

## OPTIMIZING DFMA IMPLEMENTATION IN ON-SITE CONSTRUCTION: A DECISION-MAKING FRAMEWORK

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**ABSTRACT:** The integration of Design for Manufacture and Assembly (DfMA) principles into On-site Construction (OnSC) introduces a multifaceted decision-making process, shaped by challenges across economic, technological, legal, cultural, and policy dimensions. This study identifies and categorizes key decision support factors (KDSFs) essential for successful DfMA implementation, addressing challenges such as cost overruns, technology adoption, accurate cost estimation, and interdisciplinary communication. Among these factors, economic considerations, particularly high initial capital costs and budget overruns, are the most critical. These challenges are mapped to seven key dimensions: project characteristics, supply chain, time, cost, quality, procurement, and socio-cultural aspects. For example, economic challenges align with cost-related factors like material pricing, whereas legal challenges intersect with procurement strategies and contract delivery methods. This research introduces a robust decision-making framework that integrates these challenges with KDSFs, offering stakeholders a structured approach to evaluate the feasibility and facilitate the effective implementation of DfMA in OnSC. By addressing potential risks and improving interdisciplinary collaboration, the framework enhances project efficiency and outcomes. The study highlights the necessity of a multi-criteria decision-making system to navigate the complexities of DfMA, paving the way for more effective application in on-site construction projects.

**Keywords:** Industrialised Construction, Design for Manufacture and Assembly (DfMA), Decision-Making.

### 1. INTRODUCTION

The construction industry is looking for new construction methods to improve efficiency, reduce costs, and enhance project results (O'Rourke, 2013). Design for Manufacture and Assembly (DfMA) as a methodology streamlines the design process to ensure that building components can be efficiently manufactured and assembled (Abd Razak et al., 2022). While DfMA has been discussed in Off-site Construction (OSC) in literature (Tan et al., 2020), its integration into On-site Construction (OnSC) presents unique challenges that require careful consideration. Unlike OSC, where components are manufactured in controlled environments and later assembled on-site, OnSC involves direct application of DfMA principles in dynamic and often unpredictable conditions, making decision-making more complex (Montazeri, 2024).

The adoption of DfMA in OnSC is influenced by multiple factors such as economic and financial, technological, legal contractual, technical cognitive, cultural, and policy dimensions. High initial capital investment, cost overruns and contingencies, and appropriate tools and techniques and cost of technology adoptions are significant economic and technological barriers. Additionally, legal considerations, such as

contract structures and procurement processes, further complicated implementation (Montazeri, 2024). Addressing these challenges requires a structured approach to decision-making that considers various project-specific constraints (Wuni et al., 2020). This paper introduces a Decision-Making Framework for implementing DfMA in OnSC. The framework is developed by identifying and categorizing Key Decision Support Factors (KDSFs) that influence project success, including cost estimation accuracy, technology selection, procurement strategies, and interdisciplinary coordination. The proposed framework maps these challenges to seven key dimensions—project characteristics, supply chain, time, cost, quality, procurement, and socio-cultural aspects—to provide stakeholders with a systematic approach to evaluating the feasibility of DfMA in OnSC.

The study contributes to bridging the knowledge gap in DfMA decision-making for OnSC, offering a structured method for assessing risks, improving interdisciplinary collaboration, and enhancing project efficiency. The paper is structured as follows: Section 2 reviews the existing literature on DfMA, its challenges, and key decision support factors (KDSFs). Section 3 details the research methodology used to develop the framework. Section 4 introduces the framework and its components. Section 5 presents a hypothetical case study, and Section 6 discusses the framework's effectiveness, compares it with existing approaches, and explores its practical implications. Finally, Section 7 concludes the study and offers recommendations for future research.

## 2. LITRETURE REVIEW

Design for manufacturing and assembly (DfMA) is a methodology aimed at addressing the problem of fragmentation in the industry by connecting design, manufacturing, and construction from early in the design stage and consist of two parts Design for Manufacturing (DfM) and Design for Assembly (DfA) (Boothroyd, 1996). DfMA is a method that demonstrates how a traditionally sequential process has evolved into a more iterative and non-linear approach (Abd Razak et al., 2022; Tuvayanond & Prasittisopin, 2023).

