Opportunities and Challenges of Modular Coordination: A Review

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Abstract - *Modular coordinating may significantly reduce project timelines and costs while preserving or improving the quality of the final product by moving a portion of site-based work to an off-site fabrication facility. Module coordination can also significantly improve sustainability by reducing site disruption, decreasing waste generated, enhancing relatability and reusability, causing less dust and noise pollution, and reducing equipment loss, theft, and damage. Modular coordination can also significantly improve sustainability by reducing site disruption, decreasing waste generated, improving relatability and reusability, and causing less dust and noise pollution. By examining modular coordination's existing state and features, the researchers want to uncover the potential and obstacles of using modular building methodologies.*

***Key Words*: Challenges, Components, Productivity, Modular coordination, Opportunities**

1. INTRODUCTION

Buildings and components are sized and placed in a fundamental unit or module under the notion of modular coordination of dimension and space. Off-site construction of building components is known as modular coordination. After that, they are delivered to the construction site in a finished state. While traditionally constructed structures use the same materials and adhere to the same norms and standards as modularly constructed ones, they are erected around half the time and under controlled plant conditions off-site. Structures are built off-site, under controlled plant conditions, using identical assets and planning to the same rules and norms as modestly erected offices, but in about half the time. Modular coordination is part of this cycle. Buildings are sent in "modules" that can be erected on-site to imitate the indistinguishable goal and specifics of even the most exquisite site-made office. Increasing industrialization in the construction industry has led to the creation of larger, pre-assembled items transported to the construction site from processing factories. Modular coordination necessitates selecting a size that is both acceptable and optimum. The economic and human factors should be considered while determining the ideal size. [1].

Building technologies may benefit from modular coordination, which can be used in various ways, from component construction to partial prefabrication to rationalized conventional construction methods. Additionally, renovation programmers may use components coordinated on a modular basis. Dimensional coordination between components makes it possible to employ them in various tasks [2]. The relatively new construction style, modular, is under consideration for usage in high-rise residential structures with a height of 12 stories or more [3]. For example, modular coordination minimizes the cost of constructing a structure and its long-term maintenance costs [6]. By presenting a unique house design that blends high quality and energy efficiency at an accessible price [7].

1.1 Principle of Modular Coordination

Using related modular proportions, the primary goal of modular coordination is to achieve Dimensional Compatibility between building dimensions, spans or spaces, and component and material sizes. In addition, the arrangement of the building components concerning each other and the building is often provided through Modular Coordination, which facilitates collaboration between planners, manufacturers, distributors, and contractors.

Principle of Modular Coordination:

a) Basic Module
b) Modular Dimension

c) Planning Module
d) Placing of Components
e) Modular Grid

Basic Module: This unit of measurement is crucial. The Latin word "modulus," which means "little measurement" in English, is the source of the name "module."

Modular Dimension: In most cases, engineers are taught to work with basic sums of numbers. Architectural aesthetics may be satisfied with modular coordination, which gives a solid foundation for an ordered selection of dimensions and allows for relational flexibility.

Planning Module and Placing of Components: Dimensional frame marking of the building uses many processes for finding components, such as slapping them vertically or horizontally to determine distribution across load-bearing walls. Components are either positioned axially or perpendicularly to the boundary plan.

Modular Grids: A three-dimensional mesh of lines with a desired spatial dimension is used to speed up the design process for all kinds of structures. Realizing modular cohesion in a grid structure is methodical [1].

1.2 Objective of the study

The objectives of the study are as follows:

- To study modular coordination in the construction industry.
- To find out the factors of modular coordination and compare modular coordination with traditional construction.
- To investigate the current status of the building industry toward the modular concept in the construction industry.

2. Literature Review

However, there is considerable diversity in the consequences of both on-site and modular construction, according to research conducted by **John Quale and colleagues (2012).** For example, Modular Company 1's emissions were much greater than the other two modular examples and higher than one of the five on-site firms. As compared to the other modular facilities, this one is situated in a rural region with a commute of more than twice as long. In addition to using more power than the others, this firm used fuel oil to heat itself, which resulted in greater emissions. [12].

Saiyed Farhana et. al. (2015) stated that modular coordination has many advantages over traditional construction. It has the simplicity of dexterity, which offers the capacity to supply single source establishment through production line prepared provider organization. Modular coordination is reliably great both in plan and in development. Measured coordination gives the greatest adaptability to meet the plan [4].

For a more subjective evaluation, **Palak Sachdev and colleagues (2018)** proposed an analysis technique based on cost per square foot to evaluate modular methods and an objective method that relied on posting the benefits of each development strategy separately and considering the differences between them. It is possible to evaluate the cost feasibility of the two development methods for multi-story company projects using this approach in a way that might serve as an important navigational tool [19].

