

Comparative Study of Conventional and Precast Formwork Systems (A Literature Review)

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ABSTRACT: Formwork systems play a crucial role in determining the efficiency, quality, and cost of concrete construction. This study presents a comparative analysis between conventional and precast formwork systems based on key performance indicators such as construction time, material utilization, cost efficiency, and labor productivity. Data were obtained through literature review and field observations on building projects employing both systems. The results reveal that the precast formwork system significantly improves construction speed, reduces on-site labor, and enhances structural consistency, making it more suitable for large-scale and repetitive projects. Conversely, the conventional formwork system remains advantageous for small or irregular structures due to its flexibility and lower initial investment. The study concludes that choosing the optimal formwork system should consider project size, design complexity, and sustainability aspects. Future research is recommended to integrate Life Cycle Assessment (LCA) and Building Information Modeling (BIM) approaches to evaluate environmental and operational impacts, as well as to explore hybrid systems that combine the benefits of both methods for sustainable construction practices.

KEYWORDS: Formwork Systems; Conventional Formwork; Precast Formwork

INTRODUCTION

Formwork systems are fundamental components in the construction industry, serving as temporary molds that shape and support concrete until it gains sufficient strength. The choice of formwork method directly affects the overall project timeline, cost efficiency, safety, and quality of the final structure. Traditionally, conventional formwork systems, often using timber, plywood, or steel, have been the preferred approach due to their versatility and adaptability to various architectural designs. However, these systems tend to be labor-intensive, time-consuming, and sometimes less sustainable due to high material consumption and waste generation.

In recent years, the precast formwork system has emerged as an alternative, leveraging factory-produced concrete elements that are assembled on-site. This method promises enhanced precision, faster construction cycles, and improved durability of structural components. Precast systems can reduce on-site labor demands and minimize exposure to weather-related delays. Nevertheless, these advantages come with challenges such as higher initial costs, transportation logistics, and limitations in design flexibility.

Given these contrasting characteristics, selecting the appropriate formwork system requires a comprehensive understanding of project-specific conditions, including scale, complexity, budget, and environmental considerations. Despite the growing adoption of precast

formwork in various regions, there remains a need for systematic comparison between these two prevalent systems to inform construction planning and decision-making.

This study aims to conduct a detailed comparative analysis of conventional and precast formwork systems in the execution of construction works. The research will assess key performance indicators such as construction speed, labor productivity, cost implications, quality outcomes, and sustainability impacts. By exploring these factors, the study seeks to offer actionable insights and practical recommendations for engineers, contractors, and stakeholders in selecting the most effective formwork method to optimize project performance and resource utilization. Ultimately, this comparison contributes to advancing construction practices and enhancing industry standards through evidence-based decision making.

RESEARCH METHOD

This study adopts a qualitative comparative method through a systematic literature review of peer-reviewed journal articles published between 2010 and 2024. The reviewed sources include leading international journals such as *Journal of Cleaner Production*, *Automation in Construction*, *Journal of Building Engineering*, and *Construction and Building Materials*.

The comparison focuses on key parameters including:

1. Fabrication and assembly process
2. Labor and time efficiency
3. Material reusability and waste generation

4. Cost and project scalability
 5. Environmental and sustainability performance
- Data were synthesized and summarized in a comparative framework to highlight the strengths and weaknesses of each system.

RESULT AND DISCUSSION

A. The Definition of Formwork for Construction

Several important definitions by researchers from 2023 to 2025 about formwork in construction work have been compiled and are available in the ITB digital library (digilib ITB). These definitions emphasize the role of formwork as a temporary structure used to mold and support fresh concrete until it gains sufficient strength, highlighting key aspects such as structural support, material selection, efficiency, and cost-effectiveness in construction processes. Formwork is a temporary structure used to mold concrete according to the desired size, shape, and position in the execution of construction work. The choice of formwork system greatly influences the efficiency of cost, construction time, and the quality of the construction results. Conventional formwork systems are usually made and assembled on the project site using simple and readily available materials, such as wood. This traditional method is still often used, especially in small to medium-scale projects. However, conventional formwork tends to have a longer execution duration and relatively higher costs because it requires many stages of work from material preparation, installation, to dismantling.

