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Maximizing project efficiency through construction prefabrication unveiling the benefits

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Abstract
The current study explores valuable insights into the significance of using pre-fabrication procedures within construction-based projects. The research focuses on determining how project managers have obtained project efficiencies within complex projects. The study highlights preliminary challenges associated with the conventional approach used within construction projects, i.e., increase in lead time, high operational costs, delays in construction procedures, etc., that impact overall production decisions. Lack of technological implications and expertise among the labor force put forward certain complications for project handlers to execute project deliverables. The section on methodology describes the research methodology adopted in the study as it provides readers with the researcher's strategy for investigating research objectives. By using qualitative research design study is directed to explore the benefits of pre-fabrication procedures within the construction industry. With the secondary data collection technique, the study focuses on examining the research problem highlighted in the research. With the content analysis technique, the research evaluates the aim of the study by analyzing various research articles relevant to the topic. The section on findings and discussion provides an in-depth overview of the advantages of using pre-fabrication models within construction procedures. It is evident from the study that for practicing highly sustainable dimensions within projects, the usage of modular construction methods is required that strategically direct project managers to accomplish project deliverables within the expected time phase.

Keywords: Construction prefabrication, unveiling, project efficiency

Introduction

Research background: Pre-fabrication practices are an innovative concept within the construction industry to practice waste management principles, and a cost-effective approach is applicable to it. Construction of building materials at off-site locations minimizes the extent of risks and hazards at on-site locations, as with effective planning procedures, timely construction is performed [1]. Show that with the integration of technology, it has become relatively easier for construction engineers to perform manufacturing activities within factories. With the usage of Building information modeling (BIM), managing environmental concerns has become substantial [2]. The implication of green practices is applicable to pre-construction techniques as by reducing on-site wastes; environmental wastes are minimized [3]. With planned initiatives, time within manufacturing procedures is minimized. Further, it enables in reduction of material costs and inventory expenses [4]. Maintaining quality within the pre-construction phase enables construction engineers to adopt standardized mechanism while performing construction at on-site locations. Risk assessment is strategically applicable as the probability of on-site risks and accidents is avoided to a larger extent.

Research findings of [6] conclude that it is estimated that pre-construction buildings will have a potential market worth nearly for about $153 billion by 2026. It indicates the significance of using pre-fabrication mechanisms within construction projects. The traditional approach used by project managers within the construction of residential and commercial projects includes, i.e., larger scheduling and assembling time, large-scale resource utilization, lack of expertise among labor-force deployed at construction sites, lack of contingency plans, increase in operational and material costs, fees of architectural engineers, lack of digital technology, etc. [7]. However, by introducing pre-fabrication principles, stakeholders' expectations are valued and accompanied. Stakeholders can visit factory outlets where manufacturing and assembling of building materials are performed to identify quality assurance dimensions being practiced and estimate the feasibility of the project to construct [8].

Fig 1: Source: [5]

With the significance of sustainability, construction firms have determined new patterns to manufacture high-quality building models that can resist environmental risks [9]. With prefabricated solutions, the construction of sustainable models within residential, commercial, and industrial projects can be performed. A study by [10] indicates that the pre-construction of concrete panels to the manufacturing of steel frames can be performed at off-site locations. Safety risks are ensured for front-line construction workers. Traditional practices involve the construction of building materials at on-site locations that increase hazards, and non-preventive measures increase the ratio of accidents [11]. Construction times are reduced with manufacturing at off-site locations as it provides project managers with the ability to design digitally stable model that is highly sustainable [12]. Production decisions with climate-controlled conditions maintain components, i.e., material, etc., durability through which sustainability is ensured.

Fig 2: Source: [13]

The above-mentioned figure indicates how the pre-fabrication of building materials is transferred to construction locations by using, i.e., crane arms, trucks, etc. It enables quality assurance managers and project engineers to maintain safety regulations at the pre-construction phase, i.e., fire resistance, heat insulation, etc., through which collateral damage can be avoided [14]. With manufacturing decisions in warehouses, the extent of work at on-site locations can be reduced for front-line workers, supervisors, etc. [15]. As with planned manufacturing, the involvement of a large-scale workforce can be reduced, and operational threats can be avoided. With pre-fabrication procedures, the ratio of on-site managers has been reduced, and the costs associated with the on-time training of workers can be secured within large-scale projects [16].

[17] conclude that traditional methods implemented within construction projects require, i.e., on-time monitoring, instant training of labor-force, the implication of contingency plans, environmental risks, minimal safety precautionary measures increasing extent of damage, delay within construction projects, lack of expertise among project managers, etc. that increase operational cost and overall project expenses creating complications for stakeholders who have a prior interest within construction projects. Traditional practices performed are time-consuming, and the feasibility of a project involves a larger number of challenges that reduce its potential significance [18]. Project engineers are aware of technicalities to perform within construction projects based on which outcomes of projects are obtained within the allocated time scale.

Research aim

The current study aims to identify how construction pre-fabrication enables increasing project efficiency within the construction industry.

Research objectives

- To investigate the significance of pre-fabrication procedures to boost-up project efficiency.
- To evaluate how traditional construction practices involve challenges due to a lack of pre-fabrication practices.
- To explore the benefits and advantages of pre-fabrication dimensions adopted by project managers within construction projects.

Research questions

- How do pre-fabrication procedures assist in increasing project efficiency?
- How does traditional construction practice involve challenges due to a lack of pre-fabrication practices?
- What are the benefits and advantages of pre-fabrication dimensions adopted by project managers within construction projects?

