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Critical Analysis of Lean Construction Maturity Models: A Systematic Literature Review

J. K. D. D. T. Jayanetti [1], B. A. K. S. Perera [1], K. G. A. S. Waidyasekara [1] and Mohan Siriwardena [2,*]

[1] Department of Building Economics, University of Moratuwa, Katubedda 10400, Sri Lanka; qsthamasha@gmail.com (J.K.D.D.T.J.); kanchana@uom.lk (B.A.K.S.P.); anuradha@uom.lk (K.G.A.S.W.)
[2] Faculty of Engineering and Technology, School of Civil Engineering and Built Environment, Liverpool John Moores University, Liverpool L3 3AF, UK
* Correspondence: m.l.siriwardena@ljmu.ac.uk

Abstract: Lean construction (LC) is becoming prevalent, and assessment of the level of LC implementation is vital for organizations to realize their full potential. In meeting that need, lean construction maturity models (LCMMs) play a key role. However, there is less evidence of critical reviews in spite of the significant number of LCMMs available. Therefore, this study was initiated with the aim of systematically reviewing the literature on existing lean-construction-related maturity models (MMs) through a critical review. The study adopted the PRISMA method to review 24 such models using manual content analysis. The study revealed the most common attributes among the models, along with their key strengths and weaknesses. The findings of this study can be directly used to develop more robust LCMMs and enhance the knowledge base on theoretical underpinnings. From an industry perspective, the findings assist organizations to more effectively assess LC maturity. The study invites further research on the area of LC maturity and advocates for developing new MMs addressing these areas identified for improvement.

Keywords: lean construction; maturity models; lean construction attributes; assessing lean construction; systematic review

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1. Introduction

The global construction industry faces a central challenge in improving its productivity and innovation [1,2]. According to [3], the productivity in the construction industry has been declining globally over the past decades. The construction industry is commonly faced with many challenges, such as high wastage, repeated delays, cost overruns, and quality control issues, which hinder overall efficiency [4]. As a counter-measure to conventional construction problems, Koskela's work made a significant and pioneering contribution to introducing lean principles into construction [5].

Lean construction (LC) is a philosophy evolved from lean manufacturing. Despite the perceived differences between the construction and manufacturing industries, there are notable similarities between them [6]. Therefore, the principles of lean manufacturing can be tailored and adapted for effective use in construction [7]. Lauri Koskela emphasized this need to apply lean production principles to the construction sector to improve the industry as a whole [8]. The core idea behind LC is delivering exact customer value through a continuous work flow by eliminating waste and continuous improvement [5,9–11]. Evidently, the integration of lean construction principles into conventional construction projects effectively addresses the pressing challenges within the construction industry [12–14].

Embedding lean construction in an organization typically requires many changes [15], and can be a challenging endeavor [16]. In particular, when transformations take place, it becomes crucial to measure the current state of the maturation process [17]. A prominent reason for the lack of lean implementation in the construction industry is the inability to assess the existing level of lean enactment [18,19] or to assess the real benefits of adopting lean [20]. Even though some organizations in the construction industry unwittingly practice lean tools and techniques, they are unaware that such practices belong to LC principles [21] hence, there is a need for a tool to assess LC maturity in organizations [22].

In fulfilling the above need, LCMMs provide directions and information to prioritize improvement actions and initiate a change [23]. MMs measure, compare, describe, or determine a path or roadmap [24]. Moreover, MMs assist in identifying strengths and weaknesses of certain domains of an organization [25]. Aside from assessing the current level [26], MMs provide a number of benefits, such as guidance in implementing change [27], explaining a path to achieving excellence by evaluating how to implement best practices [28], guiding transformation with information about strengths and weaknesses [29], creating awareness of the improvement requirements [30], providing support in implementing change in a systematic and well-directed way [31], and enabling sustained embedding of business processes [32].

Even though MMs provide such benefits, it is noticeable that there are fewer data on prominent, well-renowned LCMMs in contrast to other industries such as IT, software development, and manufacturing [33]. Intriguingly, there is a dearth in the literature of critical reviews on LCMMs. Although research on construction MMs exists, they have significantly less connection to lean construction [34,35]. Moreover, in the process of developing a new maturity model, Nesensohn [36], studied several MMs and their relevance, but the study only reviewed construction-related MMs, not LCMMs. Further, Rodegheri [37] carried out a study to identify the most suitable LCMMs for the Brazilian construction industry. That study used several LCMMs in the same project to identify the best-suited LCMM for Brazil. However, the study did not investigate the core of any LCMM and did not critically review the LCMMs. These pieces of evidence prove that there is a clear gap in the literature regarding the critical reviewing of LCMMs. Thus, this study is aimed at systematically reviewing the existing LC-related MMs using a critical review. To achieve that aim, firstly, the study identified the types of existing LCMMs and other relevant models for LC maturity. Secondly, the key attributes of the models were explored. Moreover, using critical analysis, the study aimed to identify the key strengths, existing gaps, and areas of improvement. It is highly important to identify the gaps in existing models in order to develop more robust LCMMs for the future, considering the increasing acceptance of lean construction. The study explored the existing LCMMs and critically reviewed the current status of the models. By doing so, the study aimed to contribute to the existing knowledge base of the LCMMs by identifying the key issues and areas for improvement to enhance the quality of LCMMs. This study contributes to the construction industry by enhancing the effectiveness of lean maturity and enabling firms to successfully adopt lean construction principles.

The paper begins with an introduction and follows with a comprehensive systematic literature synthesis of existing LCMMs using the PRISMA systematic review method. Next, the research method, comprising data collection techniques, is explained. Subsequently, data collected from the literature are critically analyzed and discussed. Finally, the findings are presented via a discussion of the analyzed data.

2. Literature Synthesis

2.1. Lean Construction

Lean construction is not an independent concept but rather a compilation of ideas and principles derived from different industries and applied to the construction sector. It draws its core principles from lean manufacturing, which originated in the Toyota Production System (TPS) in Japan during the 1950s [38]. Lauri Koskela, recognized as a pioneer in lean construction (LC), introduced the concept in 1992 through a seminal paper demonstrating how lean manufacturing principles could be tailored and implemented in the construction industry [5].

Glenn Ballard and Greg Howell founded LCI in 1997 with the goal of generating and spreading novel insights in project work management. As per LCI, the key tenets of LC are to optimize the whole, removal of waste, focus on process and flow, generation of value, and continuous improvement [39]. In the book *Lean Construction: Core Concepts and New Frontiers*, many scholars who significantly contributed to the development and evolution of LC present various concepts related to the above-mentioned LC principles, summarizing the theoretical backgrounds to themes and theories, lean construction approaches, and the new prospects of LC [40,41].

Koskela define LC as a new way of production that reduces time, resources, and effort in order to generate the best possible outcome in terms of delivering value [11]. This notion is well-supported by LCI as it defines lean construction as an approach to project delivery that employs techniques to optimize stakeholder value and minimize waste through a strong emphasis on team collaboration [39]. Howell presents a similar idea of LC, expanding on the production aspect and emphasizing LC as a production management philosophy [42]. In defining LC, there is less evidence about a commonly accepted definition; however, the central idea of LC is preserved and emulated through the existing explanations. The fundamental idea of LC can be expressed as a management philosophy that focuses on delivering bespoke customer value by minimizing waste of all forms and creating a smooth workflow embedded in continuous improvement with the idea of respect for people [11,43,44].

