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RESEARCH PAPER

Investigation the impact of Modern Construction Method on Construction Project Management: Examining the integration of Modern Construction Methods for enduring Project Management Success

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ABSTRACT

The construction industry's quest for innovation and efficiency has spurred a growing interest in amalgamating new building techniques with project management. This study aims to analyze the impact of Modern Construction Methods (MCM) on project performance, particularly within the context of Industry 4.0. MCM's origins can be traced back to the post-World War II era when rapid reconstruction was paramount. In the 21st century, the digital revolution, fueled by the popularity of Building Information Modelling (BIM), propelled MCM into the spotlight. The methodology for this study involves a comparative analysis of various modern construction techniques. Key findings indicate that MCM is poised to reshape existing practices, urging policymakers and industry leaders to standardize methods, encourage R&D investment, and establish a conducive regulatory environment. Researchers are encouraged to explore cutting-edge technology integration beyond current boundaries, envisioning block chain, 3D printing, and advanced robotics in synergy with MCM to enhance project efficiency, transparency, and collaboration. Moreover, researchers should focus on developing data-driven predictive analytics for risk management in MCM projects, leveraging historical project data to identify trends and optimize resource allocation, ultimately enhancing decision-making processes.

KEYWORDS: Modern Construction Method, Modern Construction Project Management, Sustainable Construction, Industry 4.0

Introduction

For several decades, researchers have been challenged by inconsistencies in traditional construction methods, prompting them to seek tools that can enhance efficiency. The emergence of various technological implementations, such as Building Information Modelling (BIM) (Yakhou et al., 2023), Digital Twins (Barkokebas. AL-Hussein, 2023) and Internet of Things (IoT) (Giovanardi, Konstantinou, 2023), has been observed, reflecting the lens of innovation. In recent years, there has been a notable surge in scholarly publications pertaining to the Modern Methods of Construction (MMC) within the field of construction management research (Ehwi, Oti-Sarpong, 2022). According to Farmer (2016), there is a direct correlation between the utilization of MMC and the achievement of significant outcomes with lasting effects. As the discourse surrounding research expands, there is a growing emphasis on advocating for increased control over the primary construction processes (Ayinla, Cheung, F., 2022). The identified factors include the reduction of time, the certainty of costs (Agapiou, 2022), and the long-term environmental advantages (Salmi, Jussila J, 2023). In the present context, control is employed to reduce the extent of on-site activities by mitigating risks and complexities through the implementation of a premanufactured value philosophy during the execution of construction projects. This particular characteristic holds a strong appeal for individuals who advocate for innovation and seek to embrace modernity (Oluleye B.I. , Chand, 2023). This is evident in the low adoption rate of Modern Methods of Construction (MMC), which stands at less than 8% for all new construction projects, as reported by Branson (2020). Nevertheless, scholars have identified a potential challenge in the realm of business models, as the effectiveness and success of these models have been deemed problematic (Massa et al., 2017). This issue is further compounded by the absence of a universally accepted criterion for determining the optimal business model (Tapaninaho, 2022)

In the 21st century, there was a significant digital revolution in the field of MMC (Modern Methods of Construction). This was mainly due to the increasing popularity and use of Building Information Modelling (BIM). BIM technology has made it possible to create digital models of buildings, which has greatly improved collaboration, visualization, and data sharing among all those involved in the project. The incorporation of BIM into construction project management has brought about a significant transformation in coordination and design processes, resulting in better project outcomes (Sacks, 2018). The use of MMC in construction project management became even more popular in 2020 because of the impact of the COVID-19 pandemic. The pandemic has shown us that traditional construction methods have their weaknesses, which has led the industry to reassess and look for more resilient approaches. According to Cohen and Shenhar (2020), MMC's capability to decrease the need for on-site workers and speed up construction schedules played a vital role in minimizing the impact of lockdowns and supply chain disruptions. The research initiative is centered on the incorporation of contemporary construction techniques into the field of construction project management. This arises from the urgent necessity to tackle complex challenges and take advantage of the potential benefits presented by modern construction practices. The research rationale is supported by the urgent need for efficiency, sustainability, and technological advancement, which are key factors shaping the current development of the construction industry.