The rationale of the study

This study explores the benefits of using pre-fabrication procedures within construction projects. By highlighting how projects have become efficient with the adoption of transformed models during the manufacturing phase. By investigating the benefits of pre-fabrication procedures, valuable insights related to how these practices are sustainable as compared to the traditional approach practiced by project managers.

Chapter: 2 Literature Review

Sustainable construction

Research by [19], sustainable construction is applicable to pre-fabrication procedures because by avoiding construction procedures at on-site locations; wastes are eliminated. Pre-fabrication dimensions indicate the optimization phase as that includes step-by-step procedures through which construction of a quality sustainable model is performed. Pre-planning phase for manufacturing building materials and equipment at off-site locations enables project managers to minimize environmental waste. Construction projects are major contributors to environmental concerns; therefore, implication of a cost-effective approach is applicable [20]. Operational expenses can be reduced with construction decisions performed within factory outlets. Standardized panel measurements include the development of schematics through which prefabricated building structures are outlined to stakeholders [21]. Displaying a visual overview of the

construction model during the preconstruction phase enables stakeholders to innovate the structural model of the project based on their expectations.

Project managers are timely informed about restructuring decisions to perform at off-site locations for manufacturing sustainable buildings [22]. Smart construction is one of the components of sustainable construction procedures, as with pre-fabrication dimensions, risks and hazards are minimized [23]. By assembling components of buildings at on-site locations, project managers are able to increase project efficiency as assembling building materials is planned with the usage of 3D simulation models through which digital visualization of construction to perform can be displayed among stakeholders.

Fig 3: Source: [13],

The above figure displays the modular construction phase in which front-line workers are performing assembling procedures based on manufacturing processes within factory outlets. It determines the post-manufacturing phase in which the construction of building materials is executed based on a sustainable construction plan developed by the project engineer [24]. For modular construction dimensions, the global market is estimated to grow by nearly for about $175 billion by 2025 [25]. It indicates the significance of modular construction dimensions used by project managers. A study by [26] shows that traditional dimensions that involve the large-scale building of structures at on-site locations increase, i.e., material costs, labor fees, etc., marginally increase overall operational expenses for construction projects. However, within modular construction models, market-competitive laborers are hired to utilize off and on-site locations. By providing training to skilled and experienced laborers extent of operational risks is reduced, and the significance of project completion is maintained [27].

With modular constructions, on-site locations are maintained clean and secure, through which sustainable construction procedures are performed [28]. By using high-quality materials in the construction procedure, s on-site installations are executed within the allocated time scale. Process outfitting, assembling, flooring, plumbing, electric fixtures, etc., is managed with real-time planning decisions [29]. However, modular construction procedures include, i.e., transportation costs, etc., for delivering manufactured components from factory outlets to on-site locations [30]. One of the major challenges associated while transporting manufactured materials to construction destinations is related to the hazard of damage during the transportation of materials.

A study by [31] shows that logistic functioning is a prominent phase of pre-fabrication that require strategic planning between stakeholders, i.e., project managers, construction engineers, on-site supervisors, etc. The project manages to have an adequate complication related to an excessive amount of transportation costs that might impact on project's overall defined budget [32]. Quality assurance has become one of the significant aspects within construction projects through which, i.e., resource requirements, labor training, cost estimation, operational hazards, etc., are monitored and evaluated based on which improvements are performed by project handlers.

Fig 4: Source: [13]

The above-mentioned figure highlights the assembling phase, which indicates how building materials are aligned and transferred to on-site locations for the final construction process. By using heavy machinery, building materials and equipment are relocated to accurate positions based on construction plans being developed [33]. The above figure mentions the significance of modular construction as mass production is applicable to it. Huge-scale projects, i.e., apartment buildings, hotels, etc., can be performed by assembling huge volumes of material that are manufactured within off-site factories [34]. Within European markets, project engineers are focusing on executing projects based on modular construction dimensions and pre-fabrication principles through which project costs are secured and highly sustainable models are developed [21]. Modular construction processes have created a global reputation due to an increased number of implications within the construction industry [35]. Project managers have determined it considerably to utilize a transformed pattern of manufacturing through which waste and costs are minimized.

Fig 5: Source: [36]

A study by [37] shows that modular extension is one of the cost-effective approaches, as relocating to other manufacturing outlets might increase production expenses. Nowadays, project managers align with operational managers to execute the construction of sustainable project models with effective communication procedures through which delays are avoided, and costs are managed. Restructuring decisions are performed at on-site locations when project managers identify certain hazards within

construction models [38]. It increases burdens on front-line workers and laborers involved in manufacturing procedures as reconstruction procedures require reassembling and re-manufacturing various components of a building [39]. Sustainable construction requires adequate planning, innovative strategies, contingency plans, excessive budget, advanced featured technological equipment, well-structured project design to construct, etc., through which the extent of technical errors and operational expenses are reduced [40].

Construction pre-fabrication

Recycling procedures have been determined to be essential components within the pre-fabrication phase, as by dismantling components of constructed projects, reconstruction can be performed based on which sustainability concerns are valued [41]. With time construction companies have a major strategic responsibility to contribute towards environmental concerns; therefore, restructuring decisions in which re-usage of materials is performed is applicable through which green construction is performed [42]. To avoid collateral damage for construction projects that have achieved their lifespan, the disassembly procedure is considerable to practice. Pre-fabrication is determined to be one of the essential processes to fulfill stakeholders' expectations [43]. With recycling principles, clients' priorities are valued, and sustainable construction models are designed to deliver comfort and convenience among consumers.