Regarding the practical side of LC, many lean tools and techniques have been developed. Such examples of significant lean tools are the last planner system, the pull-planning concept, and the lean project delivery method [45–47]. The lean project delivery system (LPDS) refers to an approach or system that applies lean principles and practices to project management and project delivery processes. LPDS aims to maximize stakeholder value by reducing waste, improving collaboration, enhancing productivity, and optimizing project outcomes [48]. The last planner system operates as a cohesive and integrated system, wherein each element is essential to facilitate lean project planning and execution. It is crucial to resist the temptation to fragment the system and selectively employ specific components [49].

The application of lean principles to construction has been supported by substantial evidence, highlighting numerous advantages that can be derived from embracing lean thinking in this industry [50]. The advantages encompass a wide range of benefits, including enhanced productivity, heightened reliability, improved quality, greater client satisfaction, increased predictability, shortened project schedules, minimized waste, reduced costs, improved design feasibility, and enhanced safety measures [51,52].

2.2. Maturity Models

An MM is a tool with a structured set of elements that describes a progressive path towards improvement from immature processes to mature processes [53]. Originally, thinkers of quality management expressed the idea of maturity [54,55]. MMs have now expanded into many industries [56]. In the evolution of MMs, the capability maturity model (CMM), later updated as the CMMI (capability maturity model integrated) stands as a prominent maturity model that was used later as the fundament of many other models [33,57].

Even though the construction industry is described as being distinct from the manufacturing industry [58], Ballard and Howell argue that construction is similar to manufacturing, in that production and assembly are undertaken at a specific site [59]. The idea of lean production management can be taken with appropriate changes for effective management of the construction industry [7]. In 1992, Lauri Koskela expressed the need for adaptation of the lean production philosophy to the construction sector to gain competitiveness and to increase efficiency [5]. With this revelation, lean construction became a “hot” topic amongst industry specialists, academics, and business managers [60].

With this increase, the need to assess lean construction has become vital [61]. Many scholars have noted that implementing lean in construction requires monitoring and measuring the current state of implementation and how it has improved over time [62].

In accordance, MMs have been at the forefront of assessing organizations to measure and evaluate the success of a process [63] and the new implementation on its progressive path [33]. However, considering the field of lean construction, there are limited findings to measure its maturity [36,64].

MMs relating to LC maturity are still an emerging topic. The literature provides only a few published studies that explain lean construction MMs. Table 1 portrays the identified models and general information.

Table 1. Identified maturity models.

Model Reference	Source of Reference	General Information
M1	[27]	• Based on CMMI and LC principles of Koskela; • Presents five levels of maturity; • Framework with 75 statements organized in 11 attributes classified in 6 layers, completed by external evaluator after a construction site visit and conversations with employees, evaluating through a Likert scale from 0 to 4.
M2	[65]	• Unique and easy model to evaluate the quality and degree of leanness. A quick method to assess lean maturity at a given time; • 30 questions, completed by an external evaluator after a one-hour site visit evaluating through a Likert scale from 0 to 4.
M3	[66]	• Analyze degree of LC; • Based on 11 principles of Koskela and Carvello. Performs the analysis involving different stakeholders; • Diagnoses the current state of a construction company in relation to implementation of concepts of lean construction.
M4	[67]	• Based on principles of LC by Koskela and principles of Lean Thinking (LT) by Womack and Jones and Lean Construction Institute; • Presents an Excel tool that analyzes 4 main elements with 191 attributes distributed in 36 characteristics, evaluated on a Linkert scale from 0 to 5.
M5	[68]	• Developed on principles of LC by Koskela, principles of LT by Womack and Jones, and concepts proposed by Rentes; • 24 questions, completed by an external evaluator through interviews.
M6	[69]	• Based on the principles of LT by Womack and Jones and Diekmann; • Self-assessment, evaluating 16 LC practices on a Likert scale from 0 to 5.
M7	[70]	• Data collected from 25 lean practitioners across 6 organizations; • The model applied to projects of four different organizations and the LC Maturity Ratings were calculated; • This framework provides a means to measure the current state of lean maturity to determine the prevailing degree of leanness and to understand the areas requiring improvement.
M8	[71]	• The aim is to help organizations in the Highways Agency's supply chain to determine the extent to which they have transformed themselves to adopt lean principles in providing products and services to Highways England.
M9	[72]	• Qualitative and quantitative surveys were conducted in the German construction sector to investigate the consistency between the techniques implemented and LC concepts; • The survey concerns 61 companies that are classified among the Top 100 construction companies in Germany.
M10	[73]	• Identify best practices and the most commonly used principles of LC; • Questionnaires and case studies are used to analyze; • A study to identify the best practices of LC and a Lean Conformance Model is developed.
M11	[74]	• Summarizes LC principles to assess the consciousness of the LC principal among Malaysian construction companies

Table 1. *Cont.*

Model Reference	Source of Reference	General Information
M12	[75]	• Aims at clarifying the main conceptual basis of LC philosophy; • Relationships between those principles and nine sources of waste (transportation, motion, inventory, waiting, overproduction, defects, over-processing, unused employee creativity, and work accidents) were analyzed.
M13	[76]	• The model formulated a theory, then tested using a management simulation game and computer simulation, and subsequently, developed for practical application; • The theoretical model developed is the result of the application of this approach in a holistic manner to the management of high-rise apartment building construction.
M14	[77]	• A framework for implementing lean construction and consequently improving performance levels in the construction industry in the context of Saudi Arabia; • Following a survey of 282 construction professionals, 12 critical success factors for implementing lean construction.
M15	[78]	• Aim to measure integrated BIM and lean maturity; • Maturity model based on reviewing the literature around current MMs.
M16	[79]	• Analyze compatibility of BIM with IPD and LC in the context of MMs to identify how these three concepts can be synchronized. Comparative analysis is conducted using ten accessible, free, research-based, and frequently cited BIM MMs.
M17	[80]	• Based on Toyota Production System and integrated project delivery; • Provide an Excel tool that analyzes four main elements; • 152 attributes distributed in 40 characteristics, evaluated on a Linkert scale from 0 to 5.
M18	[81]	• Principles of LC by Koskela and principles of LT by Womack and Jones; • 103 statements distributed over 15 categories where the LC practices are described and with a scientific reference set out using the LC principle. The categories have different weights.
M19	[82]	• Concepts proposed by Diekmann; • Questionnaire with 33 questions, applied by external interviewer evaluating through a Likert scale from 0 to 5.
M20	[83]	• Evaluate the implementation of LC and explore the influencing factors of lean implementation in China's construction firms; • Based on principles of LC by Koskela and principles of LT by Womack and Jones and LC tools. • Framework with 26 statements organized in 7 instruments evaluated in a Likert scale from 0 to 5 by different company actors in an interview.
M21	[84]	• Identify the parameters defining how LC is being implemented (current condition) and how LC can be further promoted (future direction); • Principles of LC by Koskela (1992), principles of LT by Womack and Jones; • Evaluate current conditions and future directions in 5 categories using Likert scale from 1 to 5.
M22	[85]	• A tool designed to guide leadership through a transformation process leading to enterprise excellence; • Originally developed with input from the aerospace industry in both the US and UK; • A tool for self-assessing the present state of "leanness".
M23	[86]	• Provides a check list to assess the manufacturing changes towards lean production using the results from a survey in the Spanish region of Aragon; • Analyzes the lean production systems, and the determinants of the use of these indicators.

