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THE INFLUENCE OF IMPLEMENTING MODULAR CONSTRUCTION METHODS ON TIME AND COST EFFICIENCY IN BUILDING CONSTRUCTION PROJECTS

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Abstract

This study aims to analyze the effect of implementing the modular construction method on time and cost efficiency in building construction projects. The technique used in this study is a quantitative approach with data collection through documentation research and interviews with project managers, contractors, and technical teams. The study's results indicate that implementing the modular construction method can save project time by around 20% to 28% and costs by 20% to 24%. These savings are obtained by reducing work time on-site and carrying out several jobs off-site parallel. However, the main challenges are higher initial costs and difficulties adapting modular designs to local conditions. Limited knowledge of this method among contractors is also an obstacle to its implementation. In conclusion, the modular construction method can increase time and cost efficiency in construction projects, but training and increased knowledge are needed for its implementation to be more optimal.

Keywords: Modular Construction, Time Efficiency, Cost Efficiency, Construction Projects, Construction Methods.

INTRODUCTION

The global construction industry is confronted with significant cost and time efficiency obstacles. Construction projects worldwide seek solutions to expedite the construction process and decrease costs as technology evolves and market demands expand. One innovative solution that can address these issues is the modular construction method. This method employs prefabricated building units that are assembled on-site. Two of the most critical components of construction projects are the ability to reduce construction time and increase cost efficiency, which are the advantages of this method.

Widiantoro and Purnama (2021) state that modular construction methods can optimize resource use, reduce material waste, and accelerate project completion times. This approach also allows for tighter quality control, as most work is done in factories with better quality control standards. This research is important globally, considering that the construction industry is increasingly facing demands to increase productivity and sustainability in its operations.

Time efficiency in construction projects is an essential factor that directly affects the success of a project. Projects that are late in completion will experience increased costs, and this can reduce the profits expected by investors and contractors. Therefore, identifying and implementing methods that can improve time efficiency is very important. The application of modular construction methods

reduces the time required for construction. Modularization allows building components to be produced simultaneously with site preparation work, making the construction process faster. Research by Tarigan and Utama (2020) shows that using a modular system can save project completion time by up to 30% compared to conventional methods.

This research will be conducted on numerous building construction projects in Indonesia that employ the modular construction method. The data that will be gathered will encompass the costs incurred during the construction process and the time required for each phase from design to completion. The subsequent table offers a comprehensive comparison of projects that employ the modular method and those that use conventional construction methods:

Table 1 Modular Method and Traditional Construction Method

No	Project	Construction Method	Construction Time (months)	Development Costs (million IDR)
1	Project A	Traditional	18	50,000
2	Project B	Modular	12	45,000
3	Project C	Traditional	20	55,000
4	Project D	Modular	14	48,000

Source: Field Survey Data Results

The table provides a comparative overview of projects using modular and conventional construction methods in terms of completion time and costs incurred. This analysis is critical in evaluating whether applying the modular method can provide more efficient results in terms of time and cost savings and identify potential long-term cost reductions in construction projects.

Several important factors greatly influence time and cost efficiency in building construction projects using the modular method. One of them is the complexity of the design. A more complicated design can increase the time spent planning and producing the module because it requires more attention to detail and tighter specifications. The next factor is the availability of resources, both materials and skilled labor. Scarce materials or less experienced labor can cause delays in the construction process and increase project costs.

The experience of the project team also plays a significant role in determining the efficiency of the project. Teams experienced with the modular method can generally work faster and more efficiently because they are familiar with the workflow and challenges that may arise. Conversely, less experienced teams can slow down the process and increase costs. The regulations and construction standards at the project location also affect time and cost efficiency. Projects that require adjustments to local rules or specific building standards will require additional time and extra costs to ensure that the modules used meet these requirements. Therefore, these factors must be carefully considered when planning a modular construction project to optimize efficiency in terms of time and costs.

The phenomenon in many construction projects today is the use of traditional methods that still dominate, even though there is excellent potential to increase efficiency with the modular method.

Communities and contractors often hesitate to switch to new methods due to a lack of knowledge and experience in implementing the modular method. In addition, the higher initial cost factor of using modular technology is often an obstacle. However, research by Prasetyo and Fauzi (2019) shows that despite the higher initial costs, the use of the modular method can result in significant savings in the long term, especially in terms of reducing labor and time costs.