Pre-fabrication models enable project engineers to manage project budgets based on the pre-planning phase through which expected profitability is obtained. Research by [44] shows that by estimating manufacturing expenses at off-site locations, i.e., operational costs, labor fees, quality assurance managers fees, purchase of inventory (i.e., raw material, etc.), etc., through which project budget is distributed. With the integration of digital technological procedures extent of errors is reduced by timely predicting default risks at construction sites and within manufacturing units [45]. Project managers supervise operational activities to minimize technical errors as it enables enhance the feasibility of a project. By conducting timely meetings with stakeholders, projection plans and construction decisions are shared during meetings to obtain their perspectives to make quality improvement dimensions based on projections being aligned to execute [46]. Construction failures have been determined to increase when no strategic planning is involved among stakeholders that impact on project's goals to attain.

Fig 6: Source: [47]

The implication of pre-fabrication procedures within construction projects has raised the significance of projects. To construct highly sustainable models, off-site construction decisions value quality maintenance principles through which environmental concerns are minimized [48]. The selection of locations where manufacturing procedures are to be performed is considerable. Constructing at site locations where the population is minimal can be substantial, through which corporate social responsibilities are valued [49]. The findings of [50] conclude that environmental hazards due to the usage of toxic chemicals, etc., at manufacturing sites can be adverse to the external ecological environment. Therefore, the selection of location is one of the major aspects to consider contributing towards sustainable development goals.

Research by [51] shows that an increase in pre-fabrication practices is determined to be a key factor for increasing productivity and consistency within the construction industry. Benefits incorporated with an increased number of its usage within projects include, i.e., a reduction in time scheduling, task completion, improvements in safety procedures, minimizing defects, reduction greenhouse gas emissions, etc. [52]. Designing products and construction materials involves sub-assembling units as production procedures performed within factory outlets, i.e., windows, bricks, tiles, etc., to minimize waste at on-site locations. Further designing of non-volumetric products at off-site locations, i.e., structural frames, wall panels, etc., and non-volumetric products, i.e., shower rooms, plant rooms, modular bathrooms, etc., are processed based on digital techniques to avoid excessive usage of resources [53].

Fig 7: Source: [54]

Findings of [55], show that an increased level of off-site production enables in delivery of cost-effective, quality products to be used within construction projects; however, executing flexibility and innovation has become a broader challenge for project managers and operational managers. The implication of pre-fabrication is a major contributor to a circular economy as a reduction in carbon emission rate, minimizing energy usage, etc., is a step forward to attaining sustainable development goals [56]. Pre-fabrication has been identified to be one of the cost-effective strategies when comparing it with on-site production procedures as, i.e., reduction in labor and material cost, minimal construction wastage, etc., enabling sustainable project designing [57]. However, pre-fabrication includes huge scale investment to purchase, i.e., new machinery, equipment, factories, etc., where sustainable manufacturing procedures are to be performed. Moreover, transportation costs, training of the labor force, etc., are associated with the modular construction phase.

Traditional practices within construction involve construction decisions and manufacturing procedures to

undertake at on-site locations that include several challenges, i.e., major delays in the construction process, disputes between stakeholders, execution of construction plan without clients' consultation, the slower flow of information among sub-contractors and project team members allocated at on-site locations, lack of management skills and expertise among project engineers, non-preventive measures to avoid bad weather conditions, etc. it reduces the efficiency of project completion within expected time scale [58]. Moreover, an increase in cost and time put-certain complexities for project managers. Research by [59] concludes that pre-fabrication has provided optimal solutions for construction engineers that include, i.e., a decrease in material wastage, reduction in defects, minimizing waiting times, reduction in over-production, etc., based on project efficiencies maintained. The feasibility of a project and risk identification is applicable to modular designing procedures [60].

Quality assurance in the pre-construction phase

The study of [61] concludes that a major characteristic associated with pre-fabrication is a factory-controlled mechanism which includes the implication of resource-efficient strategies to execute. Modular construction, which has become most common nowadays within construction businesses, involves assembling repetitive units within a controlled environment as external factors are stabilized, i.e., bad weather conditions, etc. [53]. Modern modular phase in construction has put-forward efficiency as compared to conventional construction mechanism that includes a large number of production risks and external challenges [62]. Risks in conventional procedures include mass production of material that increase wastage, non-availability of technological resources to perform quality manufacturing, etc. [63]. However, by using prefabrication procedures, complex assembling can be performed at off-site locations. The on-site construction procedures are handled and controlled with a digital technological mechanism through which, i.e., monitoring hazardous activities is performed, and deployment of fewer workers at construction sites reduce the level of risks or damage.

According to a Construction industry report, about 73% of project engineers who execute prefabrication procedures within projects are able to execute safety regulatory principles by developing health and safety plans and provisions based on which operational risks are avoided [64]. Within prefabricated manufacturing units, project managers perform quality monitoring procedures to ensure that materials to be used within the manufacturing process meet quality standards with the implication of waste management practices [65]. The pre-unit installation phase includes the execution of quality checks, project team members' requests for approval of quality assurance for each unit of assembly, and quality measurement within the post-installation phase [66]. With the implementation of these quality assurance dimensions, operational risks are avoided.

