces production costs.	[98]
Total Quality Management, Just in Time, Pull, 5S, Continuous Improvement and Visual Management System.	The study identified seven basic dimensions to measure leanness.	[99]
Lean Manufacturing	The study suggests that top management commitment, vendor participation, inventory management and quality improvement are important for Kanban deployment and towards lean manufacturing.	[100]
Lean Manufacturing	There is a positive relationship between environmental management, operational performance, lean manufacturing, and human resources.	[101]
Value Stream, Pull, Just in Time, Six Sigma, Total Quality Management	The basic results included the development of a simple tool to measure lean.	[102]
Lean Manufacturing	Accounting and control practices management form the basis for a lean environment.	[103]
Just in Time, Work in Processes, Pull	Improve the effectiveness of measuring instruments	[104]
Lean Manufacturing	Comprehensive tool to evaluate services.	[105]
Lean Manufacturing	The modeling and weighting of all the determinants in the lean tools is discussed in this paper.	[106]
Lean Manufacturing	Proposed model for lean assessment	[107]
Lean Manufacturing	The results indicate that companies that implement the lean system are able to develop quickly and at a lower cost.	[108]
Lean Manufacturing	There is a positive correlation between competitive performance and lean system.	[109]

### 3.7. Time Period 2014

The study found that there were 23 studies that included lean assessment methodology in general. In the methodology of this study, the number was limited to research that includes the word ‘lean’ as a keyword in the title. Therefore, the number was reduced to 14 papers.

#### 3.7.1. Keywords Classification

Previous studies [110-123] included the following keywords: leanness; lean implementation; lean operations; lean manufacturing; performance measures; performance analysis; quality management; Toyota production system [110], Lean manufacturing Lean accounting Operations and financial performance Survey analysis Structural equation modeling [111], Manufacturing strategy, SME, Small-to-medium-sized enterprises, Lean production, Lean implementation, Lean process [112], Brazil, Degree of leanness (DOL), Lean implementation [113], Lean Assessment, Take Time, System Dynamic [114], Lean manufacturing; National culture; Behavioral operations [115], Waste reduction, Empirical research, Lean manufacturing, Industry competitiveness [116], Lean, Kaizen, Total Productivity Maintenance, Just In Time, Standardization, 5S, Effectiveness [117], Autonomation, JIT, kaizen, lean methods, measures of operational performance [118], Lean, Road Map,

AHP, Lean Assessment [119], Leanness; Product-Service System (PSS); Conceptual model [120], Manufacturing technologies Lean practices Complementary effects Performance [121], Lean Manufacturing, Lean Implementation, Survey Research, Reliability, validity, New Variable Design [122], Lean manufacturing practice; LMP; quality initiative; continuous improvement; environmental performance [123]. It is noted that the studies have become limited to specific areas more than other years, such as the focus on the process of production, inventory and performance, human resource, and accounting management.

#### 3.7.2. Objective and Firm Classification

The objectives of previous studies [110-123] were based on the development of evaluations and the improvement of the evaluation process.

#### 3.7.3. Definitions, Methodology and Tools Classification

The studies [110-123] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data. One of the most important definitions in this time domain is that the definition of Resource-Based View (RBV) is used as a theoretical lens to examine the relationship between resources and lean practices and the operational performance.

**Table 9.** *Exploration and Analysis, Lean Tools and Main Results in Publications 2014.*

Lean Tools	Main Results	References
Just in Time, Takt time, Defect rate.	Proposing a comprehensive evaluation system that contributes to increasing the efficiency of the evaluation of firms.	[110]
Just in Time, Toyota Production System	Cooperation between accounting and processes is needed to ensure a better application of lean.	[111]
Visual Management, Workplace Organization, 5S, Just in Time and Continuous Improvement, Total Quality Management and Total Productive Maintenance	Early assessment to identify weaknesses contributes to higher efficiency for lean implementation.	[112]
Just in Time	Results showed a difference in lean application levels in companies.	[113]
Just in Time, Total Productive Maintenance and Work in Processes	Results indicate that the model contributes to decision making.	[114]



