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An Integrated Model of Lean Construction and Off-Site Construction for Industrialization Architecture: Review and Future Directions

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ABSTRACT: The construction industry is one of the most energy-consuming and Contamination industries. Lean construction (L.C.) is an advanced manufacturing approach that could potentially bring novel developments in the construction industry and seeks to elevate the value of the building, diminishing waste. Off-site construction (OSC) techniques have numerous advantages. Recent research studies have outlined the advantages of bringing together L.C. and OSC. This research aims to identify the elements of blending L.C. and OSC for the Industrialization architecture framework. The core ideas that are integrated into the framework are addressed and discussed. This research employed a 3-step bibliometric review of industrialization research within the construction and manufacturing sectors. A comprehensive systematic literature review technique to review the literature on L.C. and OSC for industrialization architecture identified factors of integrated L.C. and OSC for industrialization architecture and arrived at a conceptual model by recognizing these components. To refine AEC performance toward industrialization construction, The increased efficiency of the enhanced production system is taking a more prominent place. The introduction of automation and robotic systems into the construction process, pre-fabrication technique, construction 4.0 and use of information communication technology and digital technology (BIM, RFID,...), use of DFMA technique (design for manufacture and assembly) and sustainability ability for the elimination of construction waste are factors for integrating L.C. and OSC for industrialization architecture. This document provides a reference for future construction direction to achieve industrialization construction.

Keywords: *Lean Construction, Off-Site Construction, Industrialization Architecture, Technological Development, Future Construction.*

INTRODUCTION

Industrialization construction uses advanced tools and techniques to solve tricky problems in construction projects. It's an updated version of traditional construction. Recent research has investigated the advantages and obstacles of not using manufacturing industrialization techniques. Industrialized construction can bring down the cost of construction significantly. It can also improve productivity and shorten the time it takes to complete a project (Abanda et al., 2017; Jin et al., 2018). industrialized construction is significantly different from traditional construction, including designing, permit approvals, developing the site, and building construction (Qi et al., 2021). Using factories with off-site construction for pre-fabricating building components has provided noteworthy productivity and sustainability in the building industry and is of great value. Generally, Moving assembly processes from traditional on-site building to using pre-fabrication can improve the quality, safety, and financial outcome of your building projects. Primarily, this is the result of designing and utilizing a work atmosphere. This has allowed us to expand our horizons and benefit from tailored production and mass-produced customization. This offers us great opportunities to go deeper with integration, optimization, and automation. (Garcia de Soto & Skibniewski, 2020). While much research focuses on lean design theories and their use in L.C. or OSC, there's still little understanding of the problems when different fields, like manufacturing, construction, and architecture, try to work together (Luo, 2022). In this research, There are some questions in this regard: Research question 1: What factors are currently linked to the idea of industrialization architecture

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in the building industry? Research question 2: What factors influence properties and conditions of integrated application off-site and L.C. in industrialization architecture? Research question 3: What extensive effects does the integrated OSC and L.C. of the construction surroundings contain for future construction? Considering these inquiries, The primary aim of this investigation is to close the research gap by identifying the elements of blending L.C. and OSC for the Industrialization architecture framework. The remains of this paper are structured in the following manner: To start with, Outline of industrialization architecture for the building by executing a bibliometric analysis examination with the VOS viewer application. Afterward, We construct based on this derived definition of industrialization architecture to Locate scientific trends and relevant literature and to assess the status of the factors with systematic analysis by giving an intensive look at what is already examined and applied to L.C. and OSC, identify the elements of blending L.C. and OSC for the Industrialization architecture framework, In the next step presents the outcomes from the systematic literature analysis that is leading to a conceptual structure and the formation of a research plan for future construction.

Related Studies

Lean construction and Off-site construction

off-site construction is an eco-friendly building that has become popular in the construction industry because it has so many benefits (Ma et al., 2022). Creating components, parts, or sections in a supervised environment away from the construction site is what we call off-site construction. This process involves transferring and assembling the pieces at the construction site. Set up later in the building site (Kolo et al., 2014). It enables achieving higher levels of excellence, reducing waste, and increasing efficiency, thereby increasing the overall efficiency of the process (Pan & Goodier, 2012; Nanyam et al., 2017). Additionally, OSC possesses a variety of strengths when compared to typical building methods, as seen in Table 1. L.C. is proposed as a new method that eliminates activities without value for the project owner. Within this context, these activities that do not contribute to worth are deemed waste (Tafazzoli et al., 2020). Table 1 shows the many benefits that L.C. offers the construction industry, and lean construction is a project management philosophy that can help solve productivity and waste issues in the construction industry (Aslam et al., 2022).

Industrialization Architecture-Related Overview

Industrialized construction means focusing on the process instead of the project. Therefore, industrialized construction is not only restricted to pre-fabrication and industrial production in factories but encompasses all ordered and standardized manufacture of clearly identified building systems. Standardized building systems offer options for organized production management (Johnsson, 2011). This article primarily focuses on a more comprehensive term for the inventive building method that is generally known as industrialization architecture. Industrialized construction (I.C.) uses manufacturing principles and innovative processes to improve construction projects. L.C. is globally popular in the construction industry, but research on the best ways to use L.C. are rare (Wuni et al., 2019). This analysis characterizes industrialization building as a collection of construction processes that Promotes the progression from design to construction via savvy production and automation approaches. Its main emphasis lies in the system and the manufacturing process to ensure that only orderly and manageable production is established with regularization in the production of building systems (Andersson& Lessing, 2017).