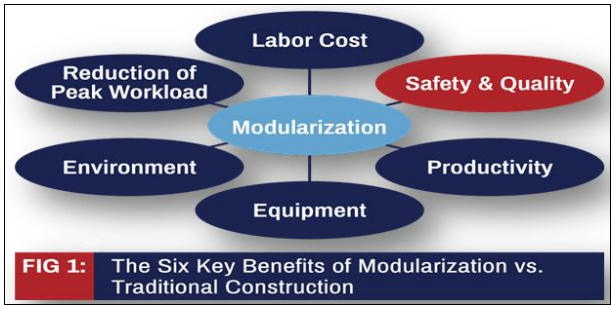

Fig 8: Source: [67]

To identify quality assurance dimensions being practiced at manufacturing units in off-site locations, key performance indicators are to be used to evaluate the timely performance ratio and practices adopted by front-line workers deployed within assembly units [68]. To meet standards, labor efficiencies are compared with quality guidelines to make improvements during the production phase. Quality control professionals have a strategic responsibility to inspect the quality of inventory and components to utilize within the manufacturing phase to obtain durability and precision [69]. The implication of quality measures is a major component during the pre-construction process, through which wastes are eliminated, and excessive production costs are minimized [39]. Show that quality control managers are to review schematic designs for construction projects and overlook construction documents to ensure that health and safety regulations are fulfilled, and production standards are practiced. Moreover, by monitoring assembling units and ensuring rather components manufactured based on pre-fabrication procedures are properly assembled and installed to obtain sustainable construction [23]. To determine, i.e., electricity breakdown, defects in wires that can create short circuits, moisture leaks, prevent the flow of air, etc., within the internal infrastructure of buildings to construct.

A research study by [70] indicates that quality assurance managers are required to conduct final inspection procedures in the post-construction phase to ensure the execution of sustainable dimensions. Perform functional testing of the building system constructed is needed to avoid risks. Quality control professionals are required to report their findings by documenting inspection and testing procedures. It enables the identification of manufacturing complexities and operational risks that project managers have come up with while performing pre-fabrication initiatives [71]. By documenting, i.e., the number of resources consumed, defects in materials, time consumed in the production of components and assembling, etc., based on which project feasibility is determined. By comparing with estimated costs and budget allocated, final quality assurance reports are submitted among stakeholders to identify their opinion about procedures adopted during the implementation of pre-fabrication [72]. To address issues in a timely manner, reporting of the construction process is needed.

Fig 9: Source: [73]

Quality assurance procedures are reliable and consistent, enabling project managers to overlook and monitor production challenges within time to ensure the implication of improvement practices. With planning process, i.e., defect identification, risk avoidance, adequate usage of resources, performance efficiency from the labor force, etc., is executed [74]. Project efficiency requires strategic collaboration between, i.e., project handlers, construction engineers, front-line workers, stakeholders, etc., based on which manufacturing challenges are minimized [75]. The prefabrication initiative introduced innovation within construction procedures by using technological aspects; quality maintenance has become significant.

Chapter: 3 Research methodology

Research methodology describes methods used to evaluate research objectives in a study. It provides an overview of the researcher's approach to obtain results to direct future researchers based on the findings gathered. The selection of data collection methods used to collect appropriate information within research has been a preliminary emphasis in this section.

Research Philosophy

Research philosophy defines the nature of information collection in a study as it identifies the origin/source where data has been extracted from. To execute the research study selection of appropriate information is required to obtain the expected outcomes [76]. By selecting different research philosophies, various methods are predicted to understand scientific research phenomena obtained within studies. It assists researchers in investigating logical reasoning and critical thinking pattern while obtaining information from a particular source [77]. Creating a scientific approach based on knowledge gathered is a particular emphasis in research philosophy. By collecting data sets with a philosophical pattern, the researcher justifies the data collection technique used and the research design selected to explore the research problem within a study. Research philosophy includes, i.e., interpretivism, positivism, etc. [78].

Interpretivism philosophy

Interpretivism philosophy describes how knowledge is interpreted by people based on their perspectives. It indicates that humans perceive particular knowledge with their understanding. To analyze a particular set of phenomena, require scientific investigation and prediction of logical reasoning through which expected outcomes can be obtained [79]. The study of [80] shows that interpretivism philosophy defines how participants perceive a particular wonder to explore. The researcher involves with the external environment to investigate the research problem and to obtain participants' perspectives within research studies. The rationale for including respondents in studies is performed by researchers to obtain various perspectives based on which quality findings can be obtained within studies [81]. Researchers interpret data findings from participants based on their own understanding to interpret logical reasoning within studies.

Positivism philosophy

The positivist approach indicates scientific knowledge extracted from authentic secondary sources, i.e., magazines, books, journal articles, etc., through which quality information with logical reasoning is used within research studies. Research by [82] concludes that extent of technical errors is minimal within scientific investigations as findings are obtained with precision and accurate measures. Secondary data obtained based on controlled experiments and observational labs indicate a positivist philosophy [78]. Positivism philosophy indicates factual information extracted from various secondary sources based on which logical reasoning is provided based on secondary findings of the study [83].

Justification of interpretivism

In this study, the interpretivism philosophy is used to investigate how project efficiency has been performed within construction businesses by using a prefabrication process that can be determined by interpreting research articles. By identifying the findings of researchers on sustainable construction procedures, quality findings are delivered in this study.

Research approach

The research approach describes the overall research direction adopted by the researcher in the study to explore the research problem [84]. Selecting an approach depends on particular assumptions and the choice of the researcher. Moreover, it depends on the research topic to examine how the researcher investigates the topic considered. The selection of the research approach provides readers with an understanding of the researcher's strategy for examining research questions. The research approach involves, i.e., inductive, deductive, etc. [85].

