Quest Journals
Journal of Architecture and Civil Engineering
Volume 10 ~ Issue 11 (November 2025) pp: 17-29
ISSN(Online): 2321-8193
www.questjournals.org

Research Paper

Design for Manufacturing and Assembly (DFMA) in the Industrialization of Buildings and Its Evolution of Large-Scale Structural Design: A Critical Review

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Abstract
As the construction industry seeks greater sustainability, efficiency, and cost-effectiveness, Design for Manufacturing and Assembly (DFMA) has emerged as a key driver in the industrialization of buildings. This paper critically reviews the application of DFMA in building industrialization and its evolution in large-scale structural design. By simplifying designs, standardizing components, and optimizing assembly processes, DFMA enhances productivity, reduces costs, and minimizes environmental impacts at construction sites. The review begins by outlining the core principles of DFMA and its proven successes in manufacturing, followed by an analysis of its practical implementation in the construction sector, highlighting case studies such as the Forge office building in London and the PPVC initiative in Singapore. The paper then discusses challenges and opportunities associated with DFMA in large-scale structural design, particularly regarding early-stage design integration, supply chain coordination, and automated prefabrication. Furthermore, it evaluates DFMA's broader impact on the future of construction, including implications for education and training, regulatory frameworks, and sustainability. The review concludes by identifying key success factors and suggesting directions for future research in DFMA implementation.
Keywords: *DFMA, Construction, Prefabrication; Construction Industry*

Received 15 Nov., 2025; Revised 28 Nov., 2025; Accepted 30 Nov., 2025 © The author(s) 2025.
Published with open access at ***www.questjournas.org***

I. Introduction

In today's rapidly evolving construction industry, Design for Manufacturing and Assembly (DFMA) is increasingly recognized as a key strategy for advancing construction industrialization. It is attracting growing attention from industry professionals due to its potential to enhance efficiency, reduce costs, and improve sustainability (Design for Manufacturing and Assembly (DfMA) | Building and Construction Authority (BCA), no date; Gao, Low and Nair, 2018a; Montazeri, Lei and Odo, 2024a). This report, titled "Design for Manufacturing and Assembly (DFMA) in the Industrialization of Buildings and Its Revolution in the Design of Large Structures: A Critical Review," aims to explore the application and transformative impact of DFMA in the building sector.

The objective of this report is to conduct an in-depth critical review of DFMA's role in the industrialization of buildings and its implications for the design of large-scale structures. Specifically, the report evaluates DFMA's effectiveness in improving construction productivity, reducing project costs, shortening construction durations, and promoting sustainability, while also assessing its feasibility in real-world projects.

The key objectives of the report are as follows:

- To analyze the current state of DFMA application in building industrialization, particularly its role in optimizing design and construction processes.
- To assess DFMA's impact on the design of large structures, focusing on improvements in design quality and construction safety.
- To identify and discuss major challenges in DFMA implementation and explore strategies to overcome them.
- To present a real-world case study illustrating DFMA's practical application and its positive outcomes.
- To examine the future potential of DFMA and its long-term contributions to sustainability in the construction industry.

This report is structured as follows: it begins with an overview of the core concepts and principles of DFMA. This is followed by an analysis of DFMA's application in building industrialization through selected case studies. Subsequently, the report explores DFMA's innovative use in large-scale structural design and evaluates the associated challenges and opportunities. Finally, it concludes with a summary of findings and proposes future research directions. Through this report, readers will gain a comprehensive understanding of DFMA and its growing significance in modern construction practices.

II. Background

In the 21st-century construction industry, traditional building methods are facing unprecedented challenges driven by rapid technological advancements and a growing emphasis on environmental sustainability. In response to these pressures (Firoozi et al., 2024), DFMA has emerged as a strategic approach to accelerate the industrialization of buildings. At its core, DFMA involves incorporating manufacturing and assembly considerations into the early stages of the design process to enhance production efficiency, reduce costs, and minimize environmental impact (Building X | Siemens Xcelerator - Siemens Xcelerator Global, no date)(Generating Demand for DfMA Projects | Building and Construction Authority (BCA), no date; What is DFMA? | Design for Manufacturing and Assembly Explained, no date).

