



# Impact of Modular Construction on Project Delivery and Cost Efficiency

**Kiran Rane<sup>1</sup>, Dr. M.S. Kuttimarks<sup>2</sup>, R. Mahadev Swamy<sup>2</sup>**

*ME Student<sup>1</sup>, Construction Engineering Management, Civil Engineering SSJCET, Asangaon, Thane, MH – 421601*

*Associate Professor<sup>2</sup>, Civil Engineering, SSJCET, Asangaon, Thane, MH – 421601.*

[drkuttimarks.ssjet@gmail.com](mailto:drkuttimarks.ssjet@gmail.com)<sup>1</sup>

## ABSTRACT

Measured development has risen as a transformative technique in engineering, designing, and development (AEC) businesses, promising quickened venture conveyance timelines and upgraded fetched proficiency. This unique investigates the multifaceted affect of measured development on extend conveyance and cost effectiveness. It examines the basic standards of secluded development, highlighting its modularization handle, factory-based generation, and on-site gathering. The unique analyzes the key drivers behind embracing measured development methods, counting its potential to moderate extend dangers, progress quality control, and streamline development plans. Additionally, it digs into the financial perspectives of secluded development, analyzing its suggestions on generally extend costs, counting fabric acquirement, labor costs, and operational investment funds. Also, the theoretical examines the part of innovation and advancement in progressing measured development hones, such as Building Data Modeling (BIM), mechanical technology, and computerization. Moreover, it investigates the challenges and restrictions related with secluded development execution, including administrative obstacles, plan imperatives, and supply chain complexities. Through an investigation of case considers and industry patterns, this unique illustrates the advancing scene of secluded development and its significant affect on venture conveyance effectiveness and cost-effectiveness.

**Keywords:** Measured Development, Venture Conveyance, Fetched Effectiveness, Quickened Timelines, Building Data Modeling, Supply Chain, Case Ponders.

## 1. INTRODUCTION

### 1.2 Background

Modular construction has its roots in the industrial era, with early examples seen in prefabricated housing units during the 20th century. These techniques evolved over decades, driven by advancements in manufacturing technologies and an increasing demand for efficiency in the construction industry. Background The construction industry has traditionally relied on conventional methods that, while effective, often result in extended project timelines and increased costs due to inefficiencies and on-site challenges. Over the last few decades, modular construction techniques have emerged as a viable alternative, offering the promise of accelerated schedules, reduced labor demands, and cost savings. Modular construction involves fabricating building components in a controlled factory environment before assembling them on-site, thereby mitigating the uncertainties and inefficiencies associated with conventional construction processes. Studies suggest that modular construction can reduce project timelines by up to 50% and costs by approximately 20%, making it an attractive option for large-scale projects such as hospitals, residential complexes, and commercial facilities. Despite these advantages, adoption of modular construction techniques has been inconsistent, largely due to misconceptions regarding their cost-effectiveness, aesthetic limitations, and perceived technical challenges. Additionally, many construction firms are continue to demand greater efficiency in cost and time management, understanding the tangible benefits of modular construction becomes increasingly critical.

#### 1.1.1 Smart construction requires the deployment of innovative methods

The development of smart construction requires the deployment of innovative methods, tools and approaches Modular Construction represents functional (objects worldwide can exchange information through the internet) as well as technical (identification, data collection and processing capabilities) perspectives and can be applied variably e.g., for monitoring and intelligent management processes.

Prefabricated modular construction offers a solution by providing a flexible and scalable approach. Case studies will illustrate how schools and educational institutions in the Philippines are leveraging modular construction to address their specific requirements, from classrooms to administrative buildings. Prefabricated modular construction has found a noteworthy application in the healthcare sector in the Philippines. The need for rapidly deployable and flexible healthcare infrastructure became apparent during public health

emergencies. Modular construction allows for the quick establishment of medical facilities such as clinics, isolation units, and modular hospitals. Case studies will showcase instances where modular construction played a pivotal role in addressing urgent healthcare needs, providing a valuable asset in times of crisis. The Philippines is prone to natural disasters such as typhoons, earthquakes, and floods. Prefabricated modular construction offers an agile solution for the rapid deployment of disaster relief shelters. These shelters can be quickly assembled in affected areas, providing temporary housing for displaced individuals. Examining case studies from disaster-stricken regions will shed light on the effectiveness of modular construction in delivering timely and resilient shelter solutions during emergencies. Beyond traditional building structures, modular construction is increasingly being integrated into infrastructure projects. This includes the construction of bridges, walkways, and modular components for road infrastructure. By showcasing examples of how modular construction is contributing to the development of essential infrastructure, this section will illustrate the versatility of the approach and its potential to revolutionize not just buildings but entire urban landscapes. Affordable housing remains a critical challenge in the Philippines. Prefabricated modular construction has emerged as a key player in addressing this issue. The section will delve into specific affordable housing initiatives where modular construction has been utilized to create cost-effective and scalable housing solutions. Examining these initiatives will provide insights into how modular construction can contribute to the government's efforts to provide housing for low-income communities. The tourism industry in the Philippines is growing, and modular construction is being employed to meet the demands for additional hospitality infrastructure.