Different studies have highlighted DfMA benefits, including reductions in cost and time (Tan et al., 2020; Wasim et al., 2020) , improved quality (Bao et al., 2022; Favi et al., 2017), enhanced sustainability and circular economy (Favi et al., 2017; Gao et al., 2018), reduced construction labor (Bakhshi et al., 2022; Machado et al., 2016), and enhancing waste management (Roxas et al., 2023). Research shows that DfMA is still not widely used in construction, and there's limited information on its adoption (Bao et al., 2022; Wasim et al., 2022). Moreover, several challenges hinder its adoption including resistance to change and a preference for traditional methods (Langston & Zhang, 2021; Montali et al., 2018), misaligned planning and building codes alignment (Bao et al., 2022), lack of government support and incentives (Chen & Lu, 2018), higher costs, strict government regulations, risk aversion (Langston & Zhang, 2021), and lack of technical standards (Wuni et al., 2020).

Based on different literature effective decision-making in construction is crucial for ensuring project success (Attouri et al., 2022b; Wuni et al., 2020), particularly when selecting new approaches like DfMA and several studies have proposed structured decision-support frameworks to help stakeholders assess project feasibility, identify challenges, and optimize construction methods. One of the most comprehensive reviews in this area is by (Wuni et al., 2020), who systematically analyzed the key decision-making factors influencing the adoption of Modular Integrated Construction (MiC). While the findings highlight the need for a multi-criteria decision-making approach when selecting advanced construction methods; DfMA in OnSC presents unique challenges that require customized approaches. Economic factors (such as initial capital costs and procurement models), technological barriers (such as tool compatibility and automation adoption), and legal considerations (such as contract structuring and compliance) all play a critical role in decision-making. This paper builds on previous decision-support frameworks by introducing a Decision-Making Framework for DfMA in OnSC, mapping key decision-support factors (KDSFs) to seven critical dimensions: project characteristics, supply chain, time, cost, quality, procurement, and socio-cultural aspects. By incorporating insights from existing models, this framework provides a structured and adaptable method for assessing the feasibility of DfMA in OnSC and facilitate its effective implementation.

### **3. METHODOLOGY**

The methodology used to develop the conceptual framework for integrating DfMA challenges and KDSFs follows a Hybrid Thematic Analysis Approach and Multi-Criteria Decision-Making (MCDM). This methodology is commonly used in construction management, decision science, and industrial engineering research.

#### **3.1 Thematic Analysis for Challenge Identification**

The thematic analysis for challenge identification, articulated in our previous study as the foundation of this research, systematically extracts and categorizes DfMA adoption barriers in OnSC (Montazeri, 2024). Through a structured review of literature, expert insights, and case studies, challenges are coded into economic, technological, legal, cultural, and policy themes. These themes are refined through expert validation and mapped to the KDSFs to ensure alignment with decision-making dimensions such as cost, quality, supply chain, and procurement (Mehdipoor et al., 2023b). This structured process provides a comprehensive understanding of barriers, forming the basis for integrating MCDM in the proposed framework.

#### **3.2 Multi-Criteria Decision-Making**

The Multi-Criteria Decision-Making (MCDM) approach for selecting DfMA, established as a core component in our previous study, systematically validates and evaluates Key Decision Support Factors (KDSFs) based on their impact on DfMA adoption (Mehdipoor et al., 2023b; Montazeri, 2024). Utilizing expert judgment and a structured scoring approach, factors are assessed across dimensions such as cost, time, quality, supply chain, and procurement. The Mean Score (MS) method ranks these factors, ensuring a data-driven hierarchy that reflects industry priorities. This ranking strengthens the decision-making framework by enabling structured selection processes, optimizing project efficiency, and enhancing interdisciplinary collaboration. However, the ranking is not directly reflected in the development of the proposed framework in this study.