Although originally developed and widely applied in industries such as automotive and aerospace, DFMA is now gaining traction in the construction sector. Its implementation not only shortens the development cycle of construction projects but also improves build quality and safety. Globally, DFMA principles have been successfully applied in several projects, including the Forge office building in London, United Kingdom ('MARK DE WOLF', no date).

PPVC construction technology in Singapore(Ortmann and Thompson, 2018), and the key technology for the construction of prefabricated fully decorated modular prefabricated structures developed by the Institute of Science and Technology Development of Shenzhen University(Technology Transfer Center , 2023,n.d). These practices demonstrate that DFMA can effectively reduce construction waste, reduce energy consumption, and improve resource utilization, thereby supporting environmentally friendly building practices(Mcfarlane, Rourke and Stehle, no date).

Despite its promising potential, the adoption of Design for Manufacturing and Assembly (DFMA) in the construction industry faces several challenges. These include the deep-rooted reliance on traditional construction practices, the relative immaturity of supporting technologies and management processes, and industry-wide uncertainty regarding the acceptance of innovative methods (MEYER and MITTAL, 2021; C. L. C. Roxas et al., 2023a). Furthermore, conventional procurement models often pose significant barriers to DFMA implementation, as they constrain cost transparency, limit coordination, and hinder the integration and optimization of design and construction workflows(Sebastion , 2011 , Vokes&Brennan , 2013 'DFMA:Engineering the Future' n.d.).

As technology continues to advance and industry demands grow, the importance of DFMA in enhancing manufacturing efficiency has become increasingly evident. With the rising demand for sustainable practices, the adoption of DFMA in the construction industry is steadily increasing. For instance, several construction companies have begun incorporating DFMA to enable fast and efficient on-site installation by prefabricating building modules in controlled factory environments(C. L. C. ; Roxas et al., 2023a; Widanage and Kim, 2024a). These practices demonstrate DFMA's effectiveness in shortening construction project timelines while simultaneously improving quality and safety on-site.

With growing technological advancements and increasing emphasis on sustainability, the relevance of DFMA in improving manufacturing efficiency has become more pronounced. The demand for sustainable construction practices has accelerated the adoption of DFMA across the industry. For example, several construction companies have already begun implementing DFMA by manufacturing building modules off-site, enabling fast and efficient on-site installation (Wasim, Vaz Serra and Ngo, 2022).

Practices highlight how DFMA can effectively reduce project timelines while improving construction quality and safety. As technology continues to evolve and industry acceptance expands, DFMA is poised to play an increasingly transformative role in the future of building industrialization (The Future of Design and Construction: Achieving Smart Construction Development, no date; Razak et al., 2022a).

III. Research Approach And Scope

This report adopts a multi-method approach to critically examine the application of DFMA in the industrialization of buildings and its influence on the design of large-scale structures. The research began with an extensive literature review to gather recent academic and industry perspectives on DFMA. Systematic searches were conducted across academic databases, industry reports, and professional publications using key terms such as "DFMA," "building industrialization," and "large-scale structural design" to ensure comprehensive coverage of relevant studies.

Following this, several representative case studies were selected for detailed analysis, including the Prefabricated Prefinished Volumetric Construction (PPVC) project in Singapore and the Forge office building in London, UK. These cases were examined to assess the practical benefits, challenges, and lessons learned from DFMA implementation in real-world contexts.

In addition to the case study analysis, a technology assessment was conducted to evaluate DFMA-related tools and digital systemssuch as Building Information Modelling (BIM) and Enterprise Resource Planning (ERP)—and their role in streamlining the design and manufacturing processes. Furthermore, a policy analysis was carried out to understand regulatory frameworks that support DFMA adoption, with particular focus on China's "Interdepartmental Opinions on Accelerating the Industrialization of New Buildings" issued by the Ministry of Housing and Urban-Rural Development and related agencies.