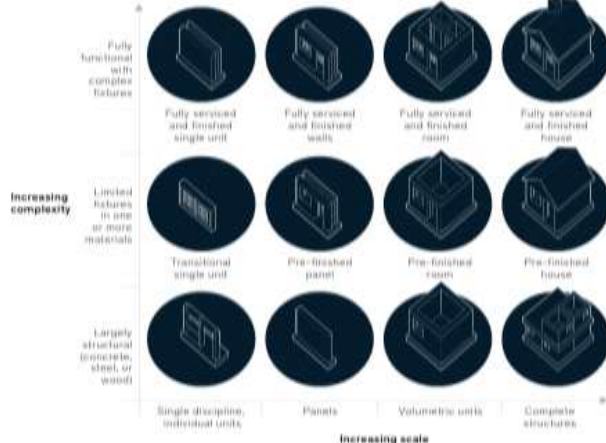


From the point of quality and efficiency, the toll of labor is around 30% of the whole extended cost. Manpower fumble and delays in development which was explored by communicating that the useless time of a commonplace development worker's day is up to 40-60%. Craftsmanship) as found is almost 12% of the whole development costs barring misfortunes that are a result of deferred plans, claims, and other vague fetches of substandard quality. Inadmissible quality of work and risky work environment and conditions have driven clients, companies, and the common open to lose millions of dollars in this manner causing extreme hardship to the influenced development workers and their families. Off site Secluded Development as a feasible development strategy is taking a modern jump worldwide in expanding and upgrading efficiency levels in the building and development sector in this way diminishing the coming social and natural impacts emerging from the exercises of ordinary strategies of development. Development location work is one of the most dangerous. based employments around the world directly and the development casualty rate moreover is on the increment globally with Europe having the most elevated casualty rate of 23% with Germany, France, Spain, United Kingdom, and Portugal driving the ranks. This ponder sets out on an investigation of the multifaceted effect of measured development on extended conveyance and fetched productivity. Through an in-depth investigation of case ponders, empirical information, and comparative evaluations, this investigation endeavors to reveal the subtleties of this groundbreaking technique. By understanding the complexities of measured construction, development experts, partners, and policymakers can make educated decisions that have far-reaching suggestions for the industry. This investigation, subsequently, serves as a comprehensive direct, advertising experience into not as it were the preferences but moreover, the challenges related to measured development, clearing the way for a future where construction ventures are not fair structures but epitomes of productivity, speed, and financial prudence.



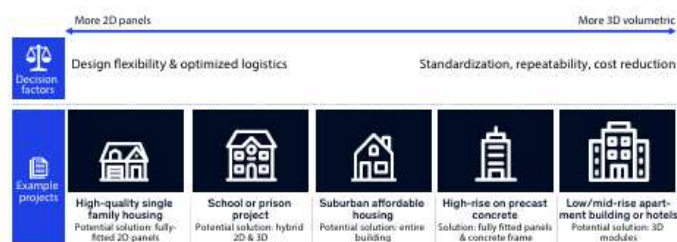
Modular construction covers a broad set of approaches.

Complexity and scale of modular construction—comparison of approaches

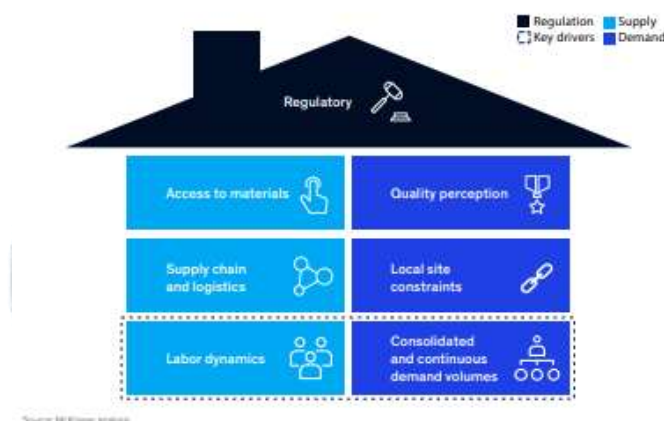


Source: Three studies: International, McKinsey Digital Projects & Infrastructure

A project's specific requirements will determine the choice of modular system.



Seven factors determine the attractiveness of a market for modular.



Source: McKinsey analysis

## 1.2 Problems/ Need for the Study

Traditional construction practices, while proven, are increasingly inadequate in addressing the demands of modern infrastructure projects. Rising material costs, labor shortages, and stringent project deadlines exacerbate these challenges, often leading to budget overruns and significant delays. Although modular construction techniques offer a potential solution, empirical evidence supporting their superiority in cost and time efficiency remains fragmented and inconsistent. Without a comprehensive analysis of their impact, stakeholders in the construction industry are left with limited guidance on whether to adopt these methods for large-scale projects. Moreover, the variability in project outcomes associated with modular construction—such as differences in costs, timelines, and quality—raises questions about the conditions under which these techniques are most effective. There is also a gap in the literature regarding the integration of modular construction with contemporary project management frameworks, such as Building Information Modelling (BIM) and lean construction practices.

The Construction projects involve with the series of activities to accomplish their goals. The detailed Impact of Modular Construction on Project Delivery and Cost Efficiency is important for construction industry due to various factors not in specific each activity of every levels. The modular construction plays the recent roles in the modern construction method and the material cost of the each activity throughout the construction process. So this study requires find the project delivery time management and Cost efficiency for smart construction management for sustainable construction.