MATERIALS AND METHODS

One of the goals of this research is to combine studies and understanding of knowledge and provide a conceptual model and specify the direction of research for future construction in the field of integrating lean construction and off-site construction to industrialization architecture the production and construction process. To respond to the research queries (research questions 1- 3) indicated in the incentive section, research planning is a combined plan done in stages Fig 1. To get the answer to question 1, Our main goal is to create an inventory with a definition of the phrase industrialization architecture, which includes a bibliometric analysis (Vos

Table 1: Advantages of L.C. and OSC

Advantages of L.C.	Advantages of osc
- diminished waste and improved collaborative connections (Green & May 2005). -Maximize your process proficiency and the Ability and efficiency of the labor force (Goh & Goh, 2019). - Increase excellence and efficiency with successful teamwork between those involved (Bernstein & Jones, 2013).	- Productive excellence assurance in adhering to quality standards (Blismas et al., 2006). - Minimize initial costs and reduce on-site destruction while enhancing economic worth (Elnaas et al., 2014). - minimize damage to the site, remove the need for prolonged operations outside the site, and perform work both off-site and on-site simultaneously (Blismas et al., 2006). - Carefully planned protocols in a plant lead to minimized risk and improved safety (Ajayi et al., 2016).

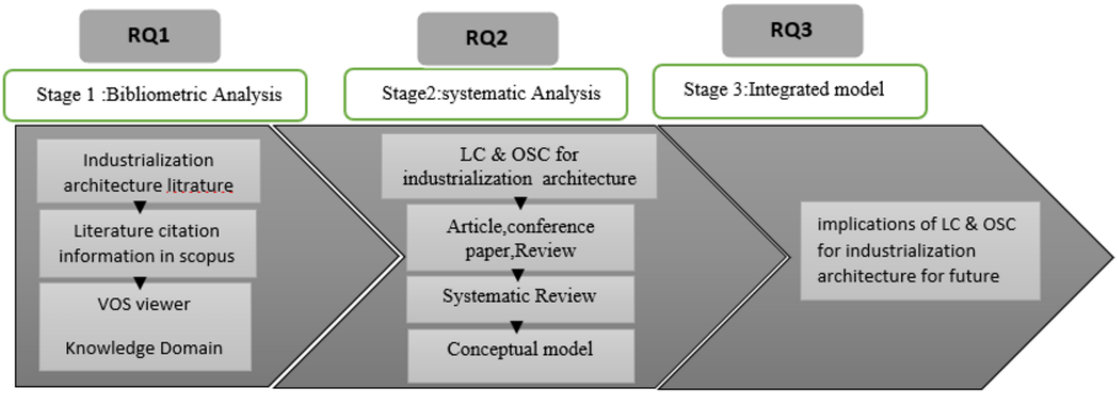


Fig. 1: an overview of the research methodology

viewer) of industrialization architecture literature. The achievements of this stage of the research are summarized in this section. To obtain the answer to question 2, we continue our research, which includes a systematic literature review based on the results of the previous step, step up to investigate the current of the detected uniting integration of L.C. and off-site development for industrialization architecture and To respond to question 3, a generalization is formulated in the form of a conceptual model of combining lean construction and off-site construction as a guideline for future construction as technology develops.

Bibliometric Analysis (Stages 1)

Bibliometric analysis has been used to advance the goal of this research to reach a comprehensive concept concerning the field of industrialization architecture knowledge. As shown in Figure 1, In the direction of bibliometric analysis to reach the content of the knowledge of industrialization of architecture, it is done in order through steps 1.

Data Acquisition

The reviewed literature related to the industrialization of architecture was retrieved in the Scopus database, chosen keywords "industrialization" or "industrialized" and "construction" or "building" or" architecture" Table 2. A careful selection process was repeated to refine the outcomes to the appropriate engineering area. For instance, research papers concerning medicine or agriculture were eliminated in this phase. To better select articles, irrelevant articles from journals or conference articles were removed according to the source. For bibliometric analysis, the final selected articles were given to Vos viewer for visualization. The process of conducting bibliometric analysis, including the selection of keywords and their results, are given in Table 2.

From 2015 to 2023, Fig 2 shows a general upward trend in publications. As a result, it is anticipated that the research outputs in industrialization architecture will continue to increase, given this current trend.

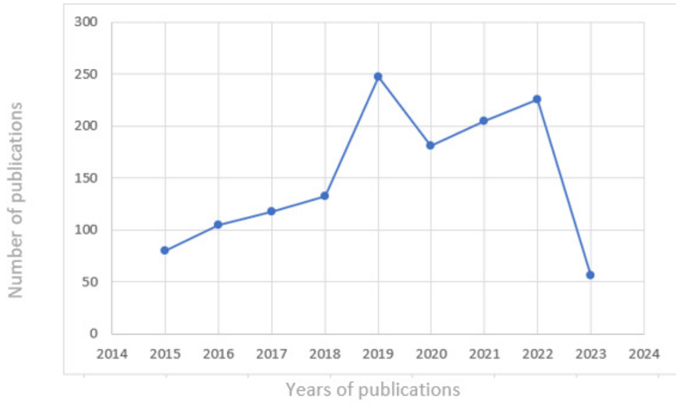
Systematic Analysis (Stage 2)

The authors devised the assessment procedure based on stages Denyer and Tranfield (2009), which is considered in research design and systematic analysis: This research (1) uses several selected articles and reviews their quality and their texts in a systematic review method L.C. and OSC for the industrialization architecture ; (2) It presents a clear and principled picture of the research process to the audience, which includes the selected database, study retrieval, and indicators and criteria for selecting target articles; and (3) is Ability to update and repeatedly; (4) Representation and integration of studies conducted in the

Field of L.C. and OSC to achieve the industrialization architecture to discover selected research goals Figure 3. Due to the Implementing the bibliometric analysis in stage 1, According to Figure 1, a qualitative analysis of the selected articles was done. This analysis was done manually by

Table 2: Literature search strategies and their results

Topic	Search Keywords	Period	Number of results
Industrialization architecture	ALL (“industrialization” or “industrialized”) AND (“construction” OR “building” OR “architecture”)	2015-2023	1,444



*Note: the number of articles selected in 2015 was up to February 2023 for industrialization architecture.