Lean Tools	Main Results	References
Lean Practices, Just in Time	The results indicate that knowledge of cultural dimensions helps managers adapt lean practices	[115]
Value Stream Mapping, Work in Processes, 5S, Just in Time, and Continuous Improvement	Detecting the barriers to lean implementation in Indian companies.	[116]
Lean, Kaizen, Total Productivity Maintenance, Just In Time, Standardization, 5S	The study showed the effectiveness of lean tools in raising productivity.	[117]
Just in Time, Value Stream Mapping, Total productive Management, Kaizen and Autonomation	The results indicate that JIT and automation have the strongest significance on the operational performance.	[118]
Lean	The results showed that the identification of the tracks for the implementation of the lean was very important.	[119]
Lean	The proposed model can be used as benchmarks to improve the evaluation process.	[120]
Total Quality Management and Just and Time	The results showed that the lean practices and manufacturing technologies have a unique effect on performance.	[121]
Value Stream Mapping, Pull and Just in Time	The results indicate the importance of the skill of delivery on time as well as the relationship with suppliers.	[122]
Just in Time	The results indicate the importance of customers in the success of lean.	[123]

### 3.8. Time Period 2015

The study found that there were 26 studies that included lean assessment methodology in general. The methodology of this study was limited to research that includes the word 'lean' as a keyword in the title. Therefore, the number is restricted to 10 papers.

#### 3.8.1. Keywords Classification

Previous studies [124-134] included the following keywords: Lean Manufacturing, Bayesian Belief Networks, Scenario Analysis, Business Performance [124], Lean Management; Services; Organizational culture; Lean Culture; Lean maturity; Management tool [125], lean manufacturing; production management; cultural transformation; sustainability [126], Lean production Leanness assessment, Fuzzy cognitive map (FCM), Data envelopment analysis (DEA), Fuzzy data envelopment analysis (FDEA), Decision Making Trial and Evaluation [127], lean; lean service; waste; customer value; lean methodologies applied to services [128], Lean production; human resource management; high performance work practices [129], Lean manufacturing, productivity improvement, continuous improvement [130],

Case studies, Lean production, Assessments, Learning, Adult education, Experiential learning [131], Lean metric; lean performance; lean index; qualitative analysis; quantitative analysis [132], India, Lean manufacturing, Performance improvement, Process industry [133]. It is noted that studies have become limited to specific areas more than other years, such as the focus on the process of production, inventory and performance, human resource, and accounting management.

#### 3.8.2. Objective and Firm Classification

The main objectives of previous studies [123-134] were based on exploring the financial and non-financial consequences of lean implementation, the improvement of the evaluation process and exploring the impact of employee's participation in the implementation of lean.

#### 3.8.3. Definitions, Methodology and Tools Classification

The studies [124-134] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data. One of the most important definitions in this time domain is that the definition Lean is a process of removal of unnecessary processes.

**Table 10.** Exploration and Analysis, Lean Tools and Main Results in Publications 2015.

Lean Tools	Main Results	References
Just-in-Time Total Quality Management	This study gives a new vision in applying Bayesian network for business performance.	[124]
Lean Manufacturing	The study shows that production process measures are most related to lean.	[125]
Lean Management	Organizational culture is essential for lean implementation.	[126]
Lean	Workforce development is important for lean implementation.	[127]
Value Stream Mapping, 5S, Pull and Six Sigma	The study contributes to the development of a proposed model for the provision of services without waste.	[128]
Lean Manufacturing	There is a strong relationship between empowerment and training.	[129]
5S, Kaizen, Standardized work, Just in Time, Total Productive Maintenance and Value Stream Mapping	Identifying success factors is a key to success and improvement of companies.	[130]
Just in Time, Value Stream Mapping	Design training courses or assess existing experiential learning courses.	[131]
Lean Practices	It was established that the qualitative-based lean index is subjective quantitative types that lack scope.	[132]
Lean Practices	Research contributes to identifying lean implementation strategies in India.	[133]

### 3.9. Time Period 2016

The study found that there were 22 studies that included lean assessment methodology in general. In this study, the methodology was limited to the number of research that includes the word 'lean' as a keyword in the title. Therefore, the number is restricted to 14 papers.