The Key Decision Support Factors (KDSFs) are mapped to the proposed framework by aligning the most influential decision-making dimensions with the identified DfMA challenges in OnSC. This mapping ensures that the most critical factors such as time, quality, and socio-cultural aspects receive sufficient attention when addressing economic, technological, legal, and procedural barriers to DfMA adoption. Each dimension (e.g., Time, Quality, Sociocultural, etc.) is linked to corresponding DfMA challenges. For instance, Time is mapped to challenges related to prolonged design periods, production delays, and inefficient mobilization. Quality is connected to DfMA concerns such as defect liability, standardization, sustainability, and safety, while Cost is directly related to economic constraints such as high initial capital investment and cost overruns.

The proposed MCDM framework offers distinct advantages in optimizing resource allocation and addressing procurement challenges specific to modular construction. By incorporating diverse performance indicators and stakeholder priorities, it facilitates a balanced evaluation of procurement alternatives beyond cost alone. This comprehensive approach ensures that decisions consider factors such as supplier reliability, lead times, environmental impact, and alignment with project schedules—ultimately improving supply chain efficiency and project performance. Furthermore, its adaptability enables customization to project-specific contexts, making it a versatile tool for strategic planning in off-site construction.

By structuring the framework in this way, decision-makers can systematically analyze how each DfMA challenge interacts with prioritized decision factors, enabling the implementation of targeted mitigation strategies. The framework thus functions as a robust decision-support tool, guiding the informed selection of DfMA strategies based on both challenge severity and factor importance.

#### 4. PROPOSED DECISION-MAKING FRAMEWORK

A structured decision-making approach that integrates the various challenges with the key decision support factors is presented in Table 1. This framework establishes a systematic method for evaluating and mitigating barriers to DfMA adoption by aligning them with project-specific dimensions such as project characteristics, supply chain, time, cost, quality, procurement, and sociocultural aspects. Furthermore, the integration of KDSF and DfMA challenges is shown in Figure 1 to illustrate the connection between the key decision support factors and DfMA challenges in OnSC.

The framework categorizes DfMA challenges into their respective dimensions and provides targeted decision-making strategies to address them. Economic and financial challenges, such as high initial capital and cost estimation uncertainties, are tackled through cost benchmarking tools and financial incentive models. Similarly, technological barriers including interoperability issues and high digital adoption costs are addressed through BIM-enabled data extraction, modular design approaches, and collaborative supply chain integration. Legal and procurement-related concerns, such as unclear role definitions and ineffective contract models, necessitate the implementation of collaborative contracts, early contractor involvement, and procurement models tailored for DfMA adoption.