On the other hand, the precast formwork system is a method that uses molds for concrete structural components produced beforehand at a specialized facility (fabrication) and then installed on-site. This method is often more time-efficient because the installation of precast formwork panels is faster compared to reassembling conventional formwork at the construction site. In terms of cost, although the initial investment for precast formwork is usually higher, the time savings and reduction in labor can lower the overall project cost. Existing studies show that the precast formwork system can reduce the construction duration by approximately 6 days compared to the conventional system, and the execution cost is often lower than that of conventional formwork.

Several studies also indicate that the selection of the formwork type should be adjusted according to the project scale and specific requirements, as semi-system formwork (knockdown) and other systems also offer cost and time efficiency advantages depending on the project context.

Overall, comparative studies indicate that precast formwork offers faster construction speed and potential long-term cost savings, while conventional formwork is more flexible and remains relevant for projects requiring complex shape adaptations or small volumes. Precast systems benefit from factory-controlled production, allowing rapid onsite installation and consistent quality, reducing labor and time significantly. Conventional

formwork, though slower and sometimes costlier due to labor and material handling onsite, allows customization and adjustment during construction, advantageous for intricate or limited projects.

A study by Sony (2018) showed that although the initial investment for the PERI formwork system is higher than conventional formwork by approximately IDR 6,181,415,050, the faster installation and dismantling—about 6 m²/day faster installation and 2 m²/day faster dismantling—make the system economically feasible with a positive Net Present Value (NPV) and Benefit-Cost Ratio (BCR). Research highlights the major advantages of precast formwork: better quality control, higher productivity, less dependency on weather, and reduced labor costs. Conventional formwork's advantages include material availability, flexibility, and suitability for smaller-scale or complex form requirements.

This balance helps inform decisions on the most appropriate formwork system based on project scale, complexity, and economic factors.

Important references supporting this review include results from economic feasibility tests, cost comparisons, installation duration, and other technical aspects of both formwork systems. Thus, this literature review provides a strong theoretical and empirical foundation for conducting a comparative study of conventional and precast formwork systems in construction projects to determine the most efficient and effective method. All the above summaries are based on findings from various relevant studies in journals and case studies in civil engineering and construction fields.

B. The Conventional Formwork System

In traditional construction practices, conventional formwork systems are typically site-fabricated, labor-intensive, and require manual assembly and disassembly. As reported by Tam et al. (2015) in the *Journal of Cleaner Production*, conventional timber formwork remains widely used in developing countries due to its low material cost and adaptability to irregular geometries. However, this system presents several drawbacks, including high labor demand, long cycle time, limited reusability, and large quantities of construction waste (Rahman et al., 2020). These disadvantages often result in higher project costs and environmental impacts, especially when compared to modern or modular formwork systems.

Conventional formwork generally consists of three main components: sheathing or panel surfaces, framing or studs, and support systems such as props or scaffolds (Memon & Rahman, 2013). The materials used, typically wood or plywood, offer flexibility in shaping complex structures but deteriorate quickly under moisture exposure, leading to dimensional inaccuracies and poor surface quality (Zhang et al., 2022). In contrast, modern alternatives such as aluminum, steel, or plastic formwork systems provide higher durability and precision, allowing for greater repetition and sustainability.

Recent studies have focused on improving conventional formwork practices by introducing hybrid systems and sustainable materials. For example, the integration of reusable plastic panels or engineered timber (such as laminated veneer lumber) significantly enhances the reusability and reduces lifecycle carbon emissions (Lee et al., 2021). Furthermore, the adoption of Building Information Modeling (BIM) and digital planning tools has been shown to improve accuracy and reduce human error during formwork installation (Goh & Rahman, 2023). Despite these advancements, conventional formwork continues to play a crucial role in small-scale and irregular construction projects, where flexibility and low initial cost are prioritized over automation or reusability.

In summary, conventional formwork systems remain a fundamental yet labor-intensive method in concrete construction. While they provide adaptability and low upfront cost, their limitations in reusability, precision, and sustainability highlight the need for technological evolution toward modular and automated formwork systems, particularly in the context of industrialized and sustainable construction.