#### 3.9.1. Keywords Classification

Previous studies [124-134] included the following keywords: (Multi Criteria Decision, Analytic Hierarchy Process, Lean manufacturing, Six Sigma [134], Lean manufacturing; performance measurement; variability analysis [135], Lean manufacturing, Lean tools, Supply chain [136], Lean thinking, Waste, Lean manufacturing, Manufacturing industry [137], Lean manufacturing Green manufacturing, AHP, Dynamic sensitivity analysis [138], Lean Manufacturing [139], Lean Product Development (Lean PPD), Lean Transformation, Lean Readiness, Lean Assessment, LeanThinking, Set-Based Concurrent Engineering [140], Lean manufacturing, Leanness, Fuzzy logic, Performance measurement [141], Lean manufacturing; lean assessment tool; system dynamics [142], Lean manufacturing implementation; lean manufacturing attributes; operational performance parameters; lean manufacturing impact [143], Healthcare, lean management, productivity,

maturity, complexity, value [144], Lean manufacturing, lean practices, India, Indian industries [145], Lean Manufacturing system, Lean manufacturing attributes, Graph theory, Graph Theory and Matrix, Approach Permanent function [146], Lean manufacturing; Toyota Production System; small and medium enterprises; survey; performance [147]. It is noted that studies have become limited to specific areas more than other years, such as the focus on the process of production, inventory and performance, human resource, and accounting management.

#### 3.9.2. Objective and Firm Classification

The main objectives of previous studies [123-134] were based on the improve assessments, identifying lean practice levels and lean relationships impact of lean on the production factors.

#### 3.9.3. Definitions, Methodology and Tools Classification

The studies [134-147] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data, mathematical model and fuzzy logic. One of the most important definitions in this time domain is that the definition Lean Manufacturing: is the set of practices intended to attain perfection in the identification and elimination of waste through continuous improvement flowing the product at the pull of the customer.

*Table 11. Exploration and Analysis, Lean Tools and Main Results Firms in Publications 2016.*

Lean Tools	Main Results	References
Lean, Six Sigma	Results showed that the combination of lean and six sigma give results that are more effective than using lean only.	[134]
Lean Manufacturing	Provide a lean assessment model that is more flexible.	[135]
Just-in-Time, Six Sigma, Pull, Kankan Process Mapping, Value Stream Mapping, Continues Improvement, Visual Management, Benchmarking, Work Standardization	The results indicate the positive effect of lean on performance, and the results indicate that the most important obstacles are the limited knowledge of lean.	[136]
Just-in-Time, Kaizen, 5S,	The results indicate that the most important practices are: operations, planning, human resources, customer relationship.	[137]
5S, Value Stream Mapping, Continues Improvement, Teamwork, Visual control.	Total productive maintenance is identified as the most important lean practice.	[138]
Lean Manufacturing	The results indicated that the lack of awareness and knowledge of staff is the most important obstacles to the implementation of lean.	[139]
Lean Manufacturing	A five-level scale was designed, showing the results of the effectiveness of the model.	[140]
Value Stream Mapping, Just in Time	The measurement model is designed according to the fuzzy logic.	[141]
Total Productive Maintenance, Just in Time	Improving lean uses in the packaging industry.	[142]
Just in Time, Total Productivity Management	The study showed the impact of lean practices on performance, quality, and cost.	[143]
Kaizen	There is a positive effect of the lean on the performance of hospitals, and it is necessary to expand attention to aspects related to patients.	[144]
Just in Time, Value Stream Mapping, Total Productivity Management, Visual Management, Benchmarking, Total Productive Maintenance, Continuous Improvement Program	The study notes that lack of experience and education are the main reasons for the lean application process in India.	[145]
Just in Time, Value Stream Mapping, Continuous improvements, 5S, Kanban	A model was designed to compare the relative importance of lean practices.	[146]
Lean Manufacturing	The results show that the companies used practices in a fragmented manner without a holistic view of Lean Manufacturing.	[147]

### 3.10. Time Period 2017

The study found 28 studies that included lean assessment methodology in general. Hence, the methodology of this study was limited to research that includes the word 'lean' as a keyword in the title. Therefore, only 10 papers were included.