Fig.2: Yearly publications from 2015-2023

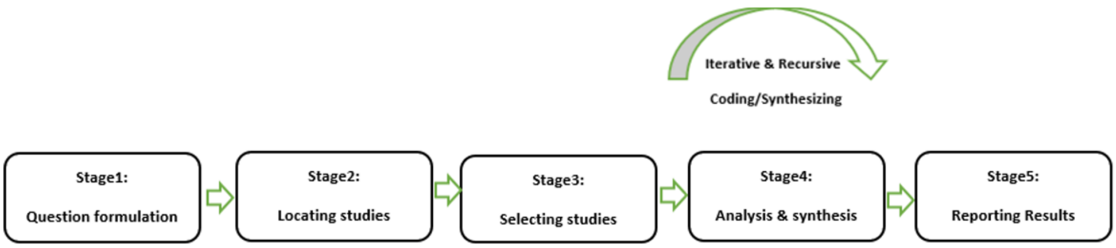


Fig. 3: Steps of qualitative research analysis (Denyer & Tranfield, 2009)

researchers. According to the research objectives, a qualitative analysis has been carried out to identify the factors and introduce a conceptual framework for integrating L.C. and OSC to industrialize architecture and identify future construction needs.

Search Strategy and the Selection of Studies

A systematic analysis of the selected articles has been done for a deeper understanding of the research done concerning lean construction and off-site construction for architectural design. We chose the Scopus database because it contains the largest abstracts and articles worldwide. The search is conducted to obtain studies related to the research objective. To begin the search, we obtained all the research related to L.C. and OSC from the Scopus database. We refined the outcome by "industrialization architecture" for the second-level filtering. This analysis solely examines the research in industrialization architecture to delineate the features further, impacting elements, and using the state of L.C. and OSC in industrialization architecture. Thus, further examination and enhancement are necessary to investigate L.C. and OSC in industrialization architecture Fig 4.

Content Analysis

To assess the effects of published papers on the development and potential future subject trends in industrialization architecture, the investigation team explored the subject sets. Upon going through the 441 chosen articles, the team discovered that the research spanned a broad scope of subjects. The 348 chosen articles were encoded by studying the titles, summaries, and key phrases. If the required data could not be procured from the title, abstracts, and keywords, The whole text was scanned and coded, with the ultimate step choosing 93 articles for coding that were linked to Lc and OSC for industrialization architecture and usage in a framework, the articles included were published in highly respected and influential journals Table 3.

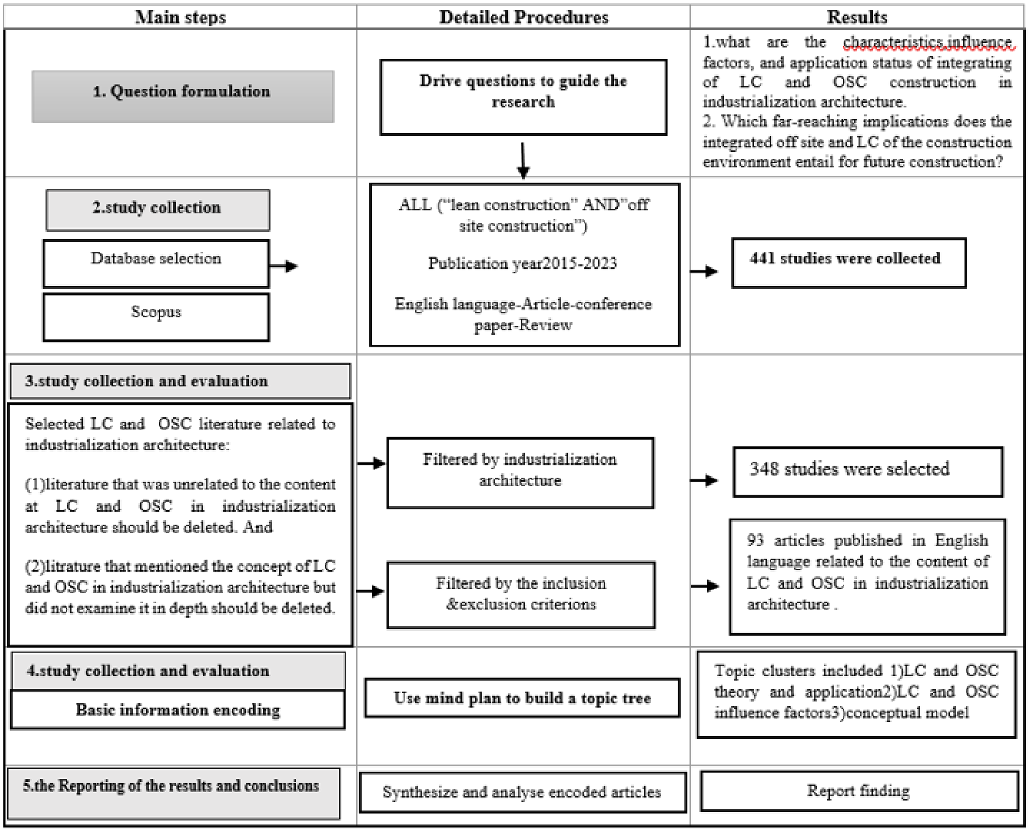


Fig4: Framework of the systematic analysis (Denyer & Tranfield, 2009)

According to the literature review in L.C. and OSC for industrialization architecture, the period of 2015 onwards is a revolution in industrial construction. The studies were conducted between 2015 and 2023, roughly a nine-year timeframe. The annual publications pattern shows a sinusoidal trend, while some periods regularly saw more publications than others. Generally, in this period to review, the number of articles in the field of L.C. and OSC is increasing Fig 5.