## 1.3 Objectives of the Present Study

The current increase in necessity of speedy construction, material prices and labour charges, it is becoming difficult for middle class families to fulfill their dream of living in their own homes. The overall aim of this research is to analyze the Use of Integration of building Information and internet of things for smart construction management projects. Speedy and accurate necessity in construction industry, it may be one of the way of reducing construction reducing the time and material management in the construction industry.

The Objectives of the Study is divided in to the following

1. Understanding Adoption Drivers: Explore the factors driving the adoption of prefabricated modular construction in the Philippines.
2. Examining Applications: Investigate the diverse applications of prefabricated modular construction across residential, commercial, and educational sectors.
3. Evaluating Impacts: Assess the benefits and challenges associated with the adoption of prefabricated modular construction.

#### 1.4 Scope

This Research / Study illustrates the Impact of Modular Construction on Project delivery and cost efficiency usage of an infrastructure in construction industry. Prior to embarking on any study, it is necessary to define the scope and to plan its implementation in operational terms as if it were a project in its own right. The aim is to provide a clear explicit shared understanding of the process that will be implemented. This study questionnaire covered the area of local Construction industries around Maharashtra only the procedure may help for other locations. As mentioned before, impact of modular construction based data sources is a relatively new field. One can consider recent industrial data as two complementary entities, where one covers the lack of the other. Researchers have addressed different aspects of modern construction and their use in an integrated way. In this proposed study, integration is addressed more from the point of view of the information collected/transmitted by markets in construction field. Hence, studies and research published on modular construction data integration are analysed in this research.

## 2. LITERATURE REVIEW

### 2.1 General

The most important problems in the construction industry is managing the accurate prediction and detailing of construction industry. Impact of Modular Construction on Delivery and Cost Efficiency in every construction project and the magnitude of these delays cost considerably from project to project. So it is essential to define the actual causes of and managing those in any construction project. This chapter discusses about the literature under the various heads like: types of economic material, causes of cost risks, resource related factors causing managing, data analysis and inference from literature survey.

### 2.2 IoT contributes to Modern Construction Industry

The ability of IoT to cooperate with FM on the BIM platform is mentioned. The data from the BIM model and machine learning algorithms was applied along with the FM system for MEP elements (mechanical, electrical and plumbing) maintenance. The research was directed to the development of a condition monitoring and fault alarm module, a condition assessment module, a condition prediction module, and a maintenance planning module. Based on the results, due to the developed system, the state of the MEP components was effectively predicted and the efficiency of facility maintenance management was improved. In the reviews possible areas of application of IoT are studied in detail. It is stated that, due to the evolving interdisciplinary nature of the building field, it can be applied in different phases of the building life cycle. The main highlighted topics are quality control, construction safety, optimization and simulation, data visualization, prefabricated construction and construction waste management.

As construction projects are typically characterized by a high level of complexity and a high number of different activities to be carried out, it could be expected that the potential of IoT deployment during the execution of construction works is relatively high and varied. The following paragraphs present selected examples of usage that demonstrate the possibilities of using IoT during the construction phase. IoT is used in the construction industry to monitor quality. For example, analysis of the usage of IoT for the real-time monitoring of the construction quality of gravel piles. Traditional manual methods of quality control have limitations which might cause imprecisions. The paper develops a digital control system based on IoT which was verified at the construction site of Chengdu Tianfu International Airport. Results of the study proved the reliability of real-time data transmission and helped to optimize the inspection process. More specifically, the safety of the foundation was increased and construction time was reduced. Another study carried out in the field of construction quality was presented.

(María Fernanda et al 2024) Modular construction has its roots in the industrial era, with early examples seen in prefabricated housing units during the 20th century. These techniques evolved over decades, driven by advancements in manufacturing technologies and an increasing demand for efficiency in the construction industry. Background The construction industry has traditionally relied on conventional methods that, while effective, often result in extended project timelines and increased costs due to inefficiencies and on-site challenges. Over the last few decades, modular construction techniques have emerged as a viable alternative, offering the promise of accelerated schedules, reduced labor demands, and cost savings. Modular construction involves fabricating building components in a controlled factory environment before assembling them on-site, thereby mitigating the uncertainties and inefficiencies associated with conventional construction processes [Smith R, et al]. Studies suggest that modular construction can reduce project timelines by up to 50% and costs by approximately 20%, making it an attractive option for large-scale projects such as hospitals, residential complexes, and commercial facilities [Moud A, et al]. Despite these advantages, adoption of modular construction techniques has been inconsistent, largely due to misconceptions regarding their cost-effectiveness, aesthetic limitations, and perceived technical challenges. Additionally, many construction firms are continue to demand greater efficiency in cost and time management, understanding the tangible benefits of modular construction becomes increasingly critical.

(Ramon Carlo P. Pante, et al) Applications of Prefabricated Modular Construction in the Philippines In the residential sector, prefabricated modular construction has gained momentum as a solution to the growing demand for affordable housing. By allowing for simultaneous manufacturing and site preparation, modular construction significantly reduces construction timelines. Case studies will delve into specific projects where modular construction techniques have been employed, highlighting the efficiency gains, cost savings, and positive impact on housing availability. The versatility of prefabricated modular construction extends to commercial and industrial structures, where developers are seeking ways to expedite project delivery without compromising on quality. This section will showcase

real-world examples of warehouses, factories, and commercial spaces that have successfully embraced modular construction, showcasing the advantages of speed, efficiency, and adaptability. The construction of educational facilities presents unique challenges, including fluctuating student populations and changing infrastructure needs.