#### 3.10.1. Keywords Classification

Previous studies [148-157] included the following keywords: Lean manufacturing practices, Socio-technical and ergonomics practices, Maturity analysis [148],

Sustainability indicators, Lean Manufacturing,

Manufacturing process, Value stream mapping, Sustainable operations [149], Lean, Green [150], Lean Manufacturing, Lean Principles, Relative Efficiency, Retail Stores, Takt Time, Value Added Services [151], Quality management system; QMS; integration; conceptual model; impact; structural equation modeling [152], Lean Manufacturing, Auto Parts industry, ANOVA, Post Hoc test [153], Lean production, workforce development and operational performance [154], lean manufacturing; cement production; waste minimization [155], Lean Performance [156], lean production, operational performance, SMEs [157]. It is noted that studies have become limited to specific areas more than other years, thus focusing on the process of production, quality management, operational performance, human resource, and accounting management.

### 3.10.2. Objective and Firm Classification

The main objectives of previous studies [148-157] were based on the studying the expected impact of soft practices on performance, improving the process of lean implementation and the improvement of the evaluation process.

### 3.10.3. Definitions, Methodology and Tools Classification

The studies [124-134] included a variety of methodologies: quantitative studies, qualitative studies, observations, historical data. One of the most important definitions in this time domain is that the definition of Lean is a manufacturing philosophy that shortens the time between the customer's order and the product build/shipment by eliminating the sources of wastes.

**Table 12.** Exploration and Analysis, Lean Tools and Main Results Firms in Publications 2017.

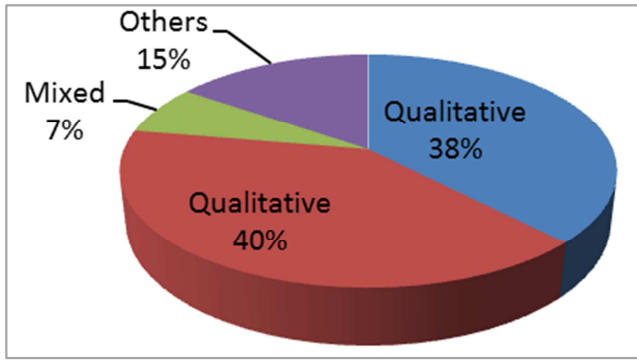
Lean Tools	Main Results	References
Flexible manpower, Pull system, Takt time, Continuous flow, Material supply, Zero defects, Quality assurance, Product / process quality planning, Standardized work, Production leveling, Maintenance system, Workplace organization, Goal oriented teams, Cross functional work, Problem solving methods, Improvement organization, Prioritization, Improvement approach Value Stream Mapping	The integration between lean and socio-technical and ergonomics contributes to the effectiveness of the organizational environment.	[148]
Green paradigm is intended to reduce environmental risks and negative environmental impacts while improving the ecological efficiency and eliminating environmental waste in organizations chain initiatives.	This method has identified three levels of sustainability.	[149]
Takt time	Develop proposals to improve the supply chain	[150]
Lean Tools	The results obtained in the three retailers are good enough to implement lean tools and enhance day to day efficiency at the outlets.	[151]
Just in Time, Load Leveling, Andon, Single, minute exchange die, Value Stream Mapping (VSM), Total Productive Maintenance, 5s, Six sigma, Kaizen, Root Cause Analyses, Group Technology, Plan Do Check Analysis, Smart goals, Key Performance Indicator, Single Piece Flow, Overall equipment efficiency, Visual factory, Standardized Work, Six Big losses, Policy development, Mudras, Mistake Proofing, Takt Time, Bottle Neck Analyses and Gemba	Results indicate the integration of Lean and quality management.	[152]
Just-in-time production, Total productive maintenance, Cellular manufacturing, Total quality management	Major barriers founded in micro, small and medium industries were lack of communication, attitude of shop floor management and degree of investment respectively.	[143]
Lean Manufacturing	The results of this study reinforce the assumption that during the implementation of lean production workforce development plays a key role due to its nature that advancement in the implementation translates to improving the performance.	[154]
Total quality control, Standardized operating procedures, Total production maintenance, Total quality control, Pull production / Kanban, Standardized operating procedures	Proposals have been made to reduce waste in the cement industry.	[155]
Process Improvement,	This study suggests that companies should implement more lean practices that affect some operational characteristics.	[156]
	The study indicates the importance of the lean and its active role in raising the level of performance.	[157]