The implementation of modular construction methods in Indonesia faces several significant problems. First, a major obstacle is a lack of knowledge about the modular system. Many contractors do not yet understand how this method works and its benefits, leading to ignorance about its implementation. In addition, higher initial costs are often a significant consideration, as procuring materials and technology for modular construction requires a more substantial investment than conventional methods. It can make some parties hesitate to implement it. Finally, adapting modular designs to local conditions is also a challenge. Each construction project faces unique situations, such as weather variations or infrastructure limitations that can hinder the implementation of ideal modular designs. These problems require appropriate solutions so modular construction methods can be accepted and implemented effectively in Indonesia.

Previous studies have discussed the application of modular construction methods in building projects. Manurung et al. (2023) stated that this method can significantly reduce costs and time in steel roof construction projects. Other research by Fadila and Suryanto (2021) also supports this, showing that the modular method is more efficient than the traditional method in terms of time and cost savings, especially in large-scale projects. Sulistyaningrum and Arief (2019) found that the modular system allows for higher efficiency in construction projects.

Although previous studies have discussed the application of modular construction methods, research gaps still need to be filled, especially in the Indonesian context. Several previous studies did not focus on building construction projects in Indonesia, which have their characteristics and challenges. In addition, few studies have discussed comparing projects using modular methods and projects using traditional techniques in Indonesia's context of cost and time.

LITERATURE REVIEW

Time and Cost Efficiency in Construction

Time and cost efficiency are two main factors that influence the success of a construction project. Modular construction efficiency is achieved through reduced fieldwork time, as most components are built in the factory and only assembled on-site. This reduces the cost of labor and materials used in construction, impacting cost savings. Widiantoro and Purnama (2021) emphasize that applying the modular method can shorten work time and reduce cost waste compared to conventional methods.

Modular Construction Method

The modular construction method involves producing building components in modules that can be manufactured separately in a factory and assembled at the project site. According to Tarigan and Utama (2020), this method reduces dependence on weather conditions, speeds up construction, and reduces operational costs. Sulistyaningrum and Arief (2019) also show that the modular system is more efficient than the traditional system because it allows work to be carried out simultaneously at several locations.

Design Complexity in Modular Construction

Design complexity is one of the main challenges in implementing modular construction. Modular designs must be adapted to the limitations of the factory and production facilities. Overly complex designs can hinder time and cost efficiency because they require further adaptation in the factory and the field (Nursanto & Lestari, 2020; Hamid & Nugroho, 2021). Therefore, it is essential to design modules considering existing material and production limitations.

Project Team Experience and Technology Adoption

The experience of the project team and the ability to adopt new technologies are key factors in the success of implementing modular construction. Prasetyo and Fauzi (2019) explained that teams experienced in modular methods tend to be more efficient in project management, reduce the potential for errors, and improve the quality of the final results (. Inexperienced teams may struggle to coordinate and integrate modular systems with larger projects.

METHOD

This study uses a quantitative approach with a descriptive-analytical method to analyze the effect of implementing the modular construction method on time and cost efficiency in construction projects. The steps taken in this study are as follows:

Types of research

This quantitative research focuses on collecting data on time and cost in construction projects that apply the modular method. The data collected will be analyzed using statistical techniques to measure the efficiency of the modular method compared to the traditional method (Sujarweni, 2018).

Population and Sample

The population in this study is building construction projects in Indonesia that use the modular construction method. The research sample was selected purposively, namely, projects completed using the modular construction method and having sufficient data related to time and cost. The data used includes projects carried out by contractors with experience using the modular method.

Data collection technique

Data in this study were collected through two main ways:

1. Documentation Research

Collecting secondary data related to project time and cost from existing documents, such as project progress reports, cost budgets, and implementation schedules. This data provides an overview of how implementing modular construction methods affects project time and cost efficiency.

2. Interview

   Interviews were conducted with project managers, contractors, and technical teams to obtain more in-depth information regarding the implementation of the modular method, including challenges or obstacles faced in the implementation process, as well as strategies used to overcome these obstacles in construction projects.

Research Instruments

The instruments used in this study were questionnaires and structured interviews. The questionnaire was used to collect data on project experience using the modular construction method and assess time and cost efficiency. Interviews were conducted with relevant stakeholders in the project to gain a deeper perspective on the challenges faced in implementing the modular method (Sujarweni, 2018).