Effects of L.C. and OSC for Industrialization Architecture for Future Construction

discover the outcomes of the organized, systematic review alongside the results of the bibliometric assessment, leading to a conceptual data model and the formation of a construction future.

RESULTS AND FINDINGS

Bibliometric Analysis for Industrialization Architecture

To build the understanding area of industrialization architecture, VOSviewer was used to co-occurrence collaborations within each research region. Network visualization was to determine the concept of industrialization architecture for the next stages of the research.

Co-occurrence Resolution of Author Keywords in Architecture Industrialization

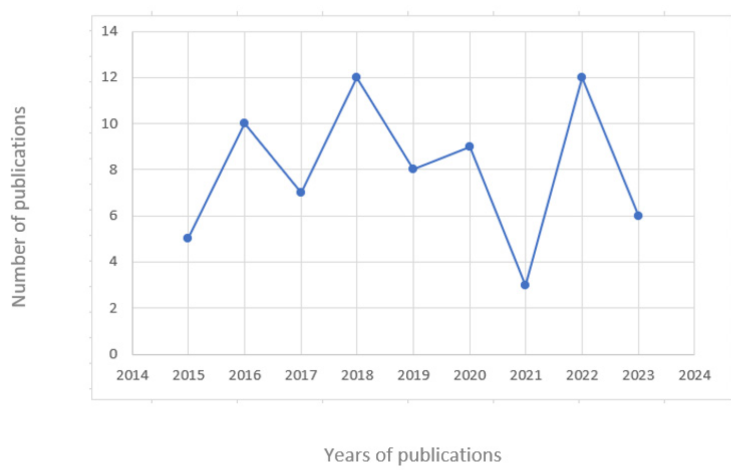
Examining Table 4, it is evident that industrialization and sustainability are extensively covered in the literature on industrialization and construction. In contrast, industrialization and automation are the newly published subjects in this field of study (about 2016 and 2019, respectively). Figure 6 illustrates several terms: off-site construction, sustainability, industry 4.0, standardization, and modular design. Appear with a larger font size, implying a higher prevalence in current literature.

Systematic Analysis

The issues were grouped under the heading of papers discussing L.C. and OSC in industrialization architecture Figure 7. Analysis of the quantity and substance of articles on L.C. and OSC in industrialization architecture Examined 93 articles published from 2015 to 2023; as a result, according to the literature review, this stage is considered as the development of L.C. and OSC for the industrialization of construction. Systematic analysis and evaluation were done for

Table 3:Journal distribution of the included studies

Name of journal	Number of articles
Automation in Construction	12
Engineering construction and Architectural Management	8
27th Annual Conference of the International Group for Lean Construction Iglc 2019	7
28th Annual Conference of the International Group for Lean Construction Iglc 2020	7
Journal of Cleaner Production	7
Proceedings of the 3rd International Conference on Engineering Science and Technologies Esat 2018	6
Advances in Transdisciplinary Engineering	6
Proceedings of The International Conference on Sustainable Smart Manufacturing S2m 2016	5
Jurnal Teknology (science & Engineering)	5
Construction Innovation	4
Journal of Construction Engineering and Management	4
Sustainability (Switzerland)	4
Journal of Management in Engineering	4
International Journal of Construction Management	3
Architectural Engineering and Design Management	3
Advances in Civil Engineering	2
Building and Environment	2
Building search and information	2
Total	**93**



*Note: the number of articles selected in 2015 was up to February 2023 for L.C. and OSC for industrialization architecture.

Fig 5: Yearly publications from 2015-2023

93 articles, which were divided into six groups after the articles were refined: 1) pre-fabrication, 2) design for manufacture& assembly (DFMA), 3) automation & Robotic system, 4) sustainable &circular economy 5) construction4.0 6) BIM (building information modeling) Figure 8.

Pre-fabrication

Pre-fabrication, a factory-based method, allows the selection of raw materials from manufactured and locally accessible natural sources. The end goods, resulting from the flexibility, are economical and energy-efficient (O'Hegarty & Kinnane, 2020). Prefab technology efficiently reduces on-site waste by