Table 1. *Cont.*

Model Reference	Source of Reference	General Information
M24	[87]	• Assessment of the concept of "leanness" for any wood products company; • A methodology for quantitative and objective assessment of the leanness of any wood products operation.

[M1] Lean Construction maturity model (LCMM) by Nesensohn, [M2] LCR–Rapid Lean Construction-Quality Rating Model, [M3] Degree Of Lean Construction (DOLC), [M4] Lean IPD Health and Maturity Model, [M5] Lean Construction Diagnostic Model (MDCE), [M6] Maturity Model For Development Of Lean Construction Principles (MMDPLC), [M7] Framework For Progressive Evaluation Of Lean Construction Maturity Using Multi-Dimensional Matrix, [M8] Highways Agency Lean Maturity Assessment Toolkit (HALMAT), [M9] Lean Construction Framework (LCF), [M10] Lean Conformance Model (LCM), [M11] Lean Construction Concept Model (LCCM), [M12] Development Of An Input–Output Model Of Lean Construction, [M13] Lean Management Model for Construction of High-Rise Apartment Buildings, [M14] Framework for the implementation of lean construction strategies using the interpretive structural modeling, [M15] Development Of An Integrated BIM And Lean Maturity Model–Ideal Maturity Model, [M16] An integrated BIM-IPD-LC (BIL) maturity model, [M17] Lean Assessment Tool Baseline for Ireland (LATB), [M18] A Protocol For Assessing The Use Of Lean Construction Practices (PALC), [M19] Assessing lean conformance (ALC), [M20] Evaluation index system of lean construction (EISLC), [M21] Current condition and future directions for lean construction in highways projects (CC&FD), [M22] Lean Enterprise Self-Assessment Tool (LESAT), [M23] Lean Production check-list, [M24] the Lean Index.

The study identified 24 key models that are discussed. Among the models, few are exclusively identified as LCMMs that clearly portray the idea of LC maturity and the models showcase a sensible path to measure LC maturity [27,66]. Another set of models/frameworks also unequivocally regards lean construction as the fundament element of the models [73,88]. Lastly, three models that do not have direct connection to LC maturity or LC were identified since they use lean principles and the adaptability of such in models/frameworks [85,86].

3. Materials and Methods

A comprehensive literature review confirms the previous studies and assists the researchers to better comprehend the important aspects relating to the area of interest [89]. In addition, a literature review is an excellent way of synthesizing research findings to show evidence on a meta-level and to uncover areas in which more research is needed, which is a critical component of creating theoretical frameworks and building conceptual models [90]. Among several methods of conducting a literature review, an integrative literature review helps scholars to identify areas of improvement regarding a topic through exploring and analyzing the existing literature. The integrative literature review is a form of research that reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated [91]. Integrative literature reviews allow scholars to take a more critical approach in the pursuit of enhancing the existing level of understanding of a subject or concept. Critical analysis of the literature involves carefully examining the main ideas and relationships of an issue and provides a critique of the existing literature [92]. Therefore, this study aimed to critically analyze existing lean construction MMs and to identify areas for improvement in order to upgrade the level of quality and effectiveness of LCMMs.

In finding literature for the study, the authors adopted the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) method. PRISMA is a comprehensive and an exhaustive technique used to collect all the available and relevant data relevant to a specific subject area and conforming to predetermined eligibility criteria [93]. By providing checklists and reporting on how the information and data were screened, PRISMA provides a systematic trail for data collection [94]. This method is further appreciated by scholars since it provides sound backing to a study, and tries to present all the available data by synthesizing previous works [95]. Since this study required the systematic identification and analysis of all the data relating to LCMMs, the PRISMA method was adopted due to its appropriateness. Figure 1 portrays the overall research process and the key steps followed.

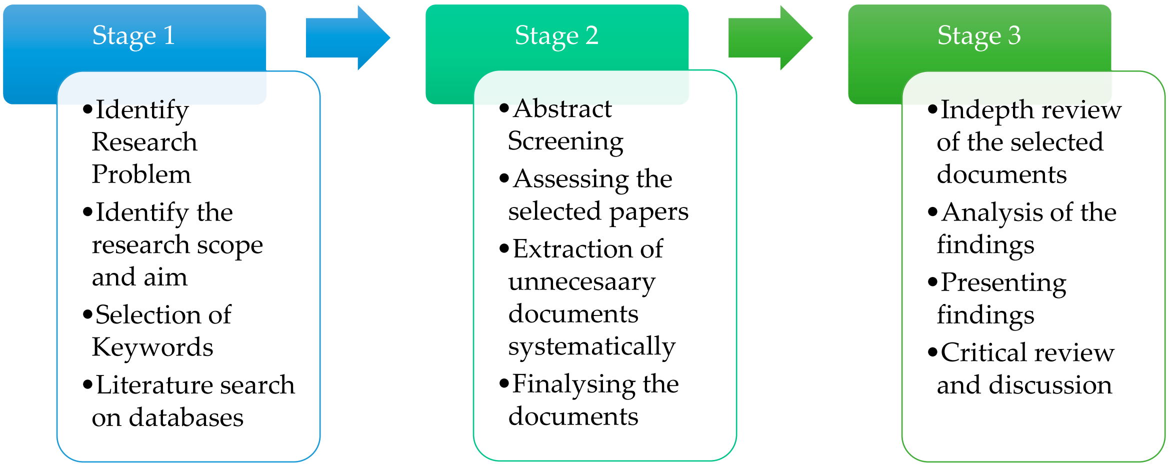

Figure 1. Research process.

As indicated in Figure 1, the study was carried out in three main stages. Firstly, the study identified the need to research the area of LCMMs since the data are lacking in this subject. As a result, the scope was determined as the critical review of existing LCMMs. In selecting documents for the review, the PRISMA method was adopted and the documents were collected. At the second stage, findings from databases were screened and the documents were sorted and finalized. In the third stage of the study, an in-depth analysis of the selected documents was carried out. With the analyzed data, the critical review was conducted.

The literature search, or information retrieval process, not only informs the results of a systematic review, it is the underlying process that establishes the data available for analysis [96]. The key words were identified as; Lean Construction Maturity, LCMMs, Modern LCMMs, Lean Construction Maturity Assessment, Lean Construction Maturity Assessment Tools, Lean Construction Maturity Framework, Assessing lean construction.

In selecting the articles from the literature search, screening was undertaken through two main lenses. Each of these lenses has different criteria, as discussed below.

1. Criteria relating to the relevance of the model to the study

In this aspect, articles were selected with respect to the suitability, compliance, and the relevance to the study. The notion here is to screen the suitable models from a plethora of models that would fit the aim of the research. Under these criteria, the following factors were considered:

- Articles that correspond to any type of LCMM;
- Articles relating to lean construction maturity;
- Articles related to lean maturity/assessment.