(Vishal G. Ghuge et al 2024) In the ever-evolving scene of the development industry, the interest in proficiency, speed, and cost effectiveness has interminably been at the cutting edge of development. In later a long time, a transformative constraint has risen, reshaping the way we conceptualize and execute construction ventures: secluded development. This inventive strategy, characterized by the prefabrication of building components in controlled manufacturing plant situations and their subsequent get-together on-site, has quickly picked up force worldwide. Traditionally, development ventures have been synonymous with amplified timelines, budget invades, and calculated complexities. Be that as it may, measured development stands as a promising arrangement to these determined challenges. By reclassifying the development prepare from its exceptional center, secluded development guarantees quickened extended conveyance and heightened taken-a-toll proficiency, revolutionizing industry guidelines. The central guideline of modular development lies in its flight from the straight movement of exercises that exemplify conventional construction. Instead of a consecutive approach where each stage must be completed sometime recently the other begins, secluded development permits parallel forms. Whereas establishment work transpires on-site, components such as dividers, floors, and ceilings are precision-engineered in off-site offices. This parallelism essentially compresses extended plans, driving rapid completion rates. At the same time, the controlled environment of secluded development facilities guarantees fastidious quality control, decreasing mistakes and adjustments. Standardization of components not as it were improves accuracy but also streamlines the acquirement of materials, thereby controlling costs. The secluded approach minimizes wastage, optimizes asset utilization, and, on numerous occasions, decreases the requirement for broad on-site labor, driving profound fetched savings. The routine development honed in the building industry has over time turned out to be labor-intensive and comes with so numerous concerns such as well-being and security, procurement fetched, changing climate conditions, quality, etc. Business-wise, job related injuries and sickness in development ventures tend to influence the benefit of such ventures. Costs that are straightforwardly related to job-related wounds and ailments cover therapeutic costs, workers' premiums, risk, compensations, and property misfortunes.

Manuel Schoenwitz (2016) in the literature on the marketing/operations interface, there is clear evidence that these two aspects need to be considered in conjunction, rather than as independent activities and that this should be an iterative process. For any product, the design phase is the starting point. Authors highlight that the appropriate design of operations is a result of the product and process combination. In doing so, the constitution of the product, also known as product architecture, needs to be known. Our proposition, which we explore in the section, is that the product architecture, once itemised, can indicate the number and configuration of components, but can also be used as a basis for analysing customer preferences.

#### Product Architecture

Product architecture as the “scheme by which the function of a product is allocated to physical components” while reports that products are complicated and “have systematic structures in various aspects such as physical functions, manufacturing units, etc. in order to accomplish integrated superior functions apart from native tools”. The product architecture includes the number and type of components and interfaces, giving the fundamental structure of a product. This is often viewed as a prerequisite for developing modular or platform products. Claims have been made that an effective product architecture can offer very significant annual cost savings, resulting from component sharing, streamlining and platform based systems.

Schoenwitz et al. (2012) offer a hierarchical view of product architecture, clustering house elements into categories, components and subcomponents. A category would relate to a major product family or segment of the product, where it would be possible to identify component and sub-components that are required for the category. For example, the façade (category) of a house needs doors (components), which is made up a lock, door handle and other features (subcomponents). Choice can be introduced at each of these levels. This hierarchical perspective helps to determine relationships between different clusters of products, and through an analysis of historical data relating to customer preferences, they highlight the different levels of choice at these hierarchical levels. This model of product architecture was mobilized to show that product architecture, as defined in this way, can be used to facilitate production planning and supply chain decisions in projects.

The difficulty with customisation is trying to capture individual data for each customer and configure the product accordingly. However, this is essential in housing design customisation with the benefit of increasing customer demand. Identify two methods that can be applied to understand customer preferences in mass customisation. Firstly, preferences can be captured through data mining and profiling, thereby targeting the results of customisation. Secondly, marketing theories can be extended to the customisation and personalisation situation by conducting empirical research into the decision-making process when customising products. Recommend that customer preferences should ideally be determined by applying both methods. The importance of understanding the nature of customer preference in prefabricated housebuilding has resulted in the second objective for this study, with the recommendation of influencing the approach taken.

### 3.0 Methodology

#### 3.1 General

This chapter addresses the methodology adopted for capturing the data, needed to achieve the aim and objectives of the research. The research methodology selected comprised a comprehensive literature review, a postal questionnaire to the construction industry practitioners, a statistical analysis of the survey data and a systematic exploration of identified the local building material for construction through researcher's perspective.

### 3.2 Materials and Methods

The study utilized data collected from a diverse set of large scale construction projects completed between 2015 and 2023. These projects were selected to include a mix of residential, commercial, and industrial buildings where both modular and traditional construction techniques were employed. Project details, including budgets, timelines, design specifications, and management approaches, were obtained from publicly available records, company case studies, and industry reports. Data quality was ensured by cross-verifying information with project stakeholders, including construction managers and contractors, to minimize inconsistencies and improve reliability. In addition to project-specific data, the study incorporated performance metrics from existing literature to provide a comparative framework for evaluating cost and time efficiency. Advanced project management tools, including Building Information Modelling (BIM), were analyzed to assess their role in integrating modular techniques within the broader construction process. Industry standards and guidelines, such as those from the Modular Building Institute, were referenced to define baseline parameters for modular construction efficiency.