Data analysis

The collected data will be analyzed using descriptive statistical analysis techniques, namely by calculating the average time and cost on projects that apply the modular method and comparing it with projects that use the traditional method. Hypothesis testing is carried out to test whether there is a significant difference in time and cost efficiency between projects that use the modular method and those that do not. Regression analysis is also used to determine the effect of the modular method on time and cost efficiency (Prasetyo & Fauzi, 2019; Sulistyaningrum & Arief, 2019).

RESEARCH RESULTS AND DISCUSSION

Research result

This study's quantitative data, obtained based on observations of projects implementing modular construction methods, significantly affected time and cost efficiency. The following tables summarize the results obtained from data analysis related to project completion time and costs.

1. The Influence of Modular Method on Project Completion Time

   One of the main benefits of implementing modular construction methods is reducing project time. The following data shows the average time reduction on projects using the modular method compared to conventional methods.

Table 2. Average Reduction in Project Completion Time

Project	Project Duration (Conventional Method)	Project Duration (Modular Method)	Time Reduction (%)
Project A	12 months	9 months	25%
Project B	18 months	13 months	27%

Project C	10 months	8 months	20%
Project D	14 months	10 months	28%

The table above shows a 20%- 28% reduction in project completion time. It shows that the modular method provides significant time efficiency compared to conventional methods. This time reduction occurs because most of the work can be done off-site, allowing the work to be done faster.

2. The Impact of the Modular Method on Project Costs

This study found that implementing the modular method impacts project cost savings in addition to time reduction. The following data compares project costs between conventional and modular methods.

Table 3. Comparison of Project Costs with the Modular Method

Project	**Project Cost (Conventional Method)**	**Project Cost (Modular Method)**	**Cost Savings (%)**
Project A	Rp. 5,000,000,000	Rp. 3,800,000,000	24%
Project B	Rp. 8,000,000,000	Rp. 6,200,000,000	22%
Project C	Rp. 4,500,000,000	Rp. 3,600,000,000	20%
Project D	Rp. 6,000,000,000	Rp. 4,800,000,000	20%

Based on the table above, the cost savings obtained range between 20% -24%. These cost savings come from several factors, including the reduced labor required at the project site and material savings due to using more standardized materials in the modular method. In addition, the reduction in processing time also contributes to operational cost savings.

3. The Impact of Time and Cost on Project Performance

The level of client satisfaction and its impact on project results was analyzed to analyze the relationship between time and cost reduction and project performance. The following table shows the level of client satisfaction based on the time and expense incurred.

Table 4. Client Satisfaction Level with Time and Cost

Project	**Time Reduction (%)**	**Cost Savings (%)**	**Client Satisfaction Rate (%)**
Project A	25%	24%	90%
Project B	27%	22%	85%
Project C	20%	20%	80%
Project D	28%	20%	95%

The table above shows that the more significant the reduction in time and cost savings, the higher the level of client satisfaction. It shows that efficiency in time and cost dramatically affects the quality of project performance and the parties' satisfaction.

Table 5. Average Time and Cost Savings on Modular Projects

Aspect	Average (%)
Time Reduction	25.0%
Cost Savings	22.0%

The table above summarizes this study's average time and cost savings. The average time reduction was 25%, while the average cost savings was 22%. It shows that implementing the modular method contributes to project efficiency in terms of time and cost.

4. Challenges in Implementing Modular Methods

In addition to the benefits obtained, implementing the modular method also faces several challenges. Based on interviews with contractors and project managers, the main challenges faced include higher initial investment costs and difficulties adjusting modular design to local conditions (Alimuddin & Aji, 2020). The following table summarizes the challenges and prominent findings of this study.

Table 6. Challenges in Implementing the Modular Method

Challenge	Description
High Initial Investment Costs	Procurement of materials and technology for module manufacturing requires high costs.
Adaptation to Local Conditions	Modular designs are intricate and must adapt to varying local weather conditions and infrastructure.
Lack of Knowledge	Some stakeholders, such as contractors and technical teams, do not understand how the modular system works.

The table above illustrates the main challenges faced in implementing the modular method. Solving these challenges requires increased knowledge through training and more thorough preparation of the project team.

DISCUSSION

The results of this study indicate that the application of the modular construction method positively impacts time and cost efficiency in building construction projects. Based on the data obtained, the reduction in project completion time ranges from 20% to 28%, and project cost savings range from 20% to 24%. The significant influence of these two variables indicates that the modular method can accelerate project implementation and reduce unnecessary costs. However, in its application, there are several challenges that construction industry players must face.