Through the search it was noticeable that there is a dearth of literature directly conforming to LCMMs. Since the existing literature is lacking on models that identify themselves as "LCMMs", the authors extended the reach to techniques and tools that discuss lean construction maturity and lean maturity that resembles the idea of lean construction maturity. This extension of the search provided the authors with the ability to identify impactful studies conforming to the study.

2. The quality and the effectiveness of the papers

Under these criteria, the evaluation of the quality of the articles was taken into consideration. The below-mentioned criteria were used to assess the quality and effectiveness of academic papers:

- Explanation of use of model attributes;
- Reliability of the publisher;
- Originality and the reliability of the model;

- Existence and clear explanation of model elements.

These criteria ensured the overall excellence, rigor, and contribution of the articles to the field of study. These criteria guided the authors to screen out the most impactful articles for the study.

Figure 2 explains in detail how the literature for the analysis was selected using the PRISMA method. Initially, the words were carefully identified to suit the scope of the study. Then, the literature search was carried out on three main databases from year 1990 to 2022, since lean construction become evident in 1992. The literature search, or information retrieval process, not only informs the results of a systematic review, it is the underlying process that establishes the data available for analysis [96]. Thus, the authors used scientific databases for the literature search. The three main databases used for the study were Science Direct, Google Scholar, and Emarald Insight.

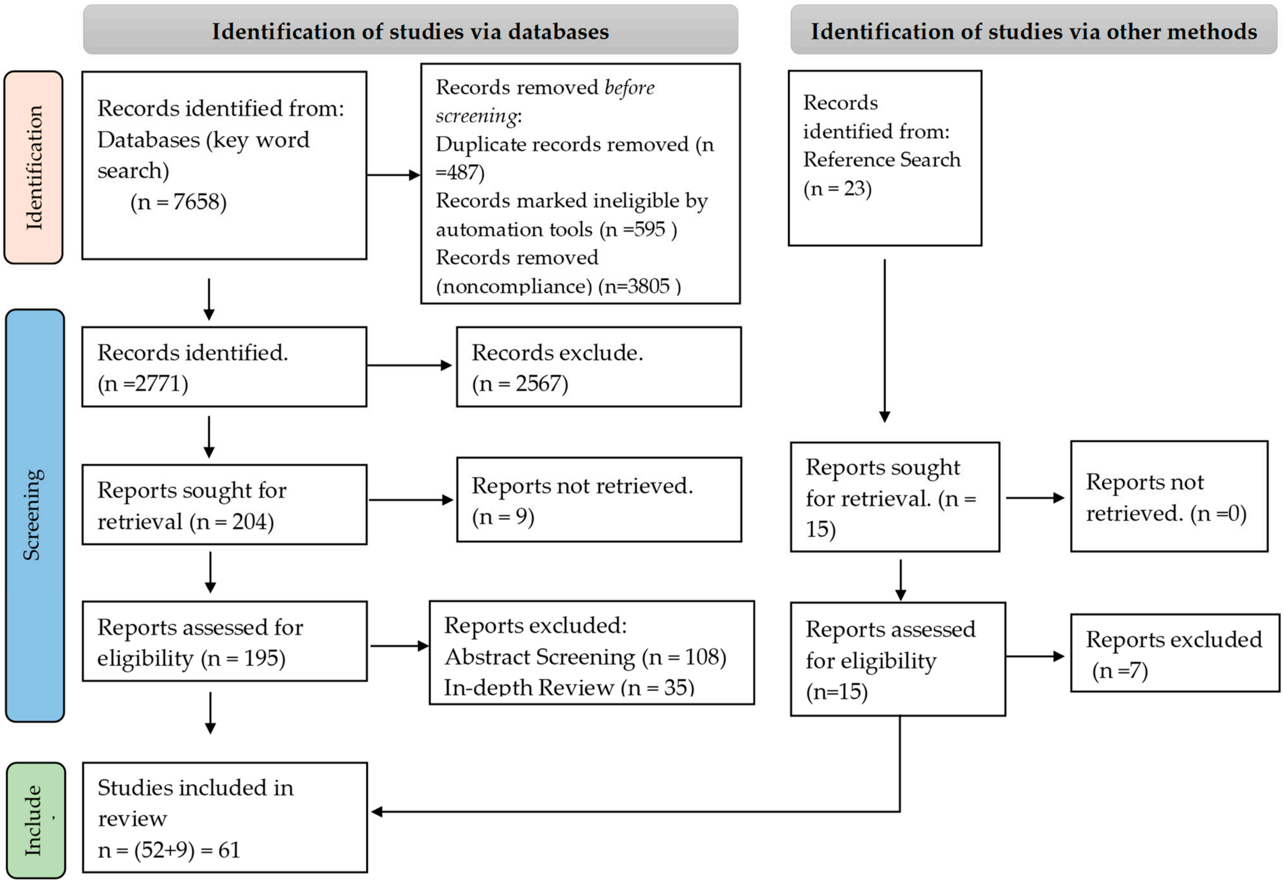

Figure 2. Stages of the Prisma systematic literature review adapted from [94].

In the beginning, authors identified 7658 results from leading databases. Articles that did not meet the criteria described above were systematically discarded, as shown in Figure 2, since they did not comply with the aim of the study. From the search results, articles were excluded since they did not provide any relevance to the study. The selected articles were screened through the titles and the abstracts. Subsequently, the identified articles were critically reviewed in detail to gain a comprehensive understanding. Through this rigorous screening, 52 articles were selected for the discussion as per the selection criteria. Subsequently, nine articles were further identified through the reference lists of the already-selected articles, and the suitable articles were also included in the study. Eventually, 61 articles were selected for the final review and analysis of the study. Ultimately, through the literature findings via the PRISMA analysis, the authors identified 24 prominent models/tools or frameworks that portray substance, relevance, and conformance for the scope of the study. These identified models are presented in the following sections.

4. Findings

4.1. Key Attributes of Existing Lean-Related Maturity Models

As pointed out by many scholars, the attributes are a key component of any model and expand the scope of the model. The attributes are the main element of the model, and are the fundament of models and the base for assessment [97]. Table 2 provides an overall outlook of the selected models and their attributes.

Table 2. Key attributes of lean-related maturity models.