While the study may not encompass all DFMA applications due to time and resource constraints, it lays the groundwork for future expansion. Additional case studies and a deeper exploration of long-term impacts are planned in subsequent research. This structured approach aims to provide a comprehensive evaluation of DFMA's potential and offer actionable insights for construction industry stakeholders.

IV. DFMA

4.1 Introduction

Design for Manufacturing and Assembly (DFMA) is a strategic design methodology that integrates the requirements of both manufacturing and assembly into the earliest stages of product development. By doing so, it ensures that designs are not only functionally effective but also feasible and cost-efficient to produce and assemble. This proactive approach significantly reduces the risk of quality issues that may arise during later stages of development (What is Design for Manufacturing or DFM?, no date; Widanage and Kim, 2024b).

DFMA has been widely adopted in industries such as automotive and aerospace due to its ability to streamline processes, improve product quality, and reduce production costs. One of the key visual frameworks (Figure 1) representing DFMA principles is The DFMA Envelope (C. L. C. ; Roxas et al., 2023a)which illustrates how design, manufacturing, and assembly requirements overlap and influence one another throughout the development cycle.

Another helpful tool for designers is the DFMA Logic Tree (

Figure ***2***), which guides decision-making on whether a component should be retained or eliminated based on movement, material, and maintenance considerations (DFMA Logic Tree Remove Part, no date). This logic-based approach supports simplification and encourages component reduction during the early design stages.

The core objectives and benefits of DFMA include:

- **Reducing Manufacturing Costs:**

DFMA minimizes complexity and resource consumption by addressing potential manufacturing and assembly challenges early in the design process. This streamlining reduces the number of components and simplifies assembly procedures, ultimately leading to substantial cost savings (Design for Manufacturing and Assembly: A comprehensive guide, no date).

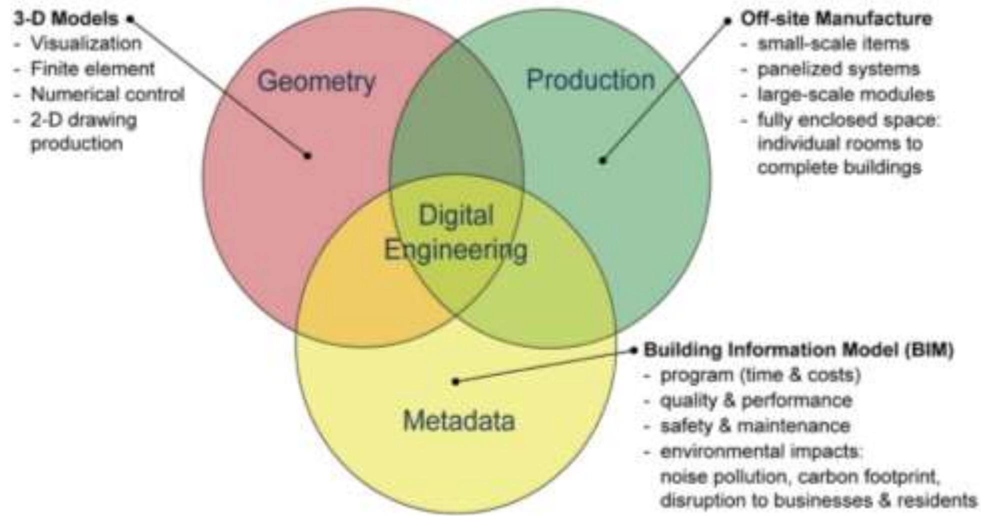

Figure 1: The DFMA Envelope (Source: Laing O'Rourke, 2013)

- **Improving Product Quality:**

By aligning design more closely with production capabilities, DFMA reduces assembly errors and inconsistencies, leading to enhanced reliability and performance of the final product (Understanding Design for Manufacture and Assembly (DfMA) - MFG Shop, no date; Widanage and Kim, 2024b