## 4. Digital Analysis of Previous Studies

This part of the study includes the digital analysis of previous studies and presents illustrations of the rules of

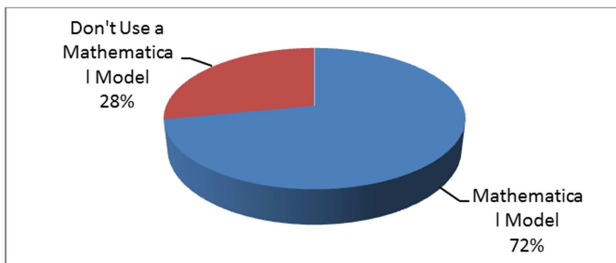
metadata for the values of repetition.

Through the descriptive analysis of the methodology used in previous studies, the results are demonstrated as in Figure 1.



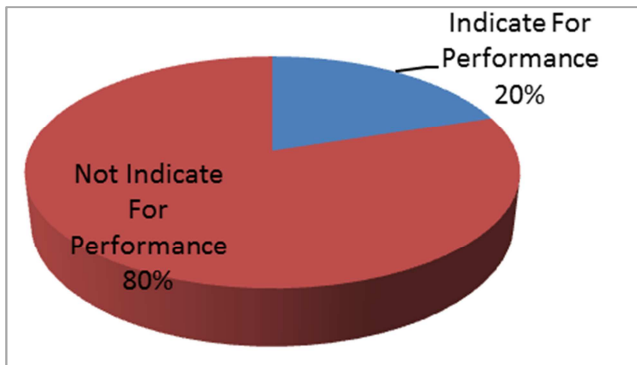
**Figure 1.** Relative Distribution of Methodology.

The descriptive analysis of the methodology (Mathematical Model, Don't Use a Mathematical Model) used in previous studies is showed in Figure 2.



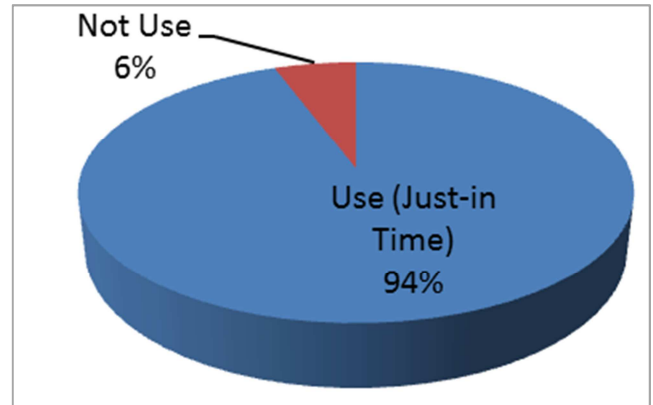
**Figure 2.** Relative Distribution of Using Mathematical Model or Not Using.

Through the descriptive analysis of studies that included references to performance in key words, objectives and results (Indicate For Performance, Not Indicate For Performance), the results are presented in Figure 3.