Model Reference	Key Attributes	Focus Area
M1	Lean leadership, Customer focus, Way of thinking, Culture and behavior, Competencies, Improvement Enablers, Processes and tools, Change, Work environment, Business results, Learning, competency development.	LC Maturity
M2	Client focus, Waste Consciousness, Quality, Material Flow, Organization, Planning, Information flow, Continuous improvement.	LC Maturity
M3	Reduce the share of non-value-adding activities, Increase output value through systematic consideration of customer requirements, Reduce variability, Reduce the cycle time, Simplify by minimizing the number of steps, parts, and linkages, Increase output flexibility, Increase process transparency, Focus control on complete process, Build continuous improvement, Balance flow improvement with conversion improvement, Benchmark.	LC Maturity
M4	Transformational change, Lean project delivery methods and management, Integrated project delivery, Lean project delivery, and Last Planner System.	LC Maturity
M5	Reduce the share of non-value-adding activities, Increase output value through systematic consideration of customer requirements, Reduce variability, Reduce the cycle time, Simplify by minimizing the number of steps and parts, Increase output flexibility, Increase process transparency, Focus control on the complete process, Build continuous improvement into the process, Balance flow improvement with conversion improvement, Benchmark.	LC Maturity
M6	Waste disposal, Standardization, Culture/people, Customer focus, Continuous improvement/Quality.	LC Maturity
M7	Physical Manifestation (Implementation of Lean Tools and Processes, Continuous Improvement, Focus on Value Creation, Work Standardization); Behavioral Manifestation (Lean Culture and Behavior, Waste Identification and Productivity, People Development); Strategic Manifestation Collaborative Working, Strategic Use of Lean, Leadership to drive Lean, Customer Focus).	LC Maturity
M8	Strategic use of Lean, Financial, information, and procurement systems, Lean leadership, People development, Lean structure and behavior, Collaborative working, Delivery of value, Standard work, Process flow, Process control and quality assurance.	LC Maturity
M9	Management, Planning Control, Behavior, Supply, Installation, Design, Collaboration, Procurement; Qualitative and quantitative surveys were conducted to investigate the current understanding of lean construction principles among German contractors.	LC
M10	Standardization, Culture/People, Continuous Improvement/Built-In Quality, Eliminate Waste, Customer Focus; containing sixteen sub-principles.	LC
M11	Specify value, Identify and map the value stream, Flow, Pull, Perfection/continuous improvement, Transparency, Process variability.	LC
M12	Customer focus, Supply, Continuous improvement, Waste elimination, People involvement, Planning and scheduling, Quality, Standardization and transparency.	LC
M13	Reduction in batch sizes, use of pull flow, work restructuring, and process improvement with multitasking.	LC

Table 2. *Cont.*

Model Reference	Key Attributes	Focus Area
M14	Top management commitment, Education and training for lean construction. Adopting alternative procurement methods, Adopting new construction technologies, Applying appropriate LC tools/techniques, Implementing organizational change, Promoting a culture of teamwork, Adoption of continuous improvement, Clear definition of client's requirements, Applying the lean methodology, Coordinating and promoting, Establishing long-term relationships.	LC
M15	Integrated BIM and lean maturity concepts which could serve as a basis in terms of assessing the performances of the projects implementing BIM and lean together.	LC
M16	Lean Leadership, Customer Focus, Way of Thinking, Culture and behavior, Improvement Enablers, Competencies Processes and Tools Change Work Environment Business Results Learning and Competency Development.	LC
M17	Transformational change, Integrated project delivery strategy, Last Planner System, Lean project management.	LC
M18	Human Resources, Continuous Improvement, Work Standardization, Work Safety, Layout, Quality Control, Logistics and Supply Chain Management, Information Technology and Communication, Pull Production, Visual Management, Production Planning and Control, Sustainability, Design Management and Product Development, Costs Control, Continuous Flow.	LC
M19	Customer focus. Culture/people. Workplace organization and standardization. Eliminate waste. Continuous improvement/built-in quality.	LC
M20	Last Planner System, Visible Management, Conference Management, Just in Time, Concurrent Engineering, Total Quality Management, 5S and 6S on-site management.	LC
M21	Current Condition, Project delivery, Process, Training, Project governance, Supply chain Future Direction, Project delivery, Process, Training, Project governance, Supply chain.	LC
M22	Enterprise transformation, Leadership commitment, Identify relevant stakeholders and value propositions, Enterprise effectiveness before efficiency, Ensure stability and flow, Organizational learning.	Lean Maturity in Enterprises
M23	Elimination of zero-value activities, Production and delivery Just in Time, Multifunctional teams, Continuous improvement, Supplier integration.	Lean Manufacturing Maturity
M24	Production Cost/, Production Time, Inventory Control, Yield Maximization vs. Value Maximization, Production Scheduling, Employee Commitment and Involvement, Management, Commitment, Competitive Benchmarks Market share vs. Competition Process Re-engineering Time/Cost Time to implement, Pull Manufacturing, Managing Raw Material Lead Time, Overhead/Accounting/Documentation Cost, Customer Satisfaction.	Lean Maturity in Wood Production

Models such as the LCMM by Nesensohn, LCR–Rapid Lean Construction-Quality Rating Model, DOLC, Lean IPD Health and Maturity Model, MDCE, MMDPLC, Multi-Dimensional Matrix, and HALMAT have all been identified as LCMMs. These models share several common characteristics. Primarily, all of these models have the same goal of assessing LC maturity and are designed accordingly. Further, all of these models consider LC principles as the fundament in designing model attributes [5]. Table 2 presents the attributes of each model, and it clearly depicts that the main component of model attributes is similar to that of LC principles. They are identified as follows:

- Reduce the share of non-value-adding activities;
- Increase output value through systematic consideration of customer requirements;
- Reduce variability;
- Reduce the cycle time;
- Simplify by minimizing the number of steps, parts, and linkages;
- Increase output flexibility;

- Increase process transparency;
- Focus control on the complete process;
- Build continuous improvement into the process;
- Balance flow improvement with conversion improvement;
- Benchmarking.

Notable LCMMs, such as the model by Nesensohn [36], Lean IPD Health and Maturity Model by the Lean Construction Institute [67], and DOLC by Carvalho and Scheer [66], have adopted all the LC principles in the model attributes. However, some models have only considered segments of LC principles as key attributes. This suggests that even though these models try to assess lean maturity, some key elements are excluded. Moreover, the close attention to attributes reveals that LC principles such as strategic use of lean, the customer-centric approach, enabling people, waste consciousness [98] and standardization are common among all the models [99]. Importantly, attributes act as the outer-most layer of the models. However, these attributes are further subdivided into measurable outcomes such as key performance indicators, industry best practices, and ideal statements. The measurable outcomes have drastic variations since these are shaped pertaining to the country of the developed model. Even though a resemblance is visible in the outer-most layer, the models' content inside is significantly different as the inner elements of the models present data specific for the country for which the model is developed. Consequently, in many cases, a model developed in certain industry conditions is not ideal to be used in other countries where industry characteristics are considerably different.

Moreover, another set of models was considered for the study due to their close resemblance to LCMMs and the appropriateness of the models to the study. These models, i.e., LCF, LCM, LCCM, Input–Output Model of Lean Construction, Lean Management Model for High-Rise Apartment Buildings, Framework for the implementation of lean construction, Ideal Maturity Model, BIM-IPD-LC maturity model, LATB, PALC, ALC, EISLC, and CCFD, all are closely related to lean construction maturity. For instance, even though these models do not explicitly mention the term lean construction maturity, the entire assessment process is centered around exploring the LC capabilities of the organizations. As an example, LCM assesses the conformance of an entity with LC principles. It employs six attributes i.e., standardization, culture/people, continuous improvement/built-in quality, eliminate waste, and customer focus, in assessing the level of visible LC practices. These attributes can be directly credited to LC principles [100]. Further, the model presents industry best practices with regard to LC and assists organizations to compare and contrast [73]. Although these models do not directly identify as lean MMs, they provide useful insight into the exploration of the ideas behind lean construction maturity since they directly explore the level of leanness in construction companies or organizations. Further, models such as the Input–Output Model of Lean Construction try to assess the lean capacity through LC attributes including customer focus, supply, continuous improvement, waste elimination, people involvement, planning and scheduling, quality, standardization, and transparency [75]. These model attributes also clearly outline the presence of key LC principles.