L.J. Fifield et. al. (2018) there is an urgent need for extra hospital bed spaces in the UK, and modular construction may be an energy-efficient and handy answer. A new design for the fabric and mechanical systems is essential if these facilities are safe and pleasant for patients and clinical personnel throughout the sweltering summer months. [9].

In order to alleviate the housing shortage in the United Kingdom and boost the construction industry's productivity and long-term viability, according to **Gatheeshgar Perampalam et al. (2019),** cost-effective modular building solutions with improved structural performance are urgently needed. Therefore, cold-formed hollow flange steel sections are used in modular construction systems, and computational analyses of hollow flange beam structural behavior are presented in this study [10].

Huu-Tai Thai et. al. (2020) a comprehensive audit of ongoing advances of modular innovations has been given an accentuation on primary parts of particular structures, including underlying frameworks, between module associations, primary investigation, and foundational layout. Although particular development is largely utilized in low-ascent structures, its

applications to elevated structures are restricted. The specialized difficulties impeding the broad reception of particular development for tall structures were stressed and talked about [15].

Karthik Subramanya et. al. (2020) talked about the key advantages, including venture plans, project costs, the well-being of the workers, project quality and efficiency, and natural. The significant impediments included venture arranging, transportation, public and master acknowledgment, establishing cost and cost because of intricacy, and coordination. The outcomes found that although particular development has more advantages than constraints, further exploration is expected to moderate or destroy the difficulties [5].

3. Opportunities and Challenges of Modular Coordination

The advantages and disadvantages of modular construction must be taken into account. As a result, many possibilities are tied to cost-cutting measures such as reducing the amount of time it takes to get a project started, increasing the quality of the finished product, and making it more environmentally friendly. We will go through each of these points in more detail below.

3.1 Opportunities

The opportunities for modular coordination are as follows:

Reduce Time: Multiple tasks may be completed instantly, and weather circumstances cannot impact the building schedule when using the modularization approach. Consequently, modular construction takes less time to complete than conventional techniques, which may be crucial for quick turnaround projects, such as repairing infrastructure and hospitals after a catastrophe [5]. As a result of modular coordination, the building process is faster, more efficient, and safer. Modular building has been shown to save time and money in several projects. For example, concurrent building on-site and in a factory has reduced the time to complete a project [18].

Cost Effectiveness: Modularization is supposed to lower the cost of building projects. Equipment transportation for on-site personnel is minimized, as is the extremely efficient installation of off-site building components. The absence of weather extremes also contributes to the cheaper cost. There is less engineering and time required in the design process of modular construction than in the conventional design approach [5]. Productivity and cost savings are the primary goals of this approach [14]. In order to minimize costs and enhance construction efficiency, modular construction can abbreviate project design. Modular structures are cost-effective to install. New materials and construction techniques are introduced under the substantial usage of energy-saving technology. Specialists are working to find methods to keep building expenses down. Offsite-produced modules, or "modular construction," are today one of the most promising and high-tech areas in architectural and construction development throughout the globe [8].

Highly Safe: The rising incidence of fatalities and non-fatal injuries associated with on-the-job labour has prompted a slew of academics to scour the literature for answers. Studies have shown that modularization significantly impacts reducing incidents when it comes to worker safety. When the modular building approach is applied, the incidence of construction-related accidents drops. Nevertheless, safety guidelines must be set for modularization, even though it reduces the likelihood of workplace injuries [5]. The modular coordination industry is burdened with the ordinary risks and problems of conventional construction and the additional risks and difficulties unique to modular coordination [11].

Reduce Material Waste: The amount of trash produced by conventional building processes has long been a problem for project managers and other stakeholders in terms of environmental impact. Compared to conventional building methods, modular ones create less waste and can be reused and recycled more easily. In addition, their waste can be separated at the end of their useful lives. They also produce less dust, greenhouse gases, and noise on the job site. To cut down on waste, modular construction is ideal [5] [20].

The following table 1 shows the opportunities for modular coordination in the construction industry.

Table -1: Opportunities for modular coordination in the construction industry

Opportunities → / Authors ↓	Better coordination & cooperation	Save construction time	Reduce cost	Improve quality	High safety	Reduce material waste
Palak Sachdev (2018)	√		√			
Saiyed Farhana (2015)	√	√		√		
Filomena Innella (2019)		√				
Hosang Hyun (2020)		√	√			
Karthik Subramanya (2020)		√	√		√	
Chrislyn O. Egege (2018)				√	√	
Humberto Cantu (2019)				√		
Gatheeshgar Perampalam (2019)		√	√			
John Quale (2012)						√
Ryan E. Smith (2014)		√				√

3.2 Challenges

The challenges of modular coordination are as follows:

Require Accurate Planning: Many complicated components must be created and gathered in the prefabrication process, which presents a specific challenge to the planning process. Prior to the project's initiation, precise planning with defined scope and design specifications is needed [5]. The project of Modular coordination suffers from a lack of adequate management and expertise [13]. Therefore, careful pre-planning and engineering are required prior to beginning any project. As modules become more complicated in design, more considerations and planning are required for integration and transportation, placement on the foundation, and assembly at the final project location [19].