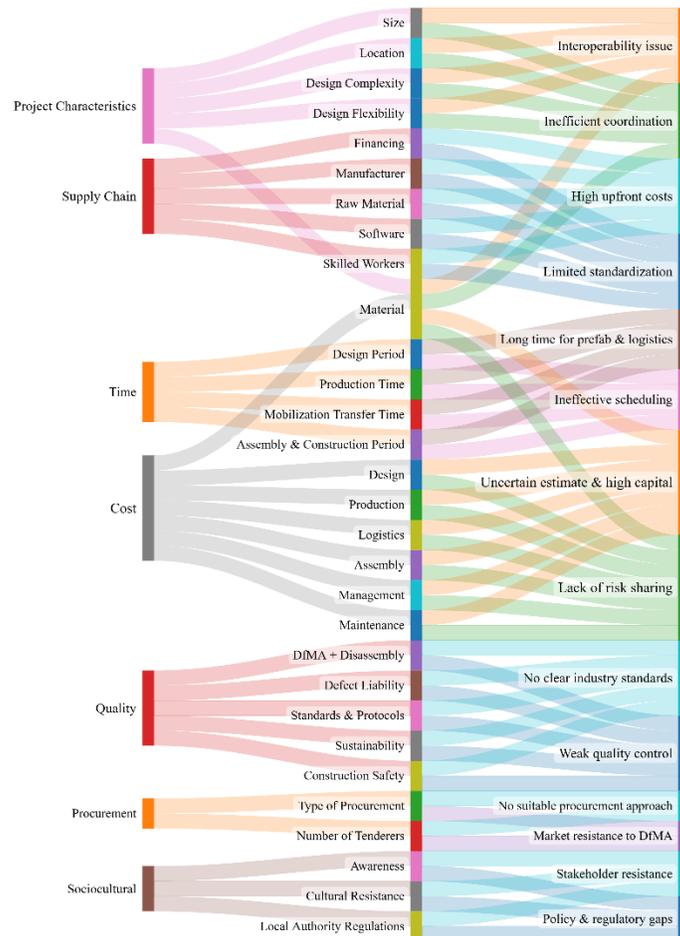


Figure 1 – Integration of KDSF and DfMA challenges in OnSC

Time constraints, including long prefabrication lead times and inefficiencies in scheduling, are optimized using AI-driven supply chain planning and digital twin simulations to enhance predictability and efficiency. Quality assurance, a crucial component in OnSC, is strengthened by establishing clear industry standards,

integrating life-cycle assessment tools, and reinforcing sustainability measures to ensure compliance with regulatory requirements. Additionally, the framework highlights sociocultural challenges such as stakeholder resistance and policy gaps, advocating for industry-wide awareness programs and regulatory improvements to support DfMA integration.

By mapping these critical challenges to decision-support strategies, this framework provides a practical and interdisciplinary approach for improving DfMA adoption in OnSC. It serves as a guide for industry professionals, policymakers, and researchers to navigate the complexities of DfMA implementation, ensuring cost efficiency, improved collaboration, and higher project success rates. The following table presents the structured framework, detailing the integration of KDSFs with DfMA challenges and corresponding decision-making strategies.

Table 1: Conceptual Framework for DfMA Selection in OnSC

<b>Dimension (Category)</b>	<b>Key Decision Support Factors (KDSFs)</b>	<b>DfMA Challenges</b>	<b>Integration Strategy (Decision-Making Approach)</b>
D1 - Project Characteristics	Size, Material, Location, Design Complexity, Design Flexibility	- Complex design & interoperability issues in OnSC	- Implement BIM-enabled data extraction for real-time adaptability
		- Inefficient interdisciplinary coordination	- Develop modular & flexible design strategies to align with OnSC constraints
D2 - Supply Chain	Financing, Manufacturer, Raw Material, Equipment, Software, Skilled Workers	- High upfront costs for DfMA technology	- Develop collaborative supply chain models to reduce cost
		- Limited standardization & supply chain inefficiencies	- Advocate for standardized DfMA components with manufacturers
D3 - Time	Design Period, Production Time, Mobilization Transfer Time, Assembly & Construction Period	- Long lead times for prefabrication & logistics	- Leverage AI-driven logistics & digital twins for predictive scheduling
		- Ineffective project scheduling in OnSC	- Optimize prefabrication & just-in-time (JIT) strategies
D4 - Cost	Design, Material, Production, Logistics, Assembly, Management, Maintenance	- Uncertain cost estimations & high capital investment	- Develop cost benchmarking & predictive analytics tools
		- Lack of risk-sharing frameworks in procurement	- Implement government incentives & risk-sharing financial models
D5 - Quality	DfMA + Disassembly, Defect Liability, Standards & Protocols, Sustainability, Construction Safety	- Absence of clear industry standards	- Establish regulatory compliance frameworks with stakeholders
		- Weak quality control at different project stages	- Integrate life-cycle assessment (LCA) tools for sustainability & safety
D6 - Procurement	Type of Procurement & Delivery Method, Number of Tenderers	- Lack of suitable procurement & contract strategies	- Implement early contractor involvement (ECI) & pre-construction planning
		- Market resistance to DfMA	- Use collaborative contracts (e.g., IPD, PPP) to align incentives
D7 - Sociocultural	Awareness, Cultural Resistance, Local Authority Regulations	- Stakeholder resistance & limited awareness	- Conduct industry training & capacity-building programs
		- Policy & regulatory gaps for DfMA adoption	- Advocate for policy standardization & DfMA-friendly regulations

## 5. HYPOTHETICAL CASE STUDY: IMPLEMENTING DFMA IN ONSC OF A RESIDENTIAL BUILDING

The objective of this hypothetical case study is to demonstrate how the proposed decision-making framework can be applied to the planning and execution of a residential building project using DfMA principles in OnSC.