Additionally, models are presented that do not belong to the category of LCMMs, nor do they relate to lean construction. Instead, these models investigate lean maturity in industries other than the construction industry. The attributes of these models do not show alignment with LC principles. However, the attributes were based on lean concepts such as lean manufacturing and lean thinking. LESAT, the Lean Production checklist, and the Lean Index are identified as lean-related models that are not primarily identified as LCMMs but which, however, provide ideas about how to assess lean maturity in other fields. These models belong to enterprise (general), manufacturing, and wood production industries, respectively.

4.2. Identified Strengths and Weaknesses of Lean-Related MMs

The study identified 24 prominent models that were considered for the study. Table 3 illustrates those models with their key strengths and weaknesses.

Table 3. Key insights from the models.

Model Reference	Key Insights/Strengths	Identified Weakness
M1	• Application of all LC principles of Koskela.; • Differentiated maturity levels; • Validation of the model; • Weighing of factors; • Clear identification of key attributes, performance areas and point of measurements.	• Key ideal statements and best practices are influenced by UK construction industry; • Best suited for UK and similar construction sectors; • Less consideration for LCMMs knowledge; • Model is too generic; • Have no recorded data on usage.
M2	• Adaptation of LC principles of Koskela; • Questions based on LC principles; • Segregation of maturity levels; • Classification of projects into 12 categories; • Qualitative evaluation through observation together with quantitative analysis; • Clear identification of key attributes, performance areas and point of measurements.	• The measurement is biased as per the reviewer; • No best practices or ideal statements presented; • 30 rating points need to be memorized; • Highly theory-based; • LCR model hardly considers the degree of mechanization in construction; • One-hour site visit for assessing (not sufficient); • Not validated.
M3	• Adaptation of LC principles of Koskela; • Providing the user with a tool that allows investigate the use of LC among the main agents involved in the value chain of the construction company; • Differentiated maturity levels; • Classification of projects in levels.	• Tailored for Brazilian LC sector; • Only checks the readiness for lean construction; • Limited to ideas of director, engineer, craftsmen, suppliers, and designers of a construction company; • No best practices or ideal statements presented; • No extensive evaluation; • Biased toward the measurer.
M4	• Highly structured model; • Provide guidance on model usage; • Application of all LC principles; • Differentiated maturity levels; • Presentation of ideal statements and industry best practices; • Highly automated excel tool for easy use.	• LCI Lean IPD covers the LC diversity but does not allow the evaluation of company culture; • More generic and needs calibration; • Provides a good base to build a customized model.
M5	• Adaptation of LC principles of Koskela; • Use of principles of LT by Womack and Jones [101], and concepts proposed by Rentes	• No validation in the industry; • No structured guideline; • Only assessed the presence of LC principles not LC maturity; • Highly theory-based; • No best practices or ideal statements presented.
M6	• Use of principles of LT by Womack and Jones [101], and concepts proposed by Rentes • Application of several LC principles of Koskela.	• A self-assessment tool; • No scale is proposed and no results presented; • Applicability is limited to Brazilian construction industry; • The measurement is biased as per the reviewer; • No best practices or ideal statements presented; • No consideration of the LC knowledge of interviewee; • Highly theory-based.

Table 3. *Cont.*

Model Reference	Key Insights/Strengths	Identified Weakness
M7	• Using actual data from organizations using LC; • Differentiated maturity levels; • Model with weighted factors; • Lean scores for the various factors are shown on a spider radar and a bar chart.; • Validated through experts.	• All the parameters of lean might not be convertible to quantifiable scales and some of the practices considered under each concept might be project-specific or need more detailing; • No industry best practices or ideal statement presented; • Less informative; • Based mainly on empirical data; • No theoretical substantiation.
M8	• Highly structured model; • Provide guidance on model usage; • Application of all LC principles; • Differentiated maturity levels; • Presentation of ideal statements and best practices.	• Specifically designed for highways in the UK; • Very limited parameter in terms of lean applications and use of theories; • Not designed to measure general construction.
M9	• Qualitative and quantitative data gathered; • Empirical data collected from 61 companies.	• Data not presented sufficiently for further evaluation; • Largely relevant to German construction companies; • Only a conceptual framework with no validation; • Limited in size and representation; • Assumes larger companies with some international connections are most likely to be those involved in innovation.
M10	• Qualitative and quantitative date gathered; • All LC principles were considered; • Identify best practices related to LC conformance.	• Check the applicability of LC principles; • Only tries to identify the best practices of lean construction; • Does not analyze maturity, instead merely checks what tools and techniques are being used; • Limited lean construction principles; • Relevant mainly for US.
M11	• Summarizes best LC practices through the literature; • Seven key LC principles were presented.	• Limited to a literature study targeting the Malaysian industry; • Does not consider the practical side; • Only summarizes LC principles.
M12	• Clarifies the main conceptual basis of LC; • Identifies interrelations among all wastes and how to tackle them using LC principles; • Provide strategies to minimize construction waste through LC principles.	• Generalization of construction to an Input–Output model; • Investigates how US organizations have implemented lean construction; • Mainly focuses on how human factor influences lean; • Based on seven case studies in US; • Provide recommendation based on seven US companies.
M13	• Adopts pull scheduling, reduced batch sizes, and a degree of multiskilling; • Presents an analysis of conventional practice, the theoretical background to the lean approach; • Specific management changes proposed to increase effectiveness of LC.	• Only relevant for housing projects; • Base of the model is one case study and its activities; • Does not measure LC maturity; • Limited applications to lean construction.

Table 3. *Cont.*

Model Reference	Key Insights/Strengths	Identified Weakness
M14	• Provide LC data from extensive survey in LC industry; • 12 critical success factors were introduced for successful LC implementation.	• Only limited for Saudi Arabian construction industry; • The case study approach has not considered the theoretical contribution; • Model is limited to only 12 critical success factors (CSFs) for implementing lean construction in the KSA; • The number of CSFs was restricted to 12; • Based on the opinions of a small group of experts, which may be biased and may not fully reflect the idea of LC maturity.
M15	• Application of certain LC principles of Koskela; • Differentiated maturity levels; • Measure integrated maturity of LC and BIM.	• Tries to identify the integrated maturity of lean + BIM; • Less relevance; • Does not cover all the LC principles; • Does not measure LC maturity directly.
M16	• Tries to identify the integrated maturity of Lean + LEAN + BIM + IPD; • Increase the understanding of practitioners and researchers about BIM interaction with LC and IPD.	• Less relevancy to LC maturity; • Not covering the full spectrum of LC principles.
M17	• Application of certain LC principles of Koskela; • Present 152 attributes relating to LC; • Provide a maturity scale for LC.	• Does not cover the full spectrum of LC principles; • No industry best practices or ideal statement presents; • Less informative about the assessment process.
M18	• Present an audit protocol to evaluates the level of lean implementation; • Protocol was composed of 4 dimensions, 35 categories, 136 items, and 223 examples of verifying evidence.	• Limitation of the protocol is concerned with the fact that no evaluation is made of the interactions among LC practices; • Suitable only for organizations that have adopted lean as a philosophy from the level of top management.
M19	• Present principles of LC by Koskela and principles of LT by Womack and Jones.	• Limited only to Jordanian construction industry; • Less relevance to LC maturity; • Does not cover the full spectrum of LC principles.
M20	• Identifies key successful factors for LC implementation; • Presents key lean tools and techniques imperative for successful LC implementation.	• Does not directly measure LC maturity; • Limited to China.; • Ignored the dissimilarities among countries, such as cultural, political, and economic differences; • Requires that companies have a good knowledge and understanding of lean construction; • Only evaluated two types of firms (state-owned firms or reformed state-owned firms).
M21	• Present principles of LC by Koskela and principles of LT by Womack and Jones; • Provides an analysis on current LC status and how to achieve higher LC capacities; • Measures the leanness from 1–5 scale.	• Only highway projects were used for the survey; • Does not directly relate to LC maturity; instead, the focus is where LC is now and how to promote it further; • Only for Small-Medium Sized Enterprises (SMEs) perspective.