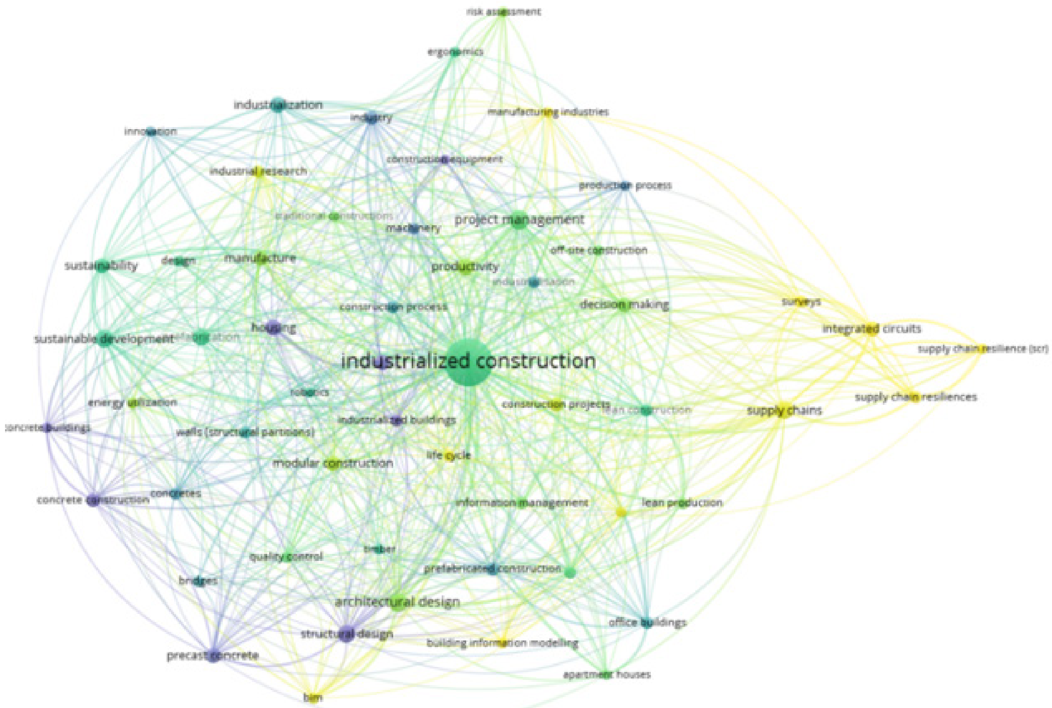


Fig. 6: Author keyword co-occurrence of industrialization architecture

Table 4:Top keywords in industrialization architecture

keyword	occurrence	Average year published	Total link	keyword	occurrence	Average year published	Total link
Industrialization	256	2017	1669	Manufacturing	29	2020	212
Sustainability	112	2018	565	Productivity	21	2018	206
Economics	80	2018	635	Pre-fabrication	27	2017	153
Investment	57	2017	495	Industrialized building system(IBS)	31	2017	142
Population statistic	50	2019	342	Modular construction	25	2017	121
Life cycle	47	2019	335	Standardization	17	2016	121
Innovation	46	2017	334	Product design	19	2015	105
Industrialized countries	55	2017	322	Technology	17	2014	101
Energy use	46	2016	288	building information modeling	18	2016	99
Costs	37	2018	282	modernization	21	2018	98
Optimization	35	2018	231	industry 4.0	24	2020	95
Developing word	32	2017	224	automation	18	2019	83
Project management	29	2017	218				

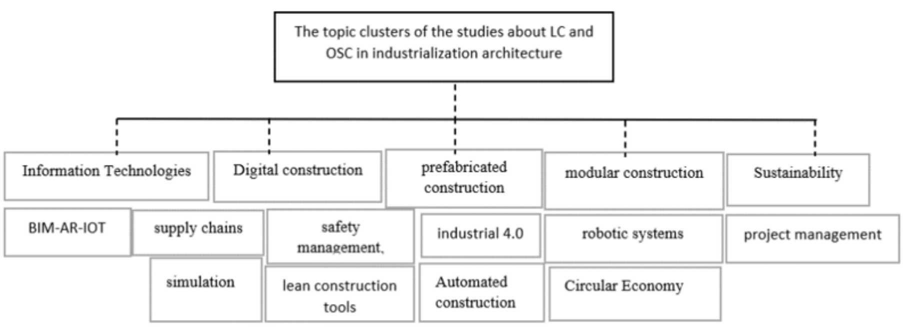


Fig. 7: The topic clusters of the studies about L.C. and OSC in architecture industrialization

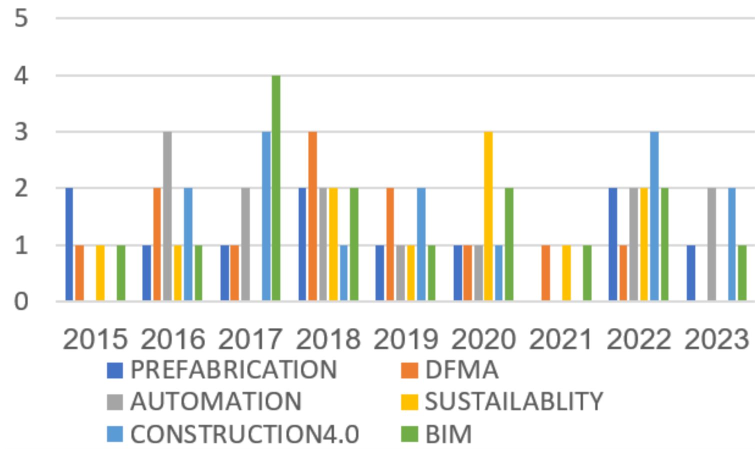


Fig. 8: Number of analyzed articles on lean construction and off-site construction for industrialization architecture

84%, saves 27% in costs, reduces carbon emissions by 30%, and saves 40% in time. Additionally, it improves quality, offers a solid choice for achieving mass construction goals, is energy efficient, and offers ecologically friendly options (Chippagiri et al., 2022). It is necessary to introduce new technologies to reduce waste in industrialization construction. Numerous scientists have proposed pre-fabrication technology as the premier instrument for lessening waste in construction (Lu & Yuan 2013) (Table 5).