Inductive approach

It includes an investigation to be conducted from the initial stage or ground level to obtain expected outcomes. Inductive reasoning is a central focus for researchers when no past social theory is available to explore the research problem [86]. The inductive approach enables researchers' ability to determine logical arguments as it provides an opportunity to explore research problems with in-depth evaluation. The end result of the inductive approach is to generate a social theory that can be used by future researchers within their studies.

Deductive approach

It is used when past social theories are available to investigate the objectives of the study. To examine theories relevant to a research topic, researchers consider variables in the study. Within the deductive approach, investigating the extent of the relationship between variables is an adequate emphasis [87]. By constructing hypotheses statement

researchers' particular emphasis is to validate each hypotheses statement by including participants within a study.

Justification of inductive approach
In this research, inductive reasoning is selected to determine the significance of the pre-fabrication process within construction businesses. By conducting a study from scratch, the point researcher will identify how project efficiencies are maintained based on sustainable initiatives being performed during construction projects.

Research design
The section on research design provides the overall research strategy obtained in a study to investigate a research problem. The selection of research design requires an in-depth analysis of the research topic, so identifying the procedure to analyze the research study depends on the researcher's critical understanding and knowledge to explore. The structure of research depends on the research design being selected within a particular set of studies. Research design includes, i.e., qualitative, quantitative, etc. [88]

Qualitative research design
The findings of [89] conclude that qualitative research is more focused on elaborating on the research problem by justifying the rationale of the study. By using words, concepts, and terms, definitions, an in-depth understanding of the research study can be gathered. Research avoids using numbers, facts, figures, etc. instead; it emphasizes detailed analysis of research objectives. With descriptive analysis, the researcher explores to obtain expected outcomes [90]. Qualitative research requires explanations to justify the research problem, as identifying the impact between variables and the extent of the relationship requires critical evaluation for investigation.

Quantitative research design
Quantitative studies are focused on using numbers rather than exploratory analysis to obtain factual information. By using facts, figures, etc. researcher is able to provide logical arguments. With statistical information, graphical representation, mathematical illustration, etc., readers will get to know about the quantitative research findings obtained [91] A research study by [92] concludes that research avoids the usage of in-depth analysis as the emphasis is particularly on quantitative data findings.

Justification of qualitative research design
For the current study, qualitative research design is used to investigate research questions. To identify how project efficiency has been maintained with the implication of prefabrication practices within construction businesses, past research articles are analyzed to explore the significance of prefabrication and modular construction models in construction projects.

Data collection process
Obtaining information within research requires the selection of an appropriate data collection technique, as the selection of the data collection method depends on the type of data required to extract from the source. The data collection process includes, i.e., primary, secondary, etc. [93].

Primary data collection process
A research study by [94] explores that first-hand information obtained from human subjects indicates primary data. To collect primary data, various techniques are used, i.e., questionnaire, interview, focus group, etc. To obtain primary data within quantitative studies closed-ended questionnaire approach is used. The research instrument required to determine the intensity of participants' responses is a 5, 7-point Likert scale.
Within qualitative studies, primary data is extracted by conducting face-to-face interviews with participants, based on which an in-depth understanding of the research topic can be gathered. To obtain primary data, both physical and online methods can be used as it depends on the researcher and participants' convenience [95].

Secondary data collection process
To obtain secondary information, authentic secondary sources are used through which published secondary data can be extracted to explore the research problem under investigation. Factual data obtained through scientific investigation within controlled labs describes secondary knowledge. Information collected based on experiments involves minimal technical errors [96].

Justification of secondary data collection process
For the current study secondary data collection procedure is used to collect related information about the benefits and significance of pre-fabrication dimensions utilized within construction projects.

Data analysis
Analyzing data sets collected within research requires the usage of various data analysis procedures to identify the significance of the information. Within quantitative studies, the primary data set collected through a questionnaire approach is analyzed by using SPSS software, through which statistical analysis is performed [97]. Within qualitative studies, primary data collected through the interview approach is analyzed by conducting a thematic analysis procedure. With secondary studies, secondary data collected is analyzed based on the content analysis approach.

Justification of data analysis
For the current study content analysis technique is used to evaluate the secondary data set obtained from various secondary sources. To obtain appropriate content related to the research topic, various research articles are analyzed to determine the significance of using pre-fabrication dimensions within construction projects.

Ethical consideration
Maintaining ethical implications within research is a prime responsibility of the researcher, as obtaining ethical consent from participants is essential to ensure the authorization of respondents within a study [98]. By providing an ethical consent form, participants' involvement in studies is approved.
Within secondary studies, ethical implications are maintained by using authentic secondary sources to obtain published secondary data sets, i.e., google scholar, etc. By using the best five research articles relevant to the study, precision, and accuracy are maintained [99]. To maintain

validity, research articles from the last five years are to be used to obtain appropriate secondary information.

Chapter: 4 Results

To investigate the research problem secondary analysis technique has been used to obtain appropriate information related to the topic under examination. To explore how excessive usage of pre-fabrication dimensions has put-forward efficiency within construction projects, various research articles are explored. With secondary data findings, broader insights can be collected in the study. The tabular section below provides results obtained in different research studies that particularly emphasize the significance of pre-fabrication.