Table 3. *Cont.*

Model Reference	Key Insights/Strengths	Identified Weakness
M22	• Identify key lean principles; • Provide strategic ideas to leadership on how to embed lean into enterprises.	• Not customized for construction industry; • Originally created with the idea of targeting the aerospace industry; • Only measure the presence of lean principles.
M23	• Present data from empirical surveys; • Provides a check list to implement lean manufacturing.	• Does not cover all the lean construction principles; • Provides only a check list to assess conformance; • Not relevant for the construction industry.
M24	• Presents a methodology for quantitative and objective assessment of the leanness of any wood products operation; • Presents a system to measure leanness introduced (Lean Index).	• Only applicable for wood production; • Only measures the presence of lean principles; • Does not cover the full spectrum of LC principles.

As shown in Table 3, the study identified 24 key models that were critically analyzed in order to provide an in-depth knowledge about the parameters of LCMMs. A key discovery identified through the analysis is that the number of models that directly falls under the category of "LCMMs" is extremely low in contrast with models in industries such as software development, manufacturing, and healthcare [33,102,103].

4.2.1. Strengths Identified in LCMMs

A key strength visible in all the models related to LC is the close alignment of model attributes with LC principles. All the models related to LC revealed that the base of the model is designed with the adaptation of LC principles. LCMM by Nesensohn, DOLC, MDCE, LCR, and HALMAT use all the LC principles. This use of LC principles in their entirety in model attributes is a key success factor for effective LC maturity assessment because the LC journey is an interconnected process. Moreover, adaptation of all LC principles assists in the measurement of the presence and extent of all essential LC practices, resulting in better LC assessment [104,105].

A key prospect identified in most of the models is the appropriate division of maturity levels, thereby clearly emphasizing the differences, so the end user can obtain a better understanding of the current situation. Many models, such as LCMM by Nesensohn [27], the LCR–Rapid Lean Construction-Quality Rating Model [65], and the Lean IPD Health and Maturity Model [67], clearly provide details about how to achieve the respective maturity levels with a comprehensible assessment mechanism. It must be noted that some models provide levels with 12 categories [65].

Further, as depicted in Table 3, few models have been validated and had their theoretical parameters readjusted considering the functional component of the construction industry [106]. The validation of elements through real cases is a key strength of a model. Many scholars have pointed out the importance and the value of validating concepts and gathered data prior to the ultimate use because it verifies the theoretical findings with industry practices [107,108]. To demonstrate this, the model developed by Nesensohn has been validated and changes to the theoretical findings have been incorporated [27].

A key success factor identified is providing measurable outcomes such as key performance indicators, ideal statements, and industry best practices, which enhance the accuracy and effectiveness of assessment [109]. LCMM by Nesensohn, the Lean IPD Health and Maturity Model, and HALMAT provide these measurable outcomes. Another merit identified is the weighting factors of attributes. In certain models, each attribute is given a certain weighting factor, thereby identifying prominence in attributes, which enhances the ultimate assessment of LC maturity [110].

4.2.2. Weaknesses and Areas for Improvement

A key point of concern identified via the analysis of the models is that the majority of these models is developed based on the conditions of the respective country or region. In particular, the ideal statements, best practices, and success factors of models are highly influenced by the surveyed firms and local conditions. The compatibility of such models in opposing or different conditions raises concerns. The key point is that the construction industry varies from country to country due to many factors, such as economical, technological, human, cultural, and geopolitical differences [111,112]. The differences are broader regarding LC since it is still an emerging concept in some parts of the world [113]. Therefore, when using these models, consideration must be given to how well the model and its attributes should be fine-tuned to address the characteristics to mitigate the issues. Moreover, models should clearly outline and explain the conditions in which the models are developed and their specific attributes, so that the end user gains a better understanding of the caliber of the model.

Models such as Lean IPD, MMDPLC, and the Multi-Dimensional Matrix only use certain segments from the LC principles. This might create a scenario where an entity measures LC maturity but does not assess all of the LC principles. For example, the main focus areas of MMDPLC are waste disposal, standardization, culture/people, customer focus, and continuous improvement/quality [69]. This clearly underlines the lack of key LC principles such as reduction in non-value adding activities and reduction in process times, which are prominent measures of LC maturity. As noted by lean experts and scholars, implementing lean requires a more holistic and comprehensive approach as it is interdependent and interconnected [50,105]. Thus, a coherent LCMM must incorporate all the lean construction principles in order to provide a more holistic, comprehensive, and all-inclusive measurement of the LC maturity.

As mentioned by lean construction specialists, assessing LC maturity is a progressive and cumbersome task [13,113]. Some of the models consider that the assessment can be completed within a brief period of time. The best example is the LCR model, which is claimed to be able to assess the degree of leanness of the organization by assessing the entity for only one hour [65]. Many scholars and specialists in the LC industry provide the counter-argument that the assessment process needs to be carefully and vigilantly handled, which consumes time and resources [27,114]. Therefore, this idea of hastened assessment lowers the credibility of the model. Thus, this is identified as a key weakness and an area for improvement.

Another key concern discovered is the lack of consideration of the entire entity as the measuring unit. Models such as DOLC, in particular, only consider several professionals, such as the director, engineer, craftsmen, suppliers, and designers. The problem that might arise with this kind of measurement is the inability to capture key professionals, such as the project manager and construction managers, who possess vital information regarding some of the instrumental LC parameters, including time management, waste reduction [115], and reduction in defects [116]. Thus, models need to consider the entire entity for assessment, so the data collection is justified. Further, when no document review is undertaken for the assessment, important aspects would also be missed from the evaluation. MMDPLC presents a self-evaluating mechanism through an internal evaluator; however, due to the nonexistence of the requirement of an outside evaluation, there is a tendency for the results to be unrealistic. Further, this model lacks best practices or the requirement that industry standards be followed; thus, the results might be highly biased toward the reviewer, thereby resulting in non-uniformity.