The project involves the construction of a 3-story residential building located in Ottawa, Canada, situated in the R2 Zone of Ottawa's residential zoning areas. The building design adheres to Ottawa's urban design zoning requirements for residential development under the R2 Zone. The R2 zone allows for low-density residential developments, including multi-unit buildings like duplexes, semi-detached homes, and low-rise apartment buildings. The building will consist of 6 residential units, each with a floor area of 85 m<sup>2</sup>, with 2 units per floor. There will also be a one-floor basement for utility and storage purposes.

### 5.1 Building Design Considerations:

- **Building Height:** The building will comply with the 11-meter height limit (approximately 3 stories), which is allowed in the R2 zone.
- **Lot Coverage:** The building footprint will be adjusted to ensure it does not exceed the 35% lot coverage limit, and landscaping will cover approximately 30-40% of the site area.
- **Parking:** parking spaces will be provided for the residential units, as required by Ottawa's residential parking standards. Additional visitor parking may also be planned.
- **Sustainability:** The design will incorporate sustainable stormwater management and energy-efficient features.
- **Setbacks:** The building will respect the required front yard and side yard setbacks as per the R2 zoning requirements.

Table 2 shows the research case study characteristics, which determine the importance and impact of each KDSF integrated with its associated DfMA challenges.

Table 2: Case study characteristics

Characteristic	Details
Location	Ottawa, Canada (R2 Residential Zone)
Building Type	3-Story Residential Building with 6 Units (85 m <sup>2</sup> each)
Unit Count	6 Units (2 units per floor)
Total Floor Area	6 Units x 85 m <sup>2</sup> = 510 m <sup>2</sup>
Basement	One-floor basement for utility and storage
Floor Area Efficiency	80%
Building Height	3 Stories (up to 11 meters)
Lot Coverage	~35% (footprint adjusted to comply with zoning)
Setbacks	Front Yard: ~6m, Side Yard: ~1.2m to 3m, Rear Yard: ~7m
Parking Requirements	6-9 parking spaces for residents, additional visitor parking
Lot Size	To be determined based on density requirements (minimum ~500 m <sup>2</sup> )
Zoning	Ottawa Residential Zone (R2)
Density Requirements	Density adjusted for 6 units
Permitted Uses	Multi-unit residential buildings
Landscaping	~30-40% of the lot area covered by landscaping
Stormwater Management	Sustainable features (permeable surfaces, retention ponds)
Sustainability	Energy-efficient building features

### 5.2 Framework implementation

Using a MCDM approach with a 1–5 scoring system two alternatives compared:

- Option A: Light Gauge Steel (LGS) panelized system assembled on-site (DfMA approach)
- Option B: Conventional cast-in-situ construction

The scoring for each decision-making dimension is based on how well each option addresses the KDSFs and associated DfMA challenges, considering the project’s specific characteristics (location, building size, design complexity, etc.).

Table 3: Integrated MCDM evaluation in the proposed framework implementation for the case study

Dimension	Associated Challenges	Integration Strategy	Option A: LGS Panelized (Score & Reason)	Option B: Cast in situ (Score & Reason)
<b>D1: Project Characteristics</b>	Complex design & interoperability issues; Inefficient coordination among disciplines	BIM-enabled data extraction; DfMA & flexible design strategies	<b>4:</b> DfMA design & BIM integration improve coordination and suit moderate complexity.	<b>3:</b> Offers design flexibility but lacks inherent DfMA benefits
<b>D2: Supply Chain</b>	High upfront DfMA costs; Limited standardization leading to inefficiencies	Collaborative supply chain models; Standardized DfMA components	<b>4:</b> Standardized components & a collaborative approach streamline procurement	<b>3:</b> Traditional supply chain is less integrated, may lead to fragmentation and inefficiencies
<b>D3: Time</b>	Long lead times for prefabrication; Scheduling inefficiencies on-site	AI-driven logistics and digital twins; Just-in-time strategies	<b>5:</b> Prefabrication reduces on-site time and minimizes weather delays	<b>3:</b> Full onsite approach is more vulnerable to delays and weather disruptions
<b>D4: Cost</b>	Uncertain cost estimates; High capital investment requirements	Cost benchmarking tools; Risk-sharing and incentive models	<b>3:</b> High upfront costs & partly offset by savings in labor & reduced time, though uncertainties remain	<b>3:</b> Conventional method avoids large capital outlays but can experience cost overruns and inefficiencies
<b>D5: Quality</b>	Lack of clear industry standards; Variability in quality control during construction	Regulatory compliance frameworks; LCA tools	<b>4:</b> Factory-controlled production ensures consistent, high-quality outcomes	<b>3:</b> On-site variability may lead to inconsistent quality and a higher defect rate
<b>D6: Procurement</b>	Inadequate procurement strategies for DfMA; Market resistance to new methods	Early contractor involvement; Collaborative contracts	<b>3:</b> Innovative procurement strategies align stakeholder incentives and support DfMA	<b>4:</b> Conventional procurement methods are reliable but not fully leverage integrated, collaborative approach
<b>D7: Sociocultural</b>	Stakeholder resistance to new methods; Policy and regulatory gaps for DfMA	Industry training and capacity-building; Advocacy for DfMA-friendly policies	<b>3:</b> New method may face resistance and requires additional training and advocacy to gain acceptance	<b>5:</b> Traditional approach is widely accepted, facing fewer regulatory or cultural hurdles
<b>Total Score</b>			<b>26</b>	<b>24</b>