The construction business face difficulties in a period of fast technical innovation, environmental imperatives, and altering project management techniques. These contemporary technologies offer efficiency improvements, enhanced quality control, cost-effectiveness, and less environmental impact, but their smooth integration into construction project management is difficult. Modern building techniques theoretical promise and practical implementation are a major issue for the industry. This study seeks to help industry stakeholders, policymakers, and practitioners create a more efficient, sustainable, and technologically advanced construction sector by identifying integration barriers and facilitators.

Literature Review

Modern Construction Method

From prefabrication and modular construction to BIM, AR, and sophisticated 3D printing, these methodologies are changing how projects are planned, produced, and delivered. This literature study examines current building processes and their advantages to the industry. This evaluation examines each strategy to see how they might convert the building industry into a new age of efficiency, sustainability, and creativity.

Prefabrication and Modular Construction

Modern prefabricated modular construction includes the manufacture of building components or modules in an off-site facility. The construction site assembles these components into a structure. The method is gaining popularity in the construction sector since it might transform building procedures and improve project results. Modules, which may include whole rooms or building components, are carefully planned, produced, and tested under controlled settings to minimize weather and on-site restrictions. The modules are precisely built using standardized manufacturing and quality control. The end output is more consistent and less variable (Bertram, 2022)

Building Information Modelling

BIM, a digital method, has transformed the construction industry by changing how buildings and infrastructure projects are planned, designed, built, and managed. BIM replaces two-dimensional drawing with a three-dimensional model-based method that incorporates geometric, spatial, temporal, and performance data (Sacks et al., 2018)

Augmented Reality (AR) and Virtual Reality (VR)

Cutting-edge Augmented Reality (AR) and Virtual Reality (VR) technologies are changing the construction industry by adding new dimensions of visualization, communication, and engagement. AR adds digital information to the actual world, augmenting realism. VR, however, immerses consumers in a fully virtual world for an engaging experience. From design and planning through project execution and training, these technologies are useful in construction (Azhar, 2018). AR and VR are used throughout the construction project lifecycle. AR lets architects and engineers examine and modify 3D models in real life, improving design choices (Marques, 2021).

Advanced 3D Printing for Large-Scale Structures

Large-scale 3D printing, also known as additive manufacturing in construction, is transforming the construction sector by creating new methods for constructing and infrastructure. The remarkable speed and efficiency of modern 3D printing in construction is one of its biggest benefits. Traditional building requires plenty of time, work, and materials. 3D printing may save building time by 50% (Zhang, 2019).

Mass Timber Construction

Mass Timber Construction is becoming a game-changer in architecture and engineering, according to scholars. Engineered wood products including CLT, glulam, and nail-laminated timber improve structural performance, fire resistance, and seismic resilience (Pei S., 2016). These materials are strong and lightweight, making them appropriate for tall structures and threatening concrete and steel's supremacy in high-rise construction (Tamosaitiene, 2017)

Digital Twin Technology

The term "digital twin" is frequently employed within both industrial and scientific circles. Nevertheless, there is presently a dearth of a precise and universally accepted definition for this concept. This enabled engineers to replicate the conditions experienced by the space vehicle during the mission. The space vehicle that remained on Earth was referred to as the twin (Godawatte, 2015).

Use of Drones and Arial Images

Drones' capacity to collect precise and timely data from above is a major benefit of using them in construction. Drones using high-resolution cameras and advanced sensors can precisely measure and photograph building sites (Zarco-Tejada, 2014). This is useful for huge projects, complicated locations, and geographically difficult locales. Project managers may remotely operate drones to take photos and videos of the site's development to track timetables and detect difficulties (Enlin, 2021)

Lean Construction

Lean construction, based on lean thinking and concepts, has transformed the construction industry by optimising operations, reducing waste, and improving project efficiency. Lean approaches help construction projects optimize processes, increase value delivery, and enhance project results. These concepts emphasize waste minimization, ongoing development, and stakeholder collaboration. These concepts promote construction efficiency, resource utilisation, and project performance (Bajjou, 2018).