Several models aim to measure the maturity of various integrated concepts. The BIL maturity model attempts to measure the integrated maturity of building information modeling (BIM), integrated project delivery, and lean construction [79]. Moreover the Ideal Maturity Model aims to measure the combined maturity of BIM and lean [78]. In this approach, relevance for LC maturity is reduced due to the integration of various major concepts since assessing LC maturity on its own is considered a highly complex, arduous task [14]. This is not to say that the models would not provide any valuable insights, although their applicability to the measurement of LC maturity is a concern.

In the case of some models, the categorization of maturity levels is not informative. This gap was clearly visible in models such as MDCE [68], which merely checks for the presence of certain LC principles without rating it on a scale. This leads to reducing the sensitivity and the accuracy of the final results of the model, and thus needs to be addressed in future models.

Among LCMMs, the LCR model does not consider the degree of mechanization involved in the construction industry in the assessment of LC maturity [65]. This is a major concern when assessing LC maturity since LC fundamentally relies on various lean tools and techniques [117,118], and encourages the consideration of certain mechanical and technological advancements [119]. Researchers must attend to this inadequacy when developing new models since LC principles evidently recognize that mechanization will reduce non-value-adding activities and wastage [120].

5. Discussion

The models identified through the literature were mainly analyzed in three main categories. Eight models were identified as LCMMs. The models offered several key points that are highly important. In the main, many of the models exhibited alignment with LC principles. To date, LC principles stand as the fundamentals of LC [11]. Even though several models have incorporated ideas from models such as CMMI, the fundaments of LC principles are visible in all the models. When a model is aimed at measuring LC maturity, it is vital that all the LC principles to be covered are included in the assessment parameters. Then, only the holistic idea of LC maturity is effectively assessed. Another area of importance identified through the analysis is model validation. Validation of a model is also identified as being essential to improve the viability of the model. As many scholars have pointed out, this allows the theoretical base to be substantiated through industry practices and developments [77,121].

Several models are shaped primarily with the data and industry specifics of the researched country or region [27,66,72]. However, construction practices, methods, and techniques vary vastly from region to region [111,112]. Therefore, even if the key attributes that comprise the outer-most layer of the models are common, the internal parts of the models tend to be country-specific. Thus, it is vital that the model specifies the conditions and areas that are specific to the model; otherwise, the model will provide results that would not be feasible to be acted upon. However, in avoiding this predicament, several models were developed under certain circumstances and further models aim to be used in specific scenarios [37]. Further, it is advised that the models outline the country-specific and generic elements in their structure.

Another key point identified through the analysis is the fact that, for a few models in the assessment process, specific personnel were chosen to be interviewed in data collection. This idea increases the risk of excluding certain highly important professionals from being interviewed. The idea here is that, since the entire organization is unable to be interviewed, authorities and professionals relevant to lean construction in the organization must be given the opportunity to present their ideas in order to capture all relevant data relating to the LC maturity. Therefore, it is better that the model itself does not predetermine the interviewees and an open platform is used so the actual features are able to be captured.

It was visible through the analysis that few models, such as the integrated project delivery, BIM, and LC, aim to measure the integrated maturity of multiple attributes. However, as many argue, because lean implementation is complex, a lean construction model would be more effective if the attribute of the model directly targets LC maturity. Further, it is evident that few models have been developed while considering the technological and mechanization aspects of construction. For instance, the LCR model does not consider the effect of mechanization in construction under the assessment of LC maturity [65]. However, novel models developed in the future must consider all the new developments in the construction industry, thereby modernizing the model to the present day.

A point to ponder in new models to be developed is that the scope of the model needs to be clearly outlined. It was found that some models do not specifically indicate the scope that can be assessed, creating ambiguity for the user. Few models were identified that precisely explain the facets of the construction sector that could ideally be assessed by the model [71,76].

A key area that needs to be addressed is establishing a uniform assessment mechanism. As identified in many models, the assessment becomes biased or influenced by several factors, such as the influence of the assessor, irregularities in the assessment criteria, and not interviewing the relevant groups. Future models need to address these areas, which would drastically improve the quality of the models. Many models identified as a limitation, that it was hard to strike a balance in the expertise on the areas of lean, construction, and maturity. Therefore, this is an area that needs further thinking and development since the concept of lean construction has not reached maturity.

Referring to all the data, the study suggests that the existing knowledge on LCMMs is still a relatively new area, and needs further research and development. This does not diminish the importance or the value the existing models add to the discussion. However, there is significant scope for improvement and modernization. The identified attributes could also be used in further analysis. In particular, the identified strengths must be considered to enhance the quality of future models, and the identified weaknesses provide a clear guideline for further developments in LCMMs.

6. Conclusions

Although LCMMs can be observed in the literature as being important to LC processes in organizations, there is a lack of LCMM reviews. Thus, this study was carried out with the aim of systematically reviewing the existing LCMMs through a critical review by studying the different types of LC maturity-related models, examining the attributes of the models, and reviewing their strengths and weaknesses. The study adopted an integrative approach and the PRISMA literature review method was used to gather data.

Using the PRISMA method, 24 key models were identified and a critical analysis was carried out. The study demonstrated several key findings. Predominantly, from the investigation of the literature, it was concluded that lean construction maturity is an area that calls for further research. Only a few LCMMs exist in the literature, proving the area is not yet saturated, and the existing models are yet to be critically reviewed.

The study concluded that the alignment of model attributes to the LC principles of Koskela is a common characteristic among the models, even though several models only adopted particular elements from the LC principles. Overall, all the LC maturity-related models used the key LC principles of Koskela; specifically, production efficiency, lean leadership, customer focus, waste reduction, enabling people, and standardization were discovered to be the most common LC principles. This provides a positive insight for new model developers and offers a platform to build on relating to the scope of model attributes.

Further, the study discovered valuable insights from exploring the strengths of the models. The proper adaptation of LC principles, the presentation of different maturity levels, the provision of ideal statements and best practices for assessment, and the validation of model components before use are noted as the key strengths identified in the models. However, the study also discovered several key inefficiencies in the studied models. Not assessing the entire entity, providing "Yes/No"-type assessments rather than scaled measurement, formulating the attributes of the models based only on theoretical underpinnings or only on empirical data, and not providing stepwise clear guidance for model usage are identified to be key shortcomings that need further improvement. These findings indicate that, even though existing models provide a sensible mechanism to assess LC maturity, they require significant improvements.

This study contributes to the existing knowledge on LC maturity by presenting novel findings to future and current users and developers of LC-related maturity models. The study presents attributes that are common to LCMMs. These attributes can be used for further developments of LCMMs. The study further contributes to the knowledge base of LCMMs by presenting key strengths and key areas that need further improvements. The discovered strengths of the models can be directly applied to future model development as a platform to build on, and the identified inefficiencies can be taken as guidelines or as areas of improvement for enhancing the robustness of future models.

The study invites further research in terms of a few aspects. Initially, scholars can use the problems recognized in the discussed models and study ways to rectify them to enhance the effectiveness of the existing models. Additionally, in further research, scholars can expand the reach of the models from attributes to measurable outcomes. Moreover, researchers can study the development of new, more resilient models using the findings and discovered strengths and weaknesses of the models as guidelines.

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