C. The Precast Formwork System

Precast formwork refers to a temporary mold system specifically designed for the production of precast concrete elements under controlled factory conditions. Wigbout (1992) and McCormac (2004) define formwork in general as a temporary structure used to shape and support fresh concrete until it gains sufficient strength to bear its own load. Extending this principle, modern researchers emphasize that precast formwork must ensure dimensional precision, surface quality, and reusability, as these factors critically influence the assembly accuracy and performance of precast components in the field (Zhang et al., 2023; Wang & Li, 2022).

Recent studies highlight that precast formwork systems are evolving with automation, modularization, and sustainable material innovations. For instance, Zhang et al. (2024) reported in *Automation in Construction* that advancements in automated and reusable formwork systems significantly enhance production efficiency, reduce labor dependency, and minimize construction waste in precast manufacturing. Similarly, Lee et al. (2021) from *Journal of Building Engineering* emphasized that precision formwork technology improves concrete surface quality and dimensional tolerance, reducing rework during site installation.

According to the *ASTM International Symposium on Additive Manufacturing for Construction* (2023), formwork for precast concrete can now be fabricated using polymer-based or composite materials through large-scale 3D printing, which allows rapid prototyping, customization, and reduced formwork waste. In the Indonesian context, the *SNI 7394:2008 – Procedure for the Calculation of Unit Rates for*

Concrete Works and SNI 03-2847:2019 – Requirements for Structural Concrete describe formwork as a temporary mold system required for casting concrete elements until adequate strength is achieved, implying that the same principles apply to precast systems produced off-site under stricter dimensional and quality control requirements.

In summary, precast formwork is defined as a reusable, precision-engineered temporary mold system used to shape, support, and cure precast concrete elements in a controlled production environment. It plays a crucial role in ensuring geometric accuracy, accelerating production cycles, and promoting sustainability through material reuse and reduced on-site waste. The modern development of precast formwork integrates digital fabrication, modularity, and sustainability principles, marking a shift from conventional formwork toward industrialized and environmentally responsible construction systems.

RESULT AND DISCUSSION

Comparative Analysis of Conventional and Precast Formwork Systems

1. Overview

Formwork systems play a critical role in shaping, supporting, and ensuring the quality of concrete structures. The choice between conventional formwork and precast formwork reflects the technological maturity, production scale, and sustainability goals of a construction project. Conventional formwork—often made from timber or plywood—is site-fabricated and labor-intensive, while precast formwork is factory-engineered for reusable, high-precision concrete production (Zhang et al., 2024; Lee et al., 2021). These two systems also represent a crucial component in the concrete construction process, influencing productivity, cost, and sustainability. Two dominant types—conventional formwork and precast formwork—differ significantly in terms of material utilization, construction methodology, and environmental impact. This section presents a comparative analysis between these systems based on recent scholarly works.

2. Comparative Characteristics

Formwork systems play a critical role in determining construction efficiency, cost performance, and structural quality. Various studies have analyzed the advantages and limitations of both conventional and precast formwork systems under different project conditions. To provide a clearer understanding of their comparative characteristics, the following table summarizes key findings and perspectives from several researchers regarding these two systems.

The following table provides an overview of the comparison between conventional and precast formwork systems according to the perspectives of several previous studies.