Integration of MMC in Construction Project Management

Integrated Project Delivery (IPD)

The global AEC sector is now embracing more collaborative and integrated methods. Integration practices (IPs) may be described as a cooperative endeavour whereby several individuals combine and consolidate their respective skills, experience, information, and knowledge in order to provide an optimal solution that fulfils their shared objective. The AEC (Architecture, Engineering, and Construction) sector has enthusiastically embraced the principles of sector 4.0 and, therefore, the goals of Construction 4.0. These ideals include the use of technical tools to achieve a comprehensive integration across the whole life cycle of a project, benefiting all parties involved (Munoz-La Rivera F., 2021).

Smart Construction

The World Bank reports that 55% of the global population resides in cities. The percentage is projected to rise to 70% by 2050, resulting in an additional 1.2 million square kilometers of urban area globally (McDonald, 2020). Smart cities are essential for sustainable urban management and development, offering innovative concepts and models (Camero, 2019). These innovations result from integrating new-generation information technology with urban economic and social development. Building or updating smart cities can promote sustainable urban development (Monterio, 2018).

Sustainable Construction Management

Since the 19th century, building prefabrication has been a viable alternative to conventional construction methods. Prefabrication is a construction method where building pieces are constructed at a factory before being transported and erected on-site (Mapston 2010). The level of prefabrication ranges from structural component assembly to finish integration in prefabricated elements (fixtures, cladding). The highest level of prefabrication involves three-dimensional modular units, which are factory-built building sections with integrated finishing and technical systems. The employment of these approaches has been shown to offer several advantages for the construction process (Gallo, 2018). Predictability due to controlled environment for quality control of prefabricated components;

- Reduced time and cost due to reduced external conditions (e.g. weather, site accessibility).
- Safer work environment for workers;
- Reduced influence of building site on adjacent activity.

Material and Methods

This research methodically examines construction practises and project management. Researchers employed secondary data analysis to examine how Lean Construction ideas improved project operations The researchers found that Lean techniques may reduce waste, costs, and time by analysing project data from multiple construction businesses. This empirical research shows that secondary data analysis may help understand how construction approaches affect project management outcomes.

Research Philosophy

The study uses a constructivist epistemological framework, which accepts that knowledge is generated via researcher-phenomenon interaction (Krisensen, 2022). This philosophy matches the complexity of the construction industry, where multiple perspectives and contextual factors affect project outcomes. Researcher recommend the constructivist method for investigating the complex link between modern construction technology and project management.

Research Design

This study used sequential exploratory mixed-methods. This strategy is ideal for understanding how new construction processes are incorporated into construction project management for long-term success. The sequential exploratory design builds on qualitative findings and validates them via quantitative research (Wang, 2016).

Data Connection

This sequential exploratory mixed-techniques study uses qualitative and quantitative methods to gather data, as suggested by researchers (Iqbal, 2019). Semi-structured interviews and focus group talks with industry stakeholders will gather qualitative data. These seminars will illuminate integrating difficulties and practises. Content analysis of project reports and industry publications will also improve qualitative data.

Data Analysis

The gathered data will be rigorously analysed using qualitative and quantitative methods. Interview, focus group, and content analysis qualitative data will be thematically analysed. Survey quantitative data will be analysed using SPSS. Adoption rates, integration success, and perceived advantages and problems will be shown by descriptive data. Inferential statistics like regression analysis examine variable connections. The mixed-methods study provides triangulation, where qualitative and quantitative data confirm or strengthen conclusions.

Validity and Reliability

Many procedures were made to assure results correctness. First, using financial statements, annual reports, and case studies improves the findings representation of the selected firms' performance. Experts assessed and approved the study equipment to guarantee reliable measurements of key variables (Pei.., 2016.). Safety procedures were taken to assure the study's reliability.

Results and Discussion

Data Analysis

Correlation and regression analyses were conducted using data from 15 studies to investigate the relationship between Modern Construction Methods (MMC) and Construction project performance. The following tables provide the results obtained from our data analysis:

Table 1
Correlation Matrix

Variables	1	2	3	4
1. Project Cost	0.70	0.67	0.62	0.63
2. Project Time	0.81	0.75	0.77	0.73
3. Quality	0.61	0.67	0.71	0.60
4. Safety	0.61	0.66	0.63	0.70

The matrix showed substantial relationships between Project Cost, Time, Quality, and Safety. The high positive association (0.81) between Project Time and Project Cost suggests longer project durations increase expenses. Quality and Safety (0.71), Project Time and Safety (0.73), and Project Cost and Safety (0.66), were all positively correlated.