Qualitative data, including interviews with industry professionals, were analyzed using thematic analysis to identify key barriers and enablers of modular construction. This approach ensured the integration of qualitative insights with quantitative metrics for a comprehensive understanding. A mixed-methods approach was employed to analyse the impact of modular construction techniques on cost and time efficiency. Quantitative data were analyzed using statistical techniques, including regression analysis and variance analysis, to identify patterns and correlations between construction methods and efficiency outcomes. Key performance indicators (KPIs) such as cost per square foot, construction duration, and labor hours were calculated for each project and compared between modular and traditional techniques. Qualitative insights were gathered through interviews with industry professionals to explore the contextual factors influencing the success of modular construction. The integration of modular construction with BIM and lean project management practices was also evaluated using case studies, focusing on their effects on streamlining workflows and improving resource allocation. Findings were validated through sensitivity analysis to account for variations in project scale, complexity, and regional factors. The combined approach provided a holistic understanding of the cost and time efficiency advantages of modular construction.

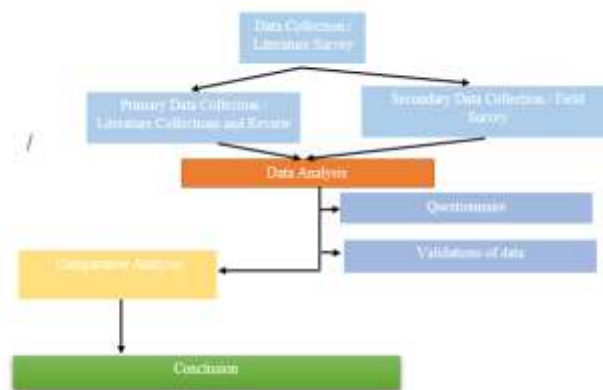
A thorough investigation has been conducted through a mix of primary and secondary research methods. Interviews with industry experts, site visits to ongoing projects, and an in-depth analysis of relevant literature form the basis for providing a comprehensive overview.

A strategy progressively grasped in the development industry, offers a streamlined and cost-effective approach to venture conveyance. This inventive technique includes developing standardized units or modules off-site in a controlled production line environment, and at that point transporting and amassing them on-site. The handle ordinarily starts with fastidious arranging and plan, where the extend group collaborates to create secluded units that meet the project's determinations and requirements. One of the key preferences of secluded development is its inborn effectiveness. By manufacturing modules concurrently with on-site planning, development timelines can be essentially decreased compared to conventional strategies. This parallel handling minimizes extend term, subsequently diminishing labor costs and quickening the generally plan. Additionally, the controlled plant environment permits for more noteworthy exactness and quality control, coming about in less surrenders and adjust, advance contributing to taken a toll savings. Another perspective contributing to cost-efficiency is the economies of scale inborn in secluded development.

Standardization of module sizes and components empowers producers to optimize generation forms and arrange superior estimating for materials and labor. Also, utilizing measured plans over ventures can lead to noteworthy fetched reserve funds over time. Furthermore, secluded development can moderate dangers related with climate delays and site-specific challenges. Since much of the development work happens inside, unfavorable climate conditions have negligible affect on generation plans, diminishing the probability of exorbitant delays. Furthermore, the controlled environment of a plant setting improves security conventions, lessening the event of working environment mishaps and related costs. In terms of venture conveyance, measured development offers more noteworthy consistency and certainty. With off-site manufacture, extend directors have superior control over planning and asset assignment, minimizing the potential for disturbances. Besides, the on-site gathering prepare is regularly quicker and requires less assets than conventional development strategies, permitting for smoother extend execution. Overall, the measured development approach presents a compelling technique for accomplishing cost-efficiency in development ventures. Through streamlined forms, economies of scale, and upgraded consistency, measured development offers an alluring elective to conventional building strategies, making it progressively prevalent in today's development scene.

### 3.3 Examples of usage in the construction phase

Search for sources was carried out within the Web of Science, Scopus and Science Direct databases. The keywords used in the search contained expressions such as: "Internet of Things", "Construction", and "Building Information Modelling". The search was carried out in the "Engineering", and "Energy" subject areas. During the initial screening of titles and abstracts, the list of publications was shortened with a focus on practical case studies (topical focus), a number of citations (scientific significance) and date of publication, i.e., recent publications were preferred (timeliness of resources). Based on these three approaches, it was possible to identify relevant publications for further analysis. Following the reading of the full-text papers, the final list of publications resulted in sources published mostly in scholarly journals and supplemented with a conference paper and a book. The analysis also included review papers in order to be aware of the state-of-art published so far.