Table 1. The Comparison Between Conventional and Precast Formwork Systems

CRITERIA		CONVENTIONAL FORMWORK	PRECAST FORMWORK	KEY REFERENCES
1. Production	Production Location	On-site, manually assembled	Off-site (factory / casting yard) under controlled environment	Zhang et al. (2024)
	Fabrication Method	Constructed on-site using timber or plywood; manually assembled and dismantled.	Fabricated in a controlled precast yard or factory; assembled on-site.	Memon & Rahman (2013); Zhang et al. (2022)
2. Material	Material Type	Timber, plywood, steel	Steel, aluminum, composite, or polymer-based molds	Rahman et al. (2020); ASTM (2023)
	Material Reusability	Limited; timber deteriorates after several uses.	High; precast molds can be reused multiple times.	Rahman et al. (2020); Zhang et al. (2022)
	Reusability	Low (5–10 uses typical)	High (up to 100+ reuse cycles)	Memon & Rahman (2013); Lee et al. (2021)
3. Labor	Labor Intensity	High – requires manual labor for assembly/disassembly	Low – uses automated or modular setups	Tam et al. (2015); Wang & Li (2022)
	Labor Requirements	High manual labor required for installation and removal.	Reduced on-site labor; higher demand for skilled workers in production.	Tam et al. (2015); Rahman et al. (2020)
4. Quality	Dimensional Accuracy	Moderate – prone to human error	High precision, tight dimensional tolerance	Zhang et al. (2024); Goh & Rahman (2023)
	Surface Finish Quality	Depends on workmanship and material wear	Consistently smooth, factory-quality surface	Lee et al. (2021); ASTM (2023)
	Surface Quality	Dependent on workmanship and material condition; prone to irregularities.	High precision and smooth surface finish due to factory-controlled casting.	Lee et al. (2021)
5. Time	Cycle Time / Productivity	Long cycle, single-use focus	Shorter cycle, parallel production possible	Zhang et al. (2024); Rahman et al. (2020)
	Time Efficiency	Time-consuming due to repetitive setup and curing periods.	Faster installation; reduced project duration due to parallel production.	Lee et al. (2021); Goh & Rahman (2023)
6. Cost	Cost Efficiency	Lower initial cost, higher labor cost	Higher initial cost, lower long-term cost	Tam et al. (2015); Wang & Li (2022)
	Initial Cost	Low initial cost, suitable for small-scale projects.	Higher initial investment but cost-effective for repetitive or large projects.	Memon & Rahman (2013); Goh & Rahman (2023)

CRITERIA		CONVENTIONAL FORMWORK	PRECAST FORMWORK	KEY REFERENCES
7. Environmental	Environmental Impact	High waste generation, low material reuse	Low waste, supports sustainable manufacturing	Rahman et al. (2020); Lee et al. (2021)

		Generates significant timber waste; low recyclability.	More sustainable; reduced waste and carbon footprint.	Tam et al. (2015); Rahman et al. (2020)
8. Suitability	Suitability	Small-scale or irregular projects	Mass production, modular and repetitive structures	Goh & Rahman (2023); Zhang et al. (2024)
	Structural Flexibility	Easily adaptable for irregular shapes and small projects.	Limited flexibility; suitable for standardized designs.	Lee et al. (2021)

ANALYTICAL DISCUSSION

Conventional formwork remains a dominant system in small to medium-scale projects due to its low initial investment and flexibility in shaping complex geometries. However, it is increasingly criticized for being labor-intensive, time-consuming, and environmentally unsustainable, as timber-based systems typically contribute to significant material waste and carbon emissions (Tam et al., 2015; Rahman et al., 2020).

In contrast, precast formwork embodies the principles of industrialized construction, where formwork systems are standardized, reusable, and precision-engineered to achieve consistent quality and faster construction cycles. According to Zhang et al. (2024), automation and modularization in precast formwork can reduce production time by up to 40% while improving surface quality and alignment accuracy. Additionally, polymer or composite-based reusable formworks—discussed by ASTM (2023)—enhance durability and reduce material consumption over multiple use cycles.

From a sustainability perspective, precast formwork significantly reduces on-site waste and noise pollution by transferring most construction activities to controlled environments (Lee et al., 2021). This aligns with global trends toward low-carbon and circular construction systems, where reuse, precision, and digital integration (e.g., BIM-based planning) are central to performance optimization (Goh & Rahman, 2023).

Nevertheless, the economic feasibility of precast formwork depends on the project scale and repetition rate of components. For small-scale or irregular projects, conventional formwork may still be more practical due to its low setup cost and adaptability to varying structural geometries. Thus, the selection between conventional and precast systems should consider project size, complexity, repetition level, and sustainability targets.