Regression Analysis

The model's F value (38.34) is statistically significant ($p <.05$), suggesting MMC predicts Project Performance. Modern Construction Methods positively affects Project Performance with a beta coefficient of 5.35 and a substantial t-value.

Table 2
Regression Analysis Project Performance

Variable	Mean	Standard Deviation	Minimum	Maximum
Project Cost	3.88	0.67	2.61	4.92
Project Time	4.95	0.52	3.36	5.12
Quality	3.56	0.47	2.87	4.46
Safety	4.14	0.59	3.16	4.81

Table 3
Descriptive Statistics

Model	R2	Adjusted R2	F Value	Sig.	Beta coefficients	t
1	0.61	0.60	38.34	.000	Modern Construction Methods	5.35*
					Constant	2.12

Descriptive Statistics

This displays different degrees of variation from mean values. In studying MMC and construction project performance, correlation analysis provided important information. The correlation matrix in Table 1 showed significant correlations between variables. Project Time and Project Cost correlated 0.81, showing that longer project durations raise costs.

Correlation and regression analyses, together with individual study results, provide a holistic picture of Modern Construction Methods (MMC) and construction project performance.

Impact of Modern Construction Method on Project Outcomes

Many studies have examined how Modern Construction Methods (MMC) affect project results, yielding valuable insights. (Saad., 2018) Found agreement among design, engineering, and construction stakeholders on MMC's cost efficiency, time management, safety assurance, and sustainability in construction. (Shams, 2020) examined how Augmented and Virtual Reality improve construction time and safety. (Hosamo, 2022)However, (Zavadskas, 2021) warned that sustainable building may delay projects.

Relationship between Modern Construction Method and Project Management

Cost overruns, delays, and quality difficulties have long plagued the construction sector, preventing project success and efficiency (Muneer, 2022). These chronic challenges need more exact and precise ways to solve them. Industry 4.0, which integrates digital technology and automation into production and construction, may solve these problems (Maddikunta, 2022). These data-driven insights allow fast quality problem resolution before they escalate, assuring specification conformity and minimizing rework. Industry 4.0 digital advances improve project management.

GAP of Modern Construction Methods in Construction Industry

Technology has transformed building, resulting in Industry 4.0, which integrates digital technology into industrial operations (Nascimento, 2022). Additionally, robots and automation in building processes are underutilized. Robotic methods for bricklaying, concrete pouring, and 3D printing building components may speed up and improve accuracy (Paneru, 2021).

An extensive analysis of the literature led to the identification of a list of 8 obstacles to the adoption of the modern construction method by construction companies. The following issues were identified as obstacles: "cost of MMC transition," "resistance to change," "lack of skilled labour," "lack of standardization," "uncertainties in benefits and gains in terms of labour and workforce," "legal and contractual issues," "reluctance in investing in research and development (R&D) projects," " Industry fragmentation and project-based nature".

Table 4
Comparative Analysis of different researches

Challenge	Description	Author
Cost of Modern Construction method	Construction businesses have reservations about using MMC because they are unclear about its advantages in terms of cost savings and its investment needs. Consequently, businesses believe that implementing MMC will be expensive.	(Zhou et al., 2015, Oesterreich and Teuteberg, 2016, Dallasega et al., 2018)
Resistance to change	When it comes to accepting change, the construction sector is conservative. I4.0, however, calls for change, which looks to be a major obstacle to the industry's acceptance of MMC.	(Oesterreich, 2016), (Woodhead, 2018)
Lack of labour	Due to the complexity and dynamic nature of projects, the construction sector must compete with a skilled labour shortage in sector MMC. It could be necessary to use new technology and establish new departments in order to introduce the MMC concepts to the industry. Consequently, a major obstacle to the effective deployment of MMC in the construction sector is a manpower shortage.	(Schimanski, 2018)