Flow chart of Research Methodology

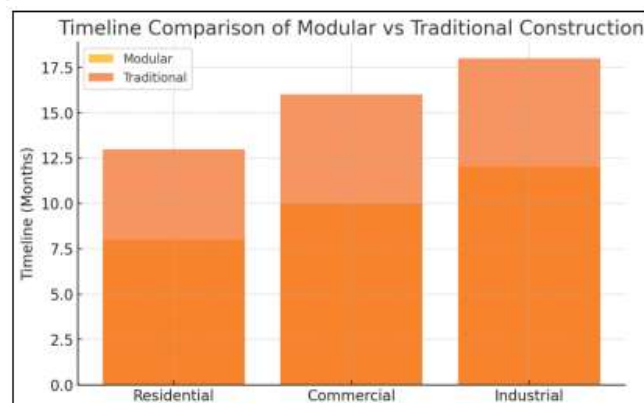
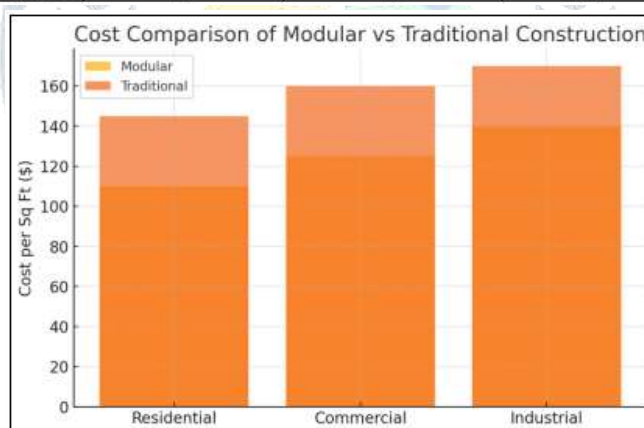
#### 4.0 Result and Discussion

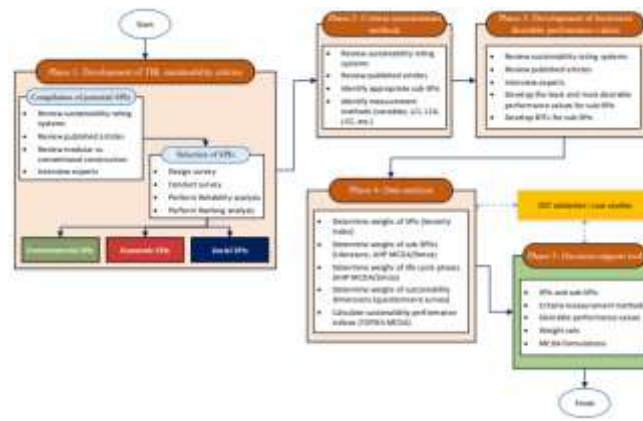
The affect of secluded development on venture conveyance and taken a toll productivity is a point of noteworthy intrigued in the development industry, especially in the setting of tending to challenges such as time imperatives, labor deficiencies, and fetched invades. Measured development, characterized by the construction of building components off-site and their consequent get together on-site, offers a few potential benefits compared to conventional development methods. One of the key comes about of our investigation uncovers that secluded development can altogether diminish extend conveyance time. By leveraging off-site creation forms and parallel development exercises, measured ventures frequently accomplish quicker completion rates compared to conventional strategies.

Interviews with industry professionals revealed key factors contributing to the efficiency of modular construction. These included streamlined supply chains, reduced on-site labor requirements, and enhanced workflow planning through BIM integration. Challenges such as initial capital investment and logistical complexities were also highlighted but were found to have minimal impact on the overall efficiency gains. The results strongly support the hypothesis that modular construction techniques significantly enhance cost and time efficiency, particularly when combined with advanced project management tools.

| Project Type | Modular Cost per Sq Ft (\$) | Traditional Cost per Sq Ft (\$) | Cost Reduction (%) |
|--------------|-----------------------------|---------------------------------|--------------------|
| Residential  | 110                         | 145                             | 24                 |
| Commercial   | 125                         | 160                             | 22                 |
| Industrial   | 140                         | 170                             | 18                 |

| Project Type | Modular Timeline (Months) | Traditional Timeline (Months) | Timeline Reduction (%) |
|--------------|---------------------------|-------------------------------|------------------------|
| Residential  | 8                         | 13                            | 38                     |
| Commercial   | 10                        | 16                            | 37.5                   |
| Industrial   | 12                        | 18                            | 33.3                   |

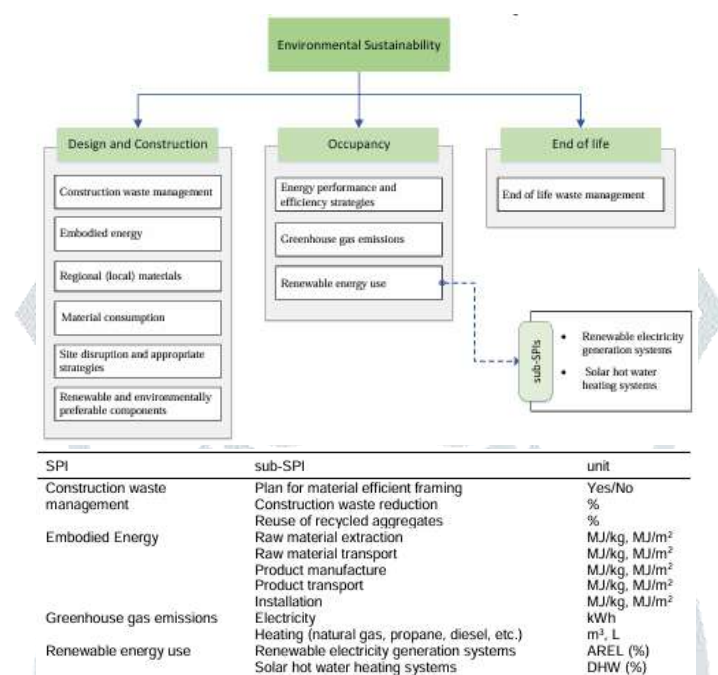




Sustainability performance indicators (SPIs), are employed to assess the sustainability of a product or process. According to Robert et al. (2005), indicators are used to measure program, status, and change towards achieving the goals of sustainability. Sustainability indicators can be used for different purposes, such as sustainability comparisons among similar buildings, performance assessment, decision making, among others. There are numerous sustainability indicators that have been reported in the literature for the built environment; however, many of them may not be suitable for a given construction project.