Research topic	Reference source of the study)	University	Research method	Findings
Sustainable Performance of Buildings through Modular Prefabrication in the Construction Phase: A Comparative Study	Jiang, Y., Zhao, D., Wang, D., and Xing, Y., 2019. Sustainable performance of buildings through modular prefabrication in the construction phase: A comparative study. *Sustainability*, *11*(20), p.5658.	School of Management Engineering, Shandong Jianzhu University, China	Qualitative primary research (i.e., interviews)	This research explores significance of modular pre-fabrication models used within construction projects as sustainable performance practices with excessive usage are determined to be an effective approach for project managers. To identify the implication of sustainable development initiatives within construction projects in China case project is considered. To compare performance between buildings constructed based on modular pre-fabrication procedures with conventional methods. Results obtained based on descriptive analysis describe the significant performance by using modular construction procedures rather than traditional practices. Based on primary data findings, the rationale for the adoption of modular construction procedures has been obtained to minimize the extent of environmental pollution, waste reduction, etc., requiring effective usage of sustainable construction models. Primary findings gathered from participants indicate that with off-site manufacturing decisions extent of prefabricated activities at on-on-site is reduced, which is identified to be sustainable performance towards environmental concerns. The usage of digital technological patterns and the deployment of a skilled labor force has been determined to be essential within pre-fabrication procedures. Based on participants' responses and findings obtained from the literature review, 16 different indicators are highlighted, from which five indicators have higher values, i.e., generating pollution, disruptions in weather, constraints at on-site locations, etc. Researchers' direct policymakers and regulatory bodies in China to initiate sustainable policies to promote pre-fabrication dimensions within construction projects. To contribute towards environmental concerns and sustainable development goals usage of smart building procedures is needed.
Design for Manufacture and Assembly of Digital Fabrication and Additive Manufacturing in Construction: A Review	Tuvayanond, W. and Prasittisopin, L., 2023. Design for Manufacture and Assembly of Digital Fabrication and Additive Manufacturing in Construction: A Review. *Buildings*, *13*(2), p.429.	Faculty of Engineering, Rajamangala University of Thanyabur, Thailand	Secondary analysis	This study explores significance of using pre-defined technological models within the manufacturing phase of construction. The significance of additive manufacturing dimensions and digital fabrication has been determined to be significant to contribute towards environmental concerns. The construction industry being larger waste polluter requires the implication of automation practices within construction-based projects. Digital fabrication techniques and additive manufacturing principles result to be adequate as within 3D simulation techniques, i.e., inventory management, utilization of resources, and effective management of manpower is performed to obtain sustainable dimensions within construction projects. To construct highly complex construction models, as with optimization procedures sustainable measures and quality assurance dimensions are utilized within the designing phase to obtain highly sustainable construction models. Material designing, project structuring, assembling raw materials etc., can be performed with digital automated principles. Stakeholders and clients are more interested in construction projects that include usage of prefabricated dimensions as performing manufacturing at off-site locations is determined to be essential sustainable construction procedures. Additive manufacturing principles include, i.e., low cost, fast restructuring procedures etc., through which quality production is performed to design and

				shape the surface of construction buildings and to customize sizes and forms, requiring 3D visual models that provide an internal overview of construction to perform. With lean engineering, BIM, CAD model, machine learning techniques, etc., predictive analysis is performed to evaluate operational risks and resources/raw materials to be used.
Prefabricated Construction in Sri Lanka: A Proposed Adoption Strategy and a Pilot Case Study from Sustainability Perspective	Jayawardana, J., Jayasinghe, J.A.S.C., Sandanayake, M., Kulatunga, A.K. and Zhang, G., 2023. Prefabricated Construction in Sri Lanka: A Proposed Adoption Strategy and a Pilot Case Study from Sustainability Perspective. *ENGINEER*, *56*(01), pp.71-80.	The Institution of Engineers, Sri Lanka	Pilot case study	This study explores significance of prefabricated dimensions within construction businesses. In developing countries integration of pre-fabrication procedures is still includes a certain amount of challenges for its effective implementation however construction projects in developed countries are majorly investing in highly sustainable business models. This study is particularly emphasizing to investigate implications of prefabricated models within the construction industry of Srilanka. Implementing pre-fabrication procedures is adequate challenge in the country due to, i.e., shortage of labor, lack of technology to perform quality assurance dimensions, to meet with environmental standards etc. Strategic efforts are required to formulate modular construction dimensions within development projects in the country, with increased number of challenges due to less industrial construction and manufacturing activities in the country, i.e., cost and budget management, etc., to obtain quality resources to conduct sustainable construction dimensions. The lack of sustainable policies from regulatory authorities in the country creates uncertain complications in adopting prefabricated dimensions within construction projects. Lack of skilled labor, technological capacities, etc., have put forward adequate constraints for project handlers. It is the strategic responsibility of the government to emphasize flexible and sustainable practices by investing in research and development and by promoting prefabrication dimensions to minimize waste pollution. The construction industry being a major contributor to GDP growth rate and economic stability within a country, requires innovative dimensions to practice for the construction of sustainable business models.
Improving project performance using lean construction in Egypt: a proposed framework	Swefie, M.G., 2021. Improving project performance using lean construction in Egypt: a proposed framework.	The American University in Cairo AUC	Quantitative analysis	This research explores broader insights related to adoption of lean dimensions within construction projects of Egypt. Implication of construction management procedures within projects has become essential to overcome operational challenges that have raised preliminary concerns for project managers. Within many construction projects certain manufacturing constraints are determined i.e., time delay in project completion, excessive budgets, lack of quality dimensions, in-adequate labor performance etc. that increase concerns for project managers. For effective utilization of resources, the study explores the significance of lean dimensions within construction projects. To execute sustainable project management principles, require strategic planning to accommodate project goals within expected time scale. In last few years construction industry in Egypt has faced numerous challenges in terms of political and economic stability that impacted adversely on construction-based projects in the region. It has raised the significance of sustainable dimensions that are strategically applicable within the implication of lean and agile dimensions. The study explores the significance of lean dimensions within construction projects as handling complex phased projects requires integration of a lean approach rather than traditional practices that include excessive time, resources, and costs to obtain project deliverables. To practice sustainable dimensions lean provides continuous improvement techniques and just-in-time mechanisms to handle and control complications within the operational phase of projects. Restructuring, recycling, and pre-fabrication procedures require the integration of a lean