DfMA (Design for Manufacture and Assembly)

To develop a constructible design toward lean construction objectives in OSC projects, design for manufacture and assembly (DfMA) concepts are considered design principles (LUO, 2022). lean construction can use its concepts to enhance the Design for Manufacture and Assembly philosophy. Utilizing DfMA and lean techniques can generate mutual advantages for the AEC sector. in Agreement to reach an optimal shared value, like Lowering the cost of construction and efforts and augmenting construction efficiency (Ogunbiyi et al., 2014). Design for manufacture and assembly (DfMA) is a crucial component of the construction industry's future because it offers the potential for accelerated project delivery, quality assurance, worker safety, and the reduction of waste on-site through thoughtful design for manufacture and assembly off-site (Langston & Zhang, 2021). The increase in housing

Table 5. pre-fabrication for industrialization architecture

pre-fabrication in integrating L.C. and OSC	Main findings
1) pre-fabrication	**Pre-fabrication and new production planning approach:** Pre-fabrication and takt planning have received enough attention in past studies to advance industrialization in the construction industry (Chauhan et al., 2018). **Standardization in products and processes**: By standardizing the production processes, a level of proficiency can be achieved, and advancement will necessitate more drastic modifications, such as incorporating other trades into the manufacturing processes (Bekdik et al., 2016). **Modularization:** Enhancing the effectiveness of site operations makes the technology more appealing to non-adopters, which is one strategy to promote pre-fabrication and off-site manufacturing (OSM) techniques, such as modular building (Goh&Goh, 2019). **Building information modeling(BIM):** The primary objective of embracing BIM in construction projects, design, and Management (CDM) is an efficient process to maximize optimization via successful interaction, organization, cooperation, and data administration over the lifecycle (Grilo & Jardim-Gonvalves, 2010). **Digital Fabrication**: modeling utilizing BIM permits digital Fabrication. **automation of production processes** **design for manufacturing and assembly (DFMA):** DFMA is an awesome design system and index that makes it easy to create products with simple materials and processes that are also cost-effective. This design system helps you get the most efficient production and assembly possible (Boothroyd et al., 2004). **ICT (information and communications technologies) & industry4.0:** Lean construction concepts and data technologies, such as building information modeling (BIM) and radio frequency identification (RFID), have been successful in aiding to trim down the doubts and getting rid of the limitations (Li et al., 2017).

Table 6.:DFMA for industrialization architecture

DFMA for integrating L.C. and OSC	Main findings
Digital technology (BIM)	Accurate modular construction for better modularization and standardization (Boothroyd et al., 2002; O'Brien et al., 2000; Bogue, 2012; Gao et al., 2018).
MMC (modern method construction)	DfMA, which includes Building Information Modelling (BIM), is seen as a more advanced approach to MMC)Treasury, 2017, chap.3; Yuan et al., 2018).
Modularization & standardization	Technological advancements in pre-fabrication (Lu et al., 2020).
Prefabrication(MIC)	MiC (modular integrated construction) & codes modularized type construction) Burgess et al., 2013; Wuni et al., 2019; Yuan et al., 2018; CIC, 2019). Establish standards and affordable technologies to successfully implement Design for Manufacturing and Assembly (DfMA) (CIC, 2019).
Design for Excellence (DfX)	

demand and construction demand in the world requires the revival of pre-fabricated construction and industrialization construction.

Furthermore, the optimal situation for advancing DfMA (Jensen et al., 2008; Yuan et al., 2018). A never-before-seen opportunity has arisen for DfMA due to the investigation of manufacturing innovation, particularly off-site building. Due to the similarities between manufacturing and off-site construction/pre-fabrication, DfMA is now at the forefront of the industry's cross-sector learning and innovation agenda (Tan et al., 2020) (Table 6).

Automation and Robotic systems

Automation technology and lean thinking have been used in many manufacturing industries, such as automotive manufacturing (Kolberg & Zuhlke, 2015). Automation can remarkably improve the design, construction, assembly, and maintenance of structures in the AEC field. (McKinsey, 2017). the coordinated use of industrialization, lean construction, and construction automation the AEC industry's building with The construction sector can benefit from learning from other industries by utilizing: (1) Use innovative tools and technology to speed up and streamline the production processes; (2) Control the manufacturing using effective management systems. (3) Setting up conditions that will allow for the industrialization of production (Gusmao Brissi et al., 2021) (Table 7).

Sustainability and Circular Economy

Building construction could become more environmentally friendly because of OSC, a cutting-edge construction technique (Jayawardana et al., 2023). Lean construction philosophy aims to achieve strategies that reduce any waste in production and time, trying to improve the traditional model of construction project management, which tries to reduce waste in the production process and save time and money to increase the maximum production value (Jørgensen., et al. 2007, Koskela, 1992). The circular economy (C.E.) seeks to manage construction materials better and view them as valuable resources after a building has reached the end of its useful life, reducing waste production (Benachio et al., 2021) (Table 8).

Construction 4.0

huge changes in technology as the fourth industrial revolution takes hold. To develop sustainable technology and build lasting infrastructure. Connecting technological disruption to the fourth industrial revolution and sustainable development

Table 7: Automation for industrialization architecture

Automated Methods and Systems for Integrating L.C. and OSC	Main findings
1) Construction Automation(CA) a) Robotic systems (R.S.s) b) Modeling and simulation(BIM) c) Digitization and virtualization (DV) d) Sensing systems e) Artificial intelligence(AI) and machine learning(ML) 2) Digital Fabrication 3) Precast components 4) Production and assembly	**Construction Automation (C.A.):** Maximizing control and reducing human intervention in construction projects' production process, employing equipment software and I.T. systems. It includes five main technologies: Robotics, simulation, modeling, sensor technology, digitalization, virtualization, artificial intelligence, and machine learning (Sawhney et al., 2020; Davila Delgado et al., 2019; Gerber et al., 2017; Nof, 2009; Oesterreich & Teuteberg, 2016; Saidi et al., 2016; Meng et al., 2020). **Robotic Systems (R.S.s):** The overall strategy for using automated construction processes, which includes the employment of robots, automated machinery, and digital fabrication tools, was given by (Linner & Bock, 2012), also emphasized BIM as a requirement for greater degrees of automation (Linner & Bock, 2012; Malik et al., 2019). **Automation and digital Fabrication:** The practical application of the L.C. principles comprehend numerous practices and techniques such as just-in-time, last planner system, six sigma, and pull planning, which is related to (1) design and engineering, (2) planning and control, (3) construction and site management and (4) health and safety management (Babalola et al., 2019). **Production and assembly:** Providing ideal conditions for the production factories to use C.A. and L.C. in the industrialization construction (Gusmao Brissi et al., 2021).