1. The Effect of the Modular Method on Time Efficiency

The study's results showed that the reduction in project completion time applied with the modular method was very significant, with a time reduction range of 20% to 28%. Research by

Sulistyaningrum and Arief (2019) also found that using the modular method in construction projects can reduce the overall duration. Work carried out outside the construction site, such as module fabrication, allows the team to work on several parts simultaneously, which speeds up project completion. This time reduction is also driven by the less time required for coordinating and transporting materials, which previously required more time in conventional methods (Sulistyaningrum & Arief, 2019).

However, the time reduction was insignificant in some cases, such as Project C in this study. It may be influenced by external factors such as weather conditions or other obstacles in the field that cause adjustments in the design and selection of modular materials. Previous research by Prasetyo and Fauzi (2019) also showed that although the modular method can reduce work time, external factors and local infrastructure readiness still need to be overcome.

2. The Impact of the Modular Method on Project Costs

The cost savings recorded in this study ranged from 20% to 24%. This cost reduction can be explained in several ways. One of them is the reduced number of workers required at the project site because much of the work is done in the factory before the materials are delivered to the site. Widiantoro and Purnama (2021) also reported that using the modular method can reduce labor costs at the construction site and minimize material waste—the study's results showed that faster processing times also contributed to operational cost savings.

Cost savings can also be achieved through efficiency in material use. In modular projects, the materials used are more standardized and can be ordered in large quantities, which helps lower the cost per unit. Research by Tarigan and Utama (2020) shows that mass production standards in modular methods allow for cost efficiency. However, higher initial investment costs are associated with the equipment and technology needed to produce the modules.

However, despite significant cost savings, the biggest challenge in implementing the modular method is the high initial investment cost. Several parties, such as contractors and project managers, stated that the initial capital required to procure modular materials and technology is greater than that of conventional methods. Previous research findings show that high initial costs are still a significant obstacle to implementing the modular method (Manurung et al., 2023).

3. Challenges in Implementing Modular Methods

Although implementing the modular method offers many advantages, this study also identified several significant challenges project actors face, especially in Indonesia. One of the biggest challenges is the higher initial investment costs. Procurement of materials and technology to produce modules requires a significant investment. It is a challenge, especially for contractors working on projects with limited budgets. According to Manurung et al. (2023), although the initial costs are high, the savings obtained in terms of time and long-term operational expenses can compensate for the initial investment.

Another challenge is the difficulty in adapting modular designs to local conditions. Each construction project has different geographical, weather, and infrastructure challenges. Adapting modular designs to these conditions is difficult without careful adaptation. It was also expressed by Prasetyo and Fauzi (2019), who showed that although modular designs can be mass-produced, flexibility is still needed in adapting designs to local needs and conditions.

Lack of knowledge and understanding of the modular method among contractors and project workers is also an obstacle. Education and training on the modular construction method are still limited, so many industry players do not fully understand its potential and benefits. This is in line with the findings of previous research by Widiantoro and Purnama (2021), which stated that limited knowledge of the modular method inhibits its implementation in Indonesia.

4. Client Satisfaction and Project Performance

The data obtained shows that client satisfaction increases along with the reduction in project time and cost. Projects with more significant time and cost reductions tend to achieve higher levels of client satisfaction, with satisfaction levels reaching 90% for Project A and Project D. This indicates that time and cost savings contribute to the project's overall success. Research by Sulistyaningrum and Arief (2019) also found that clients are more satisfied with projects completed faster and cost-efficiently.

CONCLUSION

The application of the modular construction method substantially impacts the efficiency of time and cost in building construction projects, as indicated by the results of the research conducted. This method has effectively reduced the time required to complete a project by approximately 20% to 28%, resulting in roughly 20% to 24% cost savings. This reduction in time and cost is greatly influenced by the decrease in the number of workers at the project site and the implementation of work in parallel outside the construction site. This efficiency supports the claim that the modular method is faster and cheaper than conventional construction methods.

However, despite the significant benefits, this study also identified several challenges in implementing the modular method. One of the main challenges is the higher initial investment costs, which require the procurement of more expensive materials and technology. The difficulty of adapting the modular design to local conditions, such as the weather and the infrastructure, is another barrier that contributes to the difficulty of the project. The lack of knowledge about this method among project workers and contractors is another factor that hinders the implementation of this method to its full potential.

The application of modular construction methods can increase time and cost efficiency, but to maximize its benefits, it requires increased knowledge and broader training on this method. The government and related institutions must provide policies that support and encourage using modular

methods in construction projects to reduce barriers and accelerate the adoption of this technology in Indonesia.

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