				approach through which project efficiencies are increased, and production wastes are minimized. The findings of the study emphasize the implication of a lean approach within construction-based projects in Egypt to obtain quality outcomes. To overcome manufacturing risks and environmental concerns, lean dimensions are determined to be considerable for the construction of sustainable projects.

Chapter: 5 Discussion

The section of the discussion explores each research objective constructed within the introductory section of the research.

Significance of pre-fabrication procedures in construction projects

The study by [100] critically examines the significance of implementing pre-fabrication procedures within construction-based projects, as off-site production involves effective waste management principles through which environmental concerns are managed. To obtain quality manufacturing procedures shift in construction decisions from on-site locations to other warehouses' production facilities is determined to be considerable to achieve sustainable business goals [101]. To minimize overhead costs, effective usage of resources, etc., manufacturing at production facilities is adequate. The implication of a cost-effective approach is one of the major components associated with pre-fabrication practices [102]. Moreover, the usage of quality dimensions in complex construction is performed with pre-fabrication dimensions.

The findings of [27] conclude that to fulfill project deliverables within the expected time scale, strategic planning is needed within the pre-fabrication phase through which sustainable business models are constructed. Project stakeholders nowadays are more concerned with the implication of sustainable dimensions within construction-based projects to minimize operational expenses and environmental waste [103]. Pre-fabrication practices are a step forward to achieving sustainable development goals and fulfilling corporate social responsibilities. Transferring constructed project model to an on-site location reduces the risk of hazards and manufacturing complications. Moreover, risks to labor health and safety are maintained by a distribution of production tasks among teams of skilled labor-force operational constraints are reduced [104]. A research study by [105] concludes that project efficiency has been raised with the effective utilization of pre-fabrication models within construction projects through which environmental concerns are valued and managed based on sustainable decisions considered by project managers.

Fig 10: Source: [106]

A study by [107] shows that transportation and distribution cost for constructed components at on-site locations has still subsequent concerns for project managers to handle. Moreover, the risk of damage might decrease project efficiencies. Strategic planning, i.e., task allocation, material utilization, allocation of resources, labor training, etc., is performed to achieve sustainable dimensions within construction projects. With building information modeling (BIM) scope of the project is predicted based on the strategic plan constructed [108]. Moreover, 3D simulation models and digital technological implications provide stakeholders with a visual representation of the construction model that enables them to analyze internal infrastructure to manufacture with pre-fabrication dimensions [35]. With recycling decisions, green construction initiatives are considered as dismantling and de-construction practices are major contributors to waste management dimensions. To minimize operational waste, smart construction strategies are needed to obtain optimal construction of business models. To maintain precision, accuracy, consistency, etc., the implication of quality control principles is needed to reduce manufacturing hazards, i.e., excessive production etc. [109].

Challenges in traditional construction projects

A research study by [110] concludes that traditional practices adopted within construction projects include numerous challenges that impact project efficiency and stakeholders' expectations. The lack of smart technological implications has raised complications for project managers who are dependent on conventional methods of construction. Excessive usage of time, cost, and resources has been determined to be a prime constraint while handling complex construction projects [111]. Predicting the budget, time duration, raw materials to be used, the scope of the project, etc., is a broader challenge for project handlers and on-site engineers who have focused on traditional construction dimensions. Lack of technology has put-forward risks to accomplishing construction-based tasks within the expected time scale [112]. Larger dependency on the assumption to plan construction models increases the number of operational risks and challenges for architectures, project engineers, etc. [113]. Decrease in project feasibility and efficiency due to lack of management practices performed by project managers and inadequate manufacturing decisions considered at on-site locations.

The extent of collateral damage due to, i.e., minimal resources, inadequate construction plans, lack of skilled labor force, technological adoption, etc., has been increased within traditional-based construction projects [114]. Research by [115] concludes that lack of quality assurance dimensions, inadequate risk management procedures, ineffective communication between project handlers, etc., have increased delays in project execution and maintaining its sustainable scope in the long run. Integration of the traditional approach has been adopted within developing

countries due to a lack of budget, non-supportive regulatory policies, larger dependency on project managers and on-site workers, lack of technological adoption, etc., which has raised significance for the conventional project approach [116]. The implication of sustainable practices requires the integration of highly sustainable procedures, i.e., pre-fabrication, etc. However, its utilization is still a considerable complication for the construction industry in emerging countries. Therefore, the emphasis on traditional construction dimensions to execute commercial, residential, etc. projects is the broader focus.

Fig 11: Source: [117]

A research study by [118] examines that environmental concerns have been raised within traditional practices as predicting/forecasting weather conditions is broader complexity for project managers that can adversely impact accomplishing project deliverables within the expected time scale. However, pre-fabrication procedures include manufacturing within a controlled environment through which milestones and tasks are performed effectively. To increase project efficiency, dependency on traditional methods is required to minimize to overcome the extent of operational risks associated with a conventional approach [119]. Health concerns for front-line workers are a considerable challenge for project managers who have emphasized conventional methods of construction due to non-preventive measures that increase the risk of safety for construction laborers [120].