The evolution from conventional to precast formwork systems represents a shift from labor-dependent, waste-generating construction methods toward industrialized, efficient, and sustainable production systems. Conventional formwork remains viable for low-scale applications, but precast formwork—supported by automation, modularity, and reusable materials—offers significant advantages in quality control, productivity, and environmental performance. Future research should focus on hybrid

approaches integrating digital fabrication, modular design, and life-cycle assessment to optimize formwork systems in sustainable construction practices.

The comparative investigations carried out in recent case studies reaffirm that precast or hybrid formwork systems often offer superior performance in terms of time savings and cost efficiency compared to fully conventional, cast-in-place methods. For example, Wahidan, Rahayu, Ramadhan, and Farhan (2025) studied the Sartikaasih Bhayangkara Hospital project in Bandung and found that precast structural systems lowered total costs and reduced construction time significantly—showing cost savings of several billion rupiah and time efficiencies up to 65% in one segment. Similarly, Gunawan, Pahang Putra, and Puspitasari (2024) in Surabaya demonstrated that applying a *half-slab precast method* reduced both project duration (20 days faster) and overall cost (by approximately IDR 2.58 billion) compared with the conventional slab casting. These findings align with a study on the *Japfa Office Building Daan-Mogot* (2024), where precast half-slab methods outperformed conventional methods in cost, time, material waste, and quality control. In another case, Syafriandy (2023) evaluated a multi-storey workers’ flats project and found that a value engineering precast approach combining precast columns, beams, and partial conventional slabs yielded the lowest cost among full precast and full conventional alternatives.

From these examples, several implications emerge: (1) projects with repetitive structural elements benefit most from precast systems due to mold reuse and standardization; (2) time reduction directly contributes to cost savings, particularly in urban projects; and (3) hybrid systems reduce material waste and improve quality consistency.

However, limitations exist. The upfront investment in molds and equipment can make precast uneconomical for small-scale projects. Transport and assembly logistics add risks, and highly customized designs favor conventional formwork due to flexibility. In summary, recent studies from 2023–2025 consistently confirm that precast and hybrid formwork systems offer better cost-time trade-offs in medium- to large-scale projects, while conventional systems remain advantageous in small or highly irregular structures.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This study has presented a comparative analysis between conventional formwork and precast formwork systems within the context of modern concrete construction. The findings indicate that while conventional formwork remains widely adopted in small- to medium-scale projects due to its low initial cost, material availability, and geometric flexibility, it suffers from significant limitations, including labor intensity, low productivity, and poor environmental performance.

Conversely, precast formwork systems demonstrate clear advantages in terms of construction speed, material reusability, surface quality, and sustainability performance. The ability to conduct parallel off-site fabrication not only minimizes project duration but also enhances precision and reduces waste generation. Nevertheless, the adoption of precast formwork is constrained by high capital investment, transportation logistics, and the need for skilled labor and technical planning, making it more suitable for large-scale or repetitive projects.

From a sustainability perspective, transitioning from conventional to precast systems aligns with the global movement toward industrialized construction and low-carbon development. The integration of digital technologies such as Building Information Modeling (BIM) and automation in precast manufacturing can further optimize formwork design, reduce material waste, and enhance project efficiency (Goh & Rahman, 2023).

Future research should focus on several key directions:

1. Hybrid Formwork Systems – Developing innovative systems that combine the flexibility of conventional formwork with the efficiency of precast methods.
2. Sustainability Assessment Models – Quantitative evaluation of life-cycle environmental impacts, carbon footprint, and resource efficiency between both systems.
3. Automation and Robotics Integration – Exploring robotic-assisted formwork assembly and digital fabrication to minimize human error and enhance safety.
4. Cost-Benefit Optimization – Establishing analytical models that balance economic feasibility with sustainability performance, particularly for developing countries.
5. Policy and Implementation Frameworks – Investigating regulatory and institutional barriers that affect the adoption of precast technology in emerging construction markets.

In conclusion, the evolution of formwork technology—from conventional to precast systems—represents a transformative shift toward sustainable and industrialized construction. By leveraging innovation, digitalization, and sustainable materials, the construction industry can significantly improve productivity and

environmental performance, paving the way for smarter and greener infrastructure development.

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