Transportation Challenges: For modular construction, the mass-produced components must be delivered to the workplace in an adequate number of trucks. The transfer of large components needs careful consideration, which delays development, increases costs, and complicates the process. Modular construction's transportation limits are a major impediment to the project's schedule and cost efficiency [5][19]. Modular coordination in transportation transport modules is limited by the setup (cranes) and accompanying rise in designer expenses if new to the procedure, etc. [20]

Negative Public and Expert Perception: The general public and certain construction professionals often negatively impression modular construction. Until the public is made aware of the good advantages of this technology, it will not be extensively employed [5].

Establishment and High initial Cost: Even if off-site construction costs less, it necessitates the development of a construction facility. This means that if labour and other needs for conventional building are less expensive than establishing a manufacturing facility for modular construction, stakeholders choose traditional construction. The shortage of professionals in the prefabricated building is a major impediment to implementing modular construction. Some researchers have voiced questions regarding the beneficial effects of modularization on building project costs since numerous economic papers cannot be accessible. Modules should be overseen properly to link the cost-effective elements with the success of modularization. A modular manufacturing facility requires a lot of upfront money to acquire the necessary equipment. A combination of traditional and prefabricated modular building methods may be found in these places; both structures' manufacturing and construction expenses were dissected and examined to determine the final home's total cost per square foot, a similar measurement unit which option is more cost-effective [19].

The following table 2 shows the challenges of modular coordination in the construction industry.

Table - 2: Challenges of Modular coordination in construction industry

Challenges → Authors ↓	Project planning & Management	Transportation	Cost	Labor	Risk	Flexibility
Palak Sachdev (2018)	√	√	√			
Mansooreh Moghadam (2012)	√		√			
Loránd Szabó (2016)						√
Ryan E. Smith (2014)			√	√	√	
Pei-Yuan Hsua (2018)					√	
Karthik Subramanya (2020)	√	√	√			
J. Y. R. Liewa (2018)						√
Chrislyn O. Egege (2018)			√		√	
Matthew W. Meehleis (2019)				√		
Christopher Rausch (2020)	√					
R. M. Lawson (2008)						√
Ryan E. Smith		√				√

4. Case Study

4.1 Case studies in modular prefabrication: comparative analysis and discoveries

Prefabrication, including modular building, was the focus of this research. With this comparison, China has the quickest building pace by fabricating steel modules off-site. This may have been due to Advanced Modular Technology (AMT) usage. Modular high-rise construction may enter a new era with this innovative new method. As modular prefabrication becomes more common, AMT may be used to enhance the design and collection of prefabricated flat packs. Due to study and data collecting limitations, more research into project costing might be initiated to counterbalance current research. Since neither the estimated budget nor the actual cost of the projects was made public, no fair comparison could be drawn between them. Case studies were shown to have the lowest project length throughout this investigation. However, it is possible to assess additional information about the process's costs, personnel, and duration. Even if certain case studies were completed half the time, the project cost might have been more than twice as much.

4.2 Benchmarking and improving dimensional quality on modular construction projects -A case study

A key issue in the modular building business is dimensional quality, addressed in this paper. In order to develop scales for dimensional quality, there is currently a paucity of comparison data from cross-projects. In modular building projects, aggregation challenges arise due to the dimensional unpredictability of system components and the non-conformance of end-to-end modules. This research listed revisions, structural safety, constructability, aesthetics, and utility as possible implications of low dimensional quality. The presently available resources do not consider projects' specific demands for tolerance requirements, which are merely worst-case scenarios. It is advantageous for contractors to measure regularly, scale, and enhance dimensional quality because of the product return in modular building systems. Modifying dimensional quality plans to suit particular manufacturing processes, assembly, handling, and erection may help projects succeed and save money by reducing rework. In a case study involving two identical modular building projects, methods for calculating dimensional discrepancy were presented and put into practice. Scan vs. BIM and statistical distribution analysis was then used to examine the data. Finally, a framework was used based on an ongoing study on ways to optimise the building process.

5. Conclusion

Several literature studies on the modular coordinating approach were examined. The good and negative aspects of the technique were analyzed in terms of potential problems. The most significant potential highlighted were time reduction, cost efficiency, worker safety, project quality and productivity, and environmental considerations. On the other hand,

transportation, project planning, public and expert acceptability, setup costs and high beginning costs, and coordination were among the most difficult difficulties to overcome. As a consequence of the research, it was revealed that modular coordination offers more possibilities than it does obstacles.

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