Benefits and advantages of pre-fabrication models

The implication of pre-fabrication models has improved efficiencies within construction-based projects to avoid environmental wastes and risks in manufacturing procedures; integration of quality assurance dimensions has provided strategic support to project managers [27]. To avoid damage at on-site locations, pre-fabrication dimensions enable project handlers to adopt safety regulatory policies to accommodate risk management practices. With a de-construction mechanism and recycling procedures, environmental sustainability is maintained [121]. Prefabrication structures include, i.e., schematics, etc., through which visual representations of construction models are evaluated and directed among stakeholders based on which their feedback is valued [122]. Quality assurance practices are valued within the pre-fabrication process to maintain standardized principles well-structured operational policies are constructed to execute sustainable dimensions. To ensure quality assurance dimensions at off-site construction premises is essential to determine operational strategies being practiced by operational managers [123]. The study of [124] concludes that the construction industry in developed countries has adopted pre-fabrication models to minimize the extent of risks and to obtain quality sustainable practices.

With predictive maintenance techniques and additive manufacturing dimensions, quality production is performed. To predict inventory (i.e., raw material, etc.) implication of optimization practices is essential to overcome excessive production. To ensure the integration of demanded construction, pre-fabrication has been determined to be essential within complex-based projects (Yin *et al*., 2019). To perform construction within a factory-controlled environment is strategically applicable by investing in modular construction procedures. The implication of lean and agile functioning is associated with pre-fabrication modules as it enables improving operational wastes and overhead costs [126] Research by [127] concludes that to perform sustainable construction within the allocated budget implication, continuous improvement strategies are needed.

Fig 12: Source: [106]

Risk identification, project scheduling, resource management, labor guidance, etc., can be performed with pre-fabrication dimensions [57]. Manufacturing construction components at off-site locations minimizes risks of damage at on-site locations. The modular construction phase minimizes excessive burdens on the labor force and increases the scope of the project within the allocated time scale [128]. With a controlled manufacturing environment, risks of safety can be valued as secure operational functions are performed. A study by [71] indicates that pre-fabrication models enable project managers to handle, i.e., staff members, resources, etc., as with strategic planning, construction tasks are performed based on stakeholders' expectations. With timely monitoring, controlled decisions are made, and risks are mitigated. Construction projects involve higher risks/damage; therefore, implication of the pre-fabrication model minimizes the extent of operational challenges and external environmental constraints [129]. Project managers are able to execute cost-effective approaches and waste management dimensions at off-site locations based on which quality and sustainable construction of project components is performed.

Chapter: 6 Conclusion

From the above analysis, it can be concluded that to perform sustainable efficiency within construction-based projects, the implication of pre-fabrication dimensions is needed to obtain quality outcomes within the allocated time scale. Traditional construction mechanism includes an excessive amount of challenges for project managers to fulfill project goals. However, pre-fabrication provides sustainable models for manufacturing quality components to be used within construction projects. Conducting manufacturing activities at off-site locations minimizes the extent of risks and complication for project managers. With modular

construction procedures, on-time evaluation is performed by construction managers to practice sustainable dimensions within the manufacturing process.

By using the building information modeling (BIM) technique, environmental concerns are managed by performing construction activities at environmentally controlled locations. Pre-fabrication is a step forward toward the implication of green initiatives, as by reducing material/inventory costs, operational efficiencies are maintained. Maintaining quality dimensions within the pre-construction process enables project managers to adopt standards of procedures at on-site locations. Risk assessment and quality assurance principles are applicable to the integration of pre-fabrication procedures. Construction businesses globally are focusing on practicing sustainable development principles that require the usage of the pre-fabrication model that provides convenience among stakeholders to maintain project feasibility by practicing sustainable decisions while performing construction activities. Traditional construction procedures include numerous challenges, i.e., excessive time to schedule project activities, higher overhead and operational costs, lack of technology, minimal expertise among the labor force deployed at construction sites, etc., that have raised complications for project managers to handle complex projects.

With prefabricated models, construction managers have determined sustainable procedures to overcome environmental risks. By investing in prefabricated solutions quality, construction practices are utilized in residential, commercial, and industrial-based projects. The conventional approach involves the construction of building materials at on-site locations that include, i.e., safety risks for front-line workers, etc., as with non-preventive measures, risks of accidents and hazards increased to a larger extent. However, with construction at off-site locations, manufacturing time is reduced, and it enables project handlers to utilize digitally stable models through which quality production is performed.

The section on methodology provides a research strategy adopted to investigate a research problem. By using qualitative research design and secondary data collection methods, researchers are focusing on identifying the significance of pre-fabrication dimensions within construction-based projects. With the inductive approach researcher's emphasis is to explore research objectives by conducting a study from scratch or initial phase. With interpretivism research philosophy researcher explores secondary data findings relevant to a topic under examination. To analyze data, the content analysis technique is used to highlight secondary findings obtained from various research articles. The section on findings and discussion provides an in-depth analysis of how the pre-fabrication mechanism assists project managers in adopting sustainable development goals.

It is evident from the study that traditional practices associate a large number of challenges that impose significant complications for project managers to accomplish the deliverables of the project; however, pre-fabrication models provide automation dimensions through wastes are eliminated and operational risks are minimized. By assembling and manufacturing components at off-site locations, stakeholders' expectations are valued, and sustainable dimensions are performed as by aligning manufactured components at on-site locations, quality construction is executed.

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