Table 8:sustainability for industrialization architecture

sustainable for integrating L.C. and OSC	Main findings
1) Sustainable development Last Planner System (LPS) Visual Management (V.M.) 5S Building Information Modeling (BIM) Value Stream Mapping (VSM) Pre-fabrication 2) Circular economy(CE)	The role of L.C. tools in promoting sustainable development: Last Planner System (LPS), Visual management (V.M.), 5S, Building Information Modeling (BIM), Value Stream Mapping (VSM), Pre-fabrication (Bajjou et al., 2017; Saieg et al., 2018; Babalola et al., 2019). **C.E. practices for the construction industry:** **Project design:** designing and utilizing modular buildings and a simulation within the BIM model to analyze.**Manufacture:** The manufacturers can now have ownership over the materials after the building has reached its end of life, which enables them to reuse the materials. **Construction:** The possibility of reusing previous construction materials in new construction reduces off-site construction waste. **Operation:** Evaluating the condition of materials over the lifetime and at the end of a building's use with a tool: exploring the possibility of reusing or recycling current materials instead of buying new ones as part of end-of-life analysis (Benachio et al., 2021).

is important. Industrialization is achievable through this reliable method. To make the most of the advances that Industry 4.0 brings, it's essential to have a comprehensive policy framework. An exciting and innovative new way of construction that brings digitalization into the process of Construction 4.0 (Rastogi, 2017). The idea of lean thinking also helped the construction industry advance its methods and procedures. Increased productivity in the construction sector has been greatly influenced by Industry 4.0 (Lekan et al., 2020). Artificial intelligence (A.I.), robotics, building information modeling (BIM), construction informatics, and robotics are all applicable. Collecting and evaluating data (Pascall, 2019) Construction 4.0 debut has substantially helped the construction industry grow by improving performance in terms of quality. The Management of building quality throughout the industrial revolution has been significantly impacted by elements including Industry 4.0, the Internet of Things (IoT), and Lean thinking principles (Lekan et al., 2022) (Table 9).

BIM (Building Information Modeling)

Several research projects have highlighted the advantages of combining lean construction (L.C.) and building information

Table 9: Construction 4.0 for industrialization architecture

Construction 4.0 for L.C. and OSC	Main findings
1) Construction 4.0 Lean Six Sigma Value Identification Mapping Value Stream Culture Adoption Pull Establishment Constant Improvement Flow Creation Value orientation	**Lean thinking regions impact Construction 4.0:** Lean Six Sigma -Value Identification -Mapping Value Stream - Culture adoption - Pull Establishment - Constant Improvement- Flow Creation -Value orientation (Bag et al., 2021; Prasad&Sharma, 2014; Lekan et al., 2020). **Performance goals of lean thinking and Industry 4.0 in the construction industry:** The rapid advancement of technology and industry– striving to reduce waste in construction projects, which will help increase productivity- Incorporating different concepts and ideas together- Exploring the transformation of industrial applications in a new era - Developing advanced devices and gear - Industrial manufacturing components are becoming automated The construction industry's Gross Domestic Product (GDP) has seen a rise (Lekan et al ., 2020).

Table 10: BIM for industrialization architecture

BIM for integrating L.C. and OSC	Main findings
1) Design -Visualization of form - Rapid generation and evaluation of multiple design alternatives - Maintenance of information and design model integrity -Automated generation of drawings and documents 2) Design and Fabrication Detailing Rapid generation and evaluation of construction 3) Pre-construction and construction -Rapid generation and evaluation of construction plan alternatives -Online/electronic object-based communication	**BIM Functionality:** 1-Design 2-Design and Fabrication Detailing 3-Pre-construction and Construction **1-Design:** A)Visualization of the form**: A review of Aesthetic and functional** B) Generating and evaluating various design options quickly and efficiently: **Quickly changing the design model, predicting its performance, evaluating cost estimates, and making sure it meets your program or client's standards** C) Ensuring accuracy and consistency of information and design models: **all information from one source with Automated conflict resolution** D) Automatically creating drawings and documents (Santana-Sosa & Riola-Parada, 2018; von Heyl & Teizer, 2017). **2- Designing and Crafting the Details:** Working together in design and construction**: Collaboratively editing one model across multiple disciplines- Viewing multi-discipline models together or separately with multiple users (Mahamadu et al., 2017; Von Heyl & Demir, 2019).** **3-Pre-construction and Construction:** A) Quickly producing and assessing different ideas for a construction plan**: Generating construction tasks with automation - Simulating individual, distinct events -imagination 4D of construction schedules** B) Interacting with objects electronically online: **Visualizations of process status-** Sharing product and process information online **-Computer controlled fabrication -** Connecting with our project partner's (supply chain) databases**- Gathering status information from off-site locations with the proper context (U.K. parliament, 2018; Nanyam et al., 2017;** Abanda et al., 2017**).**

modeling (BIM) (Marte Gómez et al ., 2021). Two of the key ideas challenging the established construction management practices are lean construction (L.C.) and building information modeling (BIM) (Tezel et al., 2020). BIM can help make off-site manufacturing a breeze. Specifying material needs can help us avoid getting too much and reduce waste at the construction site (Abanda et al., 2017). BIM makes it easy to accurately show each component's shape, geometry, features, and properties. This allows them to be included in digitally accessible modular building elements with ease (Nawari, 2012; Abanda et al., 2017) (Table 10).