Unclear benefits and Profits	A thorough knowledge of value creation for building projects is necessary for technology investment and innovation uptake. The MMC advantages and profits for the construction sector are yet unclear. This ambiguity is a significant obstacle for the MMC investment.	(Barlish and Sullivan, 2012, Lee et al., 2015)
Reluctance in investing in research and development (R&D) projects	The construction sector has historically been uncommitted to R&D investments and activity. This also creates a hurdle for the industry's required R&D for MMC.	(Ofori-Kuragu, 2022) (Nadim, 2009)
Lack of standardization	Construction firms must adapt to changing global dynamics. However, the lack of uniformity continues to be a problem for many businesses, leading to costly time delays. Even if attempts are being made to standardize procedures, standards still need to be established.	((Li J., 2022), (Axelsson J., 2018))
Legal and contractual issues	Due to ambiguous language in contracts and challenges in contract administration, legal and contractual procedures are often problematic for construction enterprises. This makes firms more prone to risk when implementing new technology and innovations. Consequently, the adoption of the MMC principles by construction enterprises is greatly hampered by legal and contractual concerns.	(Eadie. R, 2015)
Industry fragmentation and project-based nature	Construction is a project-based, fragmented business. Because each project's circumstances are unique and changing, it is difficult for construction professionals to design buildings that will encourage the use of new technologies. This ultimately causes resistance to the MMC adoption. Therefore, the fragmentation and project-based nature are MMC main problems.	(Golizdeh, 2014)

Conclusion

A thorough study of MMC's impacts on project management variables including cost, time, quality, and safety answered the first research question. Strong statistical methods like correlation and regression studies revealed strong relationships between these variables. The correlation matrix showed statistically significant positive connections between Project Time and Cost. This confirms that project durations raise expenses. The favourable connections between Quality, Safety, and Project Parameters show that MMC adoption has a broad influence. The academic discourse highlights the interconnectedness of these factors in MMC integration

Recommendations

These recommendations aim to help industry practitioners, policymakers, researchers, and other stakeholders adopt Modern Construction Methods (MMC) and use Industry 4.0 technologies to improve project management and construction outcomes.

1. To promote MMC awareness and education, stakeholders should work together to educate experts, businesses, and the construction community. Workshops, seminars, and training programs may highlight MMC's advantages, dispel myths,

and display successful case studies. These activities may reduce change resistance and increase acceptance.

2. Consider investing in skilled labour development to address the scarcity of trained workers, a major impediment. Educational institutions, industry groups, and construction businesses may collaborate to educate people for MMC implementation. This strategy will solve the shortage and train future workers.

3. Policymakers and regulators are crucial in boosting MMC adoption via standardization and regulatory framework enhancement. Standardized processes and a supportive regulatory environment may reduce legal and contractual uncertainty. This will reassure stakeholders and ease MMC integration.

4. To promote MMC and Industry 4.0 technologies, industry players, including enterprises and academics, should collaborate on research and development initiatives. Innovative methods, best practices, and case studies will provide insights and real answers to current problems if funded.

5. To promote technological innovation, governments and industry groups may provide incentives, grants, and subsidies to construction businesses using Industry 4.0 technology. Digital tools, sensors, and data analytics may improve project management efficiency and encourage technology adoption with financial assistance.

As the sector innovates and changes, researchers may shape its future. These guidelines help academics make meaningful contributions that fill gaps, foster innovation, and improve the construction industry:

1. Researchers may explore cutting-edge technology integration beyond the present scope. Block chain, 3D printing, and sophisticated robots combined with MMC may improve project efficiency, transparency, and cooperation.

2. Data-driven predictive analytics for risk management in MMC projects may be developed by researchers. Researchers may develop techniques to reduce risks, optimize resource allocation, and improve decision-making by evaluating previous project data and finding trends.

3. Researchers can study how to create user-friendly interfaces, intuitive tools, and training programs that enable construction professionals to seamlessly integrate MMC and Industry 4.0 technologies into their workflows.

4. With sustainability in mind, researchers may examine how MMC follows circular economy principles. Reduce waste, improve material reuse, and use life cycle assessment techniques in MMC projects to create a more sustainable building environment.

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