### 5.2.1 Project Characteristics (D1)

The standardized unit sizes and moderate design complexity (510 m<sup>2</sup> total area and 3 stories) make the project well suited for a DfMA approach. The LGS panelized system (Option A) benefits from BIM-enabled data extraction and prefabricated design strategies, which are ideal for efficiently managing the design complexities inherent in the project. In contrast, while the cast in situ approach (Option B) offers design flexibility, it lacks the inherent DfMA benefits that could expedite coordination for a project with well-defined and repetitive unit layouts.

### 5.2.2 Supply Chain (D2)

Given the project’s moderate scale and predictable material requirements, adopting standardized DfMA components via a collaborative supply chain is practical. For Option A, the use of standardized LGS elements can streamline procurement and material delivery. The project’s fixed number of units supports efficient bulk ordering and integration. Option B, with its traditional supply chain, does not fully capitalize on the opportunities for standardization indicated by the project’s uniform design.

### 5.2.3 Time (D3)

The clear schedule constraints typical of residential projects, making time efficiency critical. Off-site prefabrication in Option A can substantially reduce on-site construction time, a key advantage when building under regulated timelines and potential weather disruptions in Canada. The conventional cast in situ method (Option B) is more susceptible to on-site delays, which is a notable drawback for a project with fixed occupancy targets and construction deadlines.

### 5.2.4 Cost (D4)

Although the LGS panelized system (Option A) involves a higher upfront capital investment, the potential cost savings from reduced on-site labor and shorter construction times are significant for a project with predictable design elements. The cast in situ approach (Option B) may have lower initial capital requirements, but it risks cost overruns due to inefficiencies that are harder to manage in projects with repetitive unit layouts.

### 5.2.5 Quality (D5)

The consistency required by a residential building with uniform units (as detailed in Table 2) is more readily achieved with a factory-controlled LGS system. Option A's ability to produce consistent, high-quality components aligns with the need for uniformity across the building's units. In contrast, Option B's on-site variability may compromise quality, especially when striving for consistent finishes across all residential units.

### 5.2.6 Procurement (D6)

With the building's predictable scale and unit configuration, innovative procurement strategies, such as early contractor involvement and collaborative contracts, can be effectively implemented for Option A. This integrated approach supports efficient project delivery and is well suited to the project's standardized nature. Option B's conventional procurement methods, while reliable, do not offer the same level of integration, which may be less optimal for a project that could benefit from streamlined processes.

### 5.2.7 Sociocultural (D7)

Although Option A may face some initial stakeholder resistance and require additional training, given the novelty of DfMA approaches in certain regions, the standardized and replicable nature of the project's design (with 6 similar residential units) can help ease the transition. Option B, benefiting from traditional acceptance, scores higher in this category; however, its lack of integration with the project's inherent modular design is a limitation.