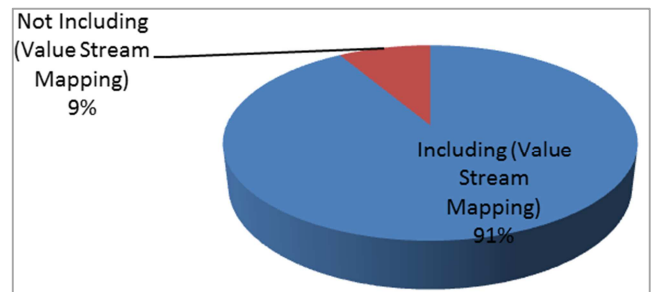
**Figure 3.** Relative Distribution of Indicate for Performance or Not.

Through the descriptive analysis of studies that included references to Just- in Time as a tool, the results are illustrated by Figure 4.



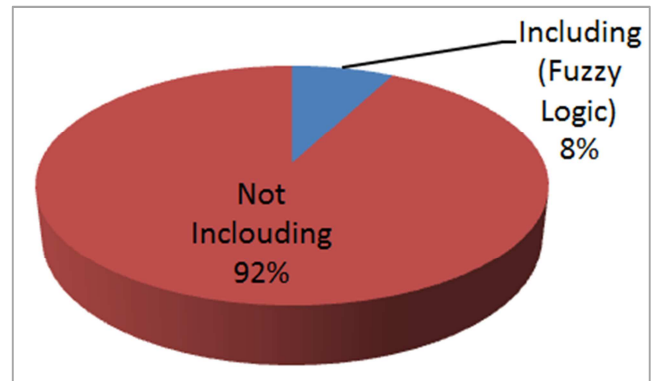
**Figure 4.** Relative Distribution of Use Just-InTime or Not Use on Tools.

The descriptive analysis for studies that included references to Value Stream Mapping is demonstrated by Figure 5.



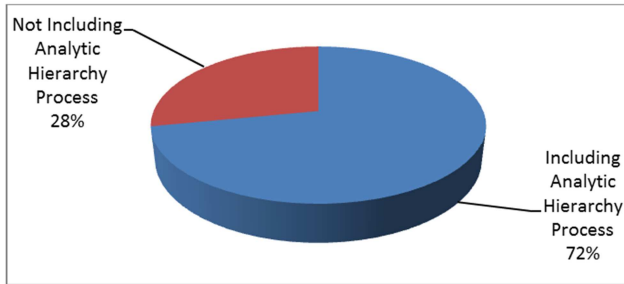
**Figure 5.** Relative Distribution of Use Value Stream Mapping or Not Use on Tools.

The descriptive analysis of studies that included references to (Fuzzy Logic) is showed by Figure 6.



**Figure 6.** Percentage of Studies that Included (Fuzzy Logic) in Their Titles.

The descriptive analysis of studies that included references to Analytic Hierarchy Processes illustrate the results as in Figure 7.



**Figure 7.** Percentage of Studies that Included (Analytic Hierarchy Process) in Methodology.

## 5. Conclusion

Previous studies indicate several key points:

- a. There is a large amount of evaluation studies on lean practices.
- b. Extend areas of application of lean practices in various industry fields and services.
- c. Most of the objectives of the studies are to measure the lean level of enterprises and companies.
- d. Studies indicate the depth of the relationship as a power sector between performance and the level of lean.
- e. Studies indicate that there is no established methodology for measuring the level of lean practices.
- f. Some studies attempt to expand the fuzzy concept in the measurement of lean levels.
- g. Most studies are based on quantitative and qualitative methodologies.
- h. There are also studies based on qualitative data, and there are studies that combined the two methods in addition to multiple methods of arithmetic. There are many industries and sectors that need new and in-depth studies on lean studies, such as energy, tourism, hotel services, communications, and education.
- i. Studies that attempted to link the evaluation process to the practical decision-making process of the lean are often more related to mathematical logic and mathematical methods.
- j. In the past five years, there has been a clear change in evaluation methodology by combining quantitative and descriptive data with mathematical models that include calculations that help in decision making, and it was clear that the Analytic Hierarchy Process was the most commonly used.

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