Conceptual Model of Integrated LC and OSC for Future Construction

Figure 9 shows the Conceptual model of integrated L.C. and off-site construction for industrialization architecture.

CONCLUSION

This study has successfully achieved its main objectives. Factors that need to be identified for integrated lean construction and off-site construction for industrialization architecture were the main aim of this study, and the effects of this integration were highlighted in this study. During the presentation, we discussed how lean and off-site construction can be applied to industrial architecture. The integration of lean and off-site construction has made a major contribution to the technological advancement of the manufacturing industry through the introduction of advanced tools. Automation, improved planning systems, and 3D simulation have been added to the design process with the introduction of Artificial Intelligence, which has significantly affected intelligent production, manufacturing, and maintenance. Industrial growth needs to have innovation. Creative innovation for design is pushing the boundaries of how we design and monitor sites. And The second goal is to identify the far-reaching implications and integration factors of L.C. and off-site construction that will be important for future construction. The increased efficiency of the enhanced production system is taking a more prominent place. The introduction of automation into the construction process, construction 4.0 and use of

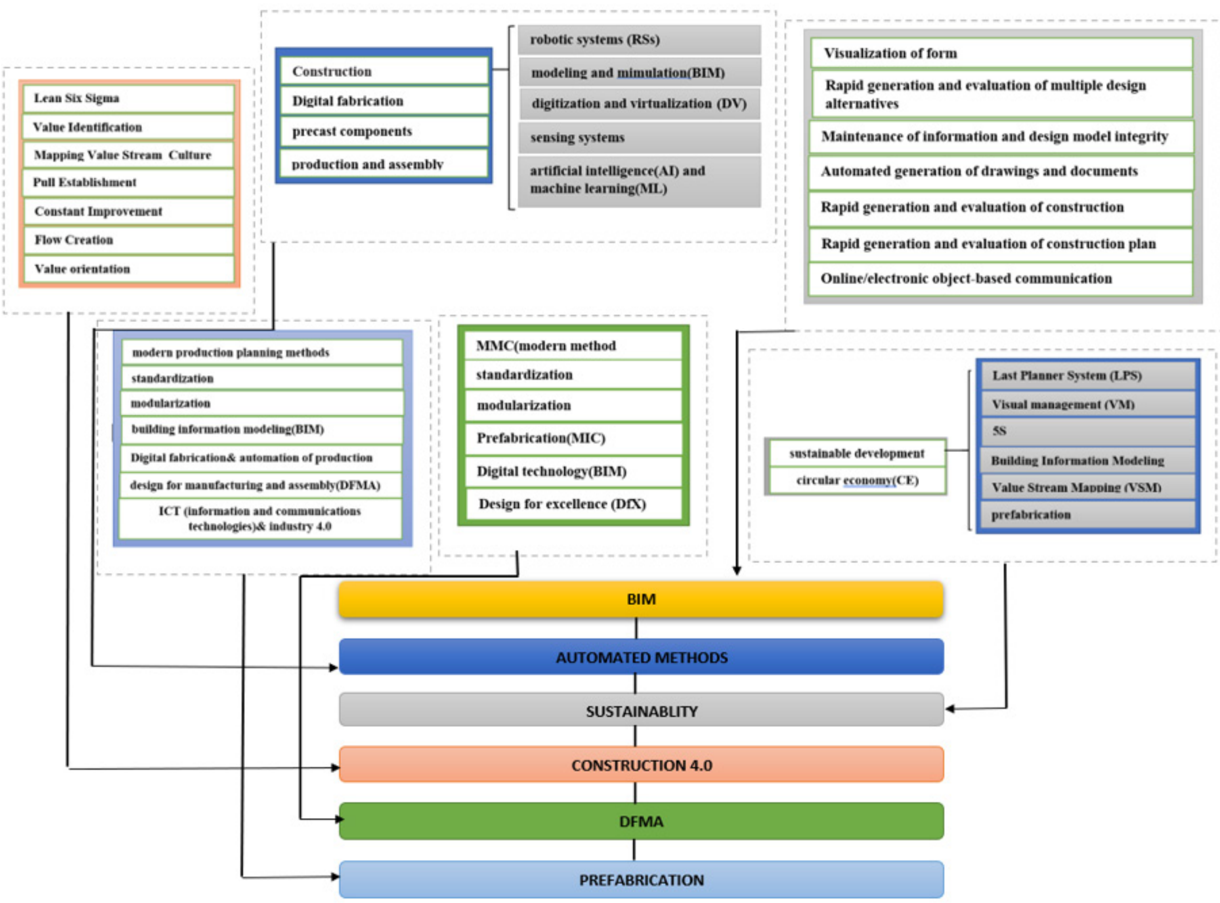


Fig 9:Conceptual model of integrated L.C. and off-site construction for industrialization architecture

information communication technology and digital technology (BIM, RFID,...), use of DFMA technique and sustainability, circular system for elimination of construction waste, and development of calibration system for industrial quality measurement for integrating off-site construction and lean construction for industrialization architecture. The research placed a great emphasis on these factors due to their usefulness. Lean thinking and off-site construction optimize processes and production and create quality results.

AUTHOR CONTRIBUTIONS

N. Esmaeili performed the literature review and experimental design, analyzed and interpreted the data, and prepared the manuscript text and edition. N.Esmaeili performed the experiments and literature review, compiled the data and manuscript preparation, and compiled the data and manuscript preparation. M. Vafamehr managed, reviewed, and evaluated the research process H. Rezaei helped in the literature review and manuscript preparation. A. Khaki performed some of the remained experiments.

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CONFLICT OF INTERESt

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication or falsification, double publication and, or submission, and redundancy, have been completely witnessed by the authors.

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