Considering the project's well-defined and standardized characteristics, the LGS panelized system (Option A) scores a total of 26, outperforming the cast in situ method (Option B) with 22. Option A's strengths in prefabrication design, supply chain integration, time efficiency, and quality control align closely with the project's requirements, making it the recommended approach. Special attention should be given to mitigating sociocultural challenges through targeted training and stakeholder engagement, ensuring the benefits of the DfMA approach are fully realized.

## 6. DISCUSSION

This research presents a Decision-Making Framework for selecting DfMA in OnSC, offering a structured and integrated approach that addresses the economic, technological, legal, cultural, and policy challenges associated with DfMA adoption. While previous studies have focused on the benefits and implementation challenges of OSC (Wuni et al., 2021; Wuni & Shen, 2019), this research extends the application of DfMA principles beyond factory-based prefabrication and modularization, examining its feasibility within the dynamic and often unpredictable conditions of OnSC.

Prior studies on OSC and DfMA have largely emphasized the efficiency of prefabrication in controlled environments (Jin et al., 2018; Van Vuuren, 2020). However, limited research has explored how DfMA principles can be effectively integrated into OnSC projects, where variability in site conditions, logistics, and workforce constraints introduce additional complexities. The proposed framework builds upon research that

identifies Key Decision Support Factors (KDSFs) influencing OSC adoption (Blismas et al., 2005; Mehdipoor et al., 2023b; Wuni et al., 2020), however this research explicitly maps KDSFs to the unique challenges of OnSC. Furthermore, research by (Attouri et al., 2022a) and (Daget & Zhang, 2019) explored decision-making models for selecting industrialized building systems.

These studies identified economic and technological factors as key drivers of OSC adoption but did not provide a systematic framework integrating legal, socio-cultural, and procurement challenges. Therefore, this study bridges that gap by offering a comprehensive mapping of challenges to decision-making dimensions, ensuring that stakeholders can systematically address interdisciplinary barriers when considering DfMA for OnSC projects.

To validate the findings of this study, particularly the outcome that option A (LGS panelized) outperforms option B (cast in situ) in the hypothetical case, a comparison was made with a real-world case study reported by Mehdipoor et al. (2023a). This study was selected for validation due to its application of a structured and quantitative decision-making approach (fuzzy logic) to assess off-site construction approach for an actual modular building project, which shares functional and technical similarities with the hypothetical scenario analyzed in this paper (Mehdipoor et al., 2023a). The case study incorporates practical decision-making factors that closely resemble those considered in this research. Notably, the real case identified a panelized light gauge steel system as the most suitable option, which aligns with the outcome of the hypothetical model presented in this study. This alignment reinforces the validity of the proposed decision-support framework and supports its relevance in real-world construction planning scenarios.

For industry professionals, the structured mapping of challenges to decision-making dimensions enables more informed and proactive adoption strategies. Additionally, the research underscores the need for policy adaptations to facilitate DfMA integration in OnSC, advocating for regulatory standardization and procurement innovation. The proposed framework provides a practical guide for industry professionals, offering a decision-support tool that balances cost, time, and quality considerations while addressing sector-specific adoption barriers. Moreover, by systematically integrating economic, technological, legal, and socio-cultural considerations, the proposed framework enhances the feasibility and effectiveness of DfMA adoption, paving the way for more efficient and sustainable construction practices.

## **7. CONCLUSIONS**

This study introduces a structured Decision-Making Framework for integrating DfMA into OnSC. By systematically mapping key decision support factors (KDSFs) to economic, technological, legal, socio-cultural, and procurement challenges, the framework provides a structured approach to evaluating the feasibility of DfMA in dynamic construction environments. While the framework offers a practical tool for stakeholders, several limitations should be acknowledged. First, the study primarily relies on a hypothetical case study, limiting direct validation through real-world project data. Future research should apply the framework to multiple live projects across different construction types and regulatory environments to further refine its applicability. Second, the framework does not fully integrate emerging technologies such as AI-driven decision-making and real-time data analytics, which could enhance its predictive capabilities. Despite these limitations, this research contributes to bridging the gap between DfMA theory and practical application in OnSC. Future work should focus on refining the framework through empirical validation and exploring digital innovations to improve decision-making processes in construction projects.

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