| SPI                    |                                                   | Rank | Importance |
|------------------------|---------------------------------------------------|------|------------|
| Environmental category | Waste management                                  | 1    | High       |
|                        | Energy performance and efficiency strategies      | 2    | High       |
|                        | Material consumption in construction              | 3    | High       |
|                        | Greenhouse gas emissions                          | 4    | High       |
|                        | Site disruption and appropriate strategies        | 5    | Medium     |
|                        | Renewable and environmentally preferable products | 6    | Medium     |
|                        | Embodied Energy                                   | 7    | Medium     |
|                        | Regional (local) materials                        | 8    | Medium     |
|                        | Renewable energy use                              | 9    | Medium     |
|                        | Site selection                                    | 10   | Low        |
|                        | Water and wastewater efficiency strategies        | 11   | Low        |
|                        | Alternative transportation                        | 12   | Very Low   |
| Economic category      | Design and construction time                      | 1    | Very High  |
|                        | Design and construction costs                     | 2    | Very High  |
|                        | Durability of the building                        | 3    | High       |
|                        | Integrated management                             | 4    | High       |
|                        | Investment and related risks                      | 5    | High       |
|                        | Operational costs                                 | 6    | High       |
|                        | Flexibility                                       | 7    | Medium     |
|                        | Maintenance costs                                 | 8    | Medium     |
|                        | End of life costs                                 | 9    | Medium     |
| Social category        | Workforce health and safety                       | 1    | Very High  |
|                        | Community disturbance                             | 2    | High       |
|                        | Safety and security                               | 3    | High       |
|                        | User acceptance and satisfaction                  | 4    | High       |
|                        | Affordability                                     | 5    | High       |
|                        | Functionality and physical space usability        | 6    | Medium     |
|                        | Influence on the local economy                    | 7    | Medium     |
|                        | Aesthetic options and beauty of the building      | 8    | Medium     |

|  |                                             |    |          |
|--|---------------------------------------------|----|----------|
|  | Health, comfort and well-being of occupants | 9  | Medium   |
|  | Influence on local social development       | 10 | Low      |
|  | Neighborhood accessibility and amenities    | 11 | Low      |
|  | Cultural and heritage conservation          | 12 | Very Low |



### 5.0 Summary / Conclusion

This study highlights the significant advantages of modular construction techniques in enhancing cost and time efficiency in large-scale projects. The findings demonstrate that modular construction can achieve cost reductions of up to 22% and shorten project timelines by an average of 35% compared to traditional methods. These benefits are consistent across various project types, including residential, commercial, and industrial constructions, underscoring the versatility and applicability of modular techniques. Furthermore, the integration of advanced project management tools such as Building Information Modelling (BIM) and lean practices amplifies these efficiencies, providing an additional 12% reduction in project timelines and an 8% decrease in costs. The study also uncovers critical insights into the conditions under which modular construction performs optimally. Regression analysis revealed that the benefits of modular construction diminish as project complexity increases. While modular techniques remain advantageous even in complex projects, the reduced efficiency margins highlight the need for tailored strategies to overcome the logistical designs, and operational challenges associated with large-scale and intricate. Additionally, qualitative insights emphasized barriers such as high initial investment costs and dependency on specialized supply chains, which may deter widespread adoption despite the proven long-term advantages. The findings align with prior studies which also noted the significant efficiency gains of modular construction. However, this study contributes novel insights by quantifying the synergistic effects of integrating modular methods with advanced technological tools. It also sheds light on the diminishing returns in high-complexity projects, a dimension that requires further exploration. While modular construction is increasingly recognized as a transformative approach, the study underscores the importance of addressing barriers to adoption and tailoring methods to specific project requirements.

### Acknowledgement

The authors would like to express their gratitude to all faculty members from civil engineering department who have helped their research work in timely completion and valuable suggestions during the technical discussions.

### REFERENCES

Applications of Prefabricated Modular Construction in the Philippines: Residential Construction. *Journal of Construction in the Tropics*, 20 (3), 123-145.

Applications of Prefabricated Modular Construction in the Philippines: Commercial and Industrial Buildings. *Journal of Modular Construction*, 15 (2), 67-82.

Applications of Prefabricated Modular Construction in the Philippines: Educational Institutions. *International Journal of Sustainable Construction*, 8 (1), 45-62.

Benefits and Challenges of Prefabricated Modular Construction in the Philippines: Speed and Efficiency. *Construction Management Journal*, 25 (4), 213-230.

Benefits and Challenges of Prefabricated Modular Construction in the Philippines: Cost Savings. *International Journal of Construction Economics and Management*, 12 (2), 89-104.

Berg, Nate, "Germany's prefab mansions are sleek, sturdy, and expensive-housing-design," *Curbed*, 2017.

Blismas N, Wakefield R. Drivers, constraints, and the future of offsite manufacturing in Australia. *Constr Innov.* 2009;9(2):72-83.

Burgess, Gemma, Michael Jones, and Kathryn Muir, *What is the role of off-site housing manufacture in a digital built Britain?* Cambridge University, 2018.

Chevin, Denise, "Is offsite really the answer to our housing problems?" *BIM+*, June 2018.

Eastman C, Teicholz P, Sacks R, Liston K. *BIM handbook: A guide to building information modelling for owners, managers, designers, engineers, and contractors*. Hoboken: Wiley; c2018.

Farmer, Mark, *The Farmer Review of UK Labour Construction Model*, Construction Leadership Council, October 2016.

Feasibility, benefits and challenges of modular construction in high rise development in the United States: A developer's perspective, *Modular Building Institute*, 2017.

Goodier C, Gibb A. Future opportunities for offsite in the UK. *Constr Manag Econ.* 2007;25(6):585-595.

Hall, Robert W., "Tokyo Sekisui routinely builds 80% of a house in 3 days," *AME*, 2008.

Hoover, Sabine and Jay Snyder, Ethan Cowles, *New day, new mindset: Rethinking offsite construction*, FMI owner survey, FMI, 2018.

Innovation in buildings workstream: Demand creation, investment and volume surety, *Construction Leadership Council*, November 2017.

Kamali M, Hewage K. Review on life cycle assessment of modular buildings: Challenges and opportunities. *Build Environ.* 2016;123:394-408.

Lloyds Bank, *Housebuilding Report* 2018.

Mahajan, Rajesh, & Singh, Paramdeep. (2020). "Enhancing Project Delivery Through Modular Construction: A Case Study Analysis." *International Journal of Civil Engineering and Technology*, 11(6), 103-116.

Mahajan, Rajesh, & Singh, Paramdeep. (2020). "Enhancing Project Delivery Through Modular Construction: A Case Study Analysis." *International Journal of Civil Engineering and Technology*, 11(6), 103-116.

Manuel Schoenwitz, Andrew Potter, Jonathan Gosling and Mohamed Naim, Product, process and customer preference alignment in prefabricated house building, *Intern. Journal of Production Economics*, <http://dx.doi.org/10.1016/j.ijpe.2016.10.015>.

María Fernanda Gómez and Ricardo Javier Sánchez (2024), "Impact of modular construction techniques on cost and time efficiency in large projects", *IJCEC* 2024; 3(2): 43-47.

MBI 2017 Q3 Report, *Modular Building Institute*, August 2017.

McKinsey & Company (2019) *Capital Projects & Infrastructure Modular Construction: from projects to products*.

Mith, John. (2020). "Modular Construction: A Review of Recent Developments and Future Trends." *Construction Management and Economics*, 38(3), 312-328. DOI: 10.1080/01446193.2020.1759234.

Mith, John. (2020). "Modular Construction: A Review of Recent Developments and Future Trends." *Construction Management and Economics*, 38(3), 312-328. DOI: 10.1080/01446193.2020.1759234.

Modern methods of construction: Views from the industry, NHBC Foundation, June 2016.

Modular Building Institute. (2020). "Modular Construction Industry Reports." Barbosa, Filipe, et al., Reinventing construction: a route to higher productivity, MGI, February 2017.

Modular Building Institute. (2020). "Modular Construction Industry Reports." [Online]. Available: [URL]

Mohammad Kamali<sup>1, 2</sup> and Kasun Hewage<sup>1</sup>, (2017) "Sustainability Performance Assessment: A Life Cycle Based Framework For Modular Buildings", Vancouver, Canada, May 31 – June 3, 2017/ Mai 31 – Juin 3, 2017.

Moud A, Safinia S. Comparative analysis of modular and conventional construction methods in terms of cost and time efficiency. J Constr Innov. 2021;14(3):198-214.

Off-Site Construction Council. (2021). "Modular Construction Cost Guide." [Online]. Available: [URL]

Peltokorpi, Antti, et al, "Categorizing modularization strategies to achieve various objectives of building investments," Construction Management and Economics, 2018.

Permanent Modular Construction, Modular Building Institute, 2017.

Prefabrication and Modularization: Increasing Productivity in the Construction Industry, McGraw Hill, 2011.

Quale, John, Offsite architecture: Constructing the Future, Ch10: "High-performance affordable homes, 2017."

Smith R, Quale J. Offsite architecture: Constructing the future. New York: Routledge; c2017.

Smith, Alice, & Johnson, David. (2018). "Accelerating Project Delivery Through Modular Construction: Opportunities and Challenges." Journal of Architectural Engineering, 24(2), 04018007. DOI: 10.1061/(ASCE)AE.1943-5568.0000315

Smith, Ryan and Talbot Rice, Offsite architecture: Constructing the Future: Ch7: "Permanent modular construction," 2017.

Smith, Ryan and Talbot Rice, Permanent modular construction: Process, practice, performance, Modular Building Institute, 2015.

Smith, Ryan E. and Ivan Rupnik, 5 in 5 modular growth initiative, Modular Building Institute, 2018.

Stern, Dale, "Steel-framed modular construction for high-rise hotels: What you need to know," Hotel Online, December 2017.

Transforming Construction Landscape in the Philippines: The Rise of Prefabricated Modular Construction. City: Publisher.

Velamati, Sri, Conference Report: State of the Art Modular construction in 2017, 2012. Xie, Jenny, "Preparing for our prefab future," Curbed, 2015.

Wong, Emily. (2019). "Assessing the Cost Efficiency of Modular Construction: A Case Study Approach." Journal of Construction Engineering and Management, 145(11), 04019094. DOI: 10.1061/(ASCE)CO.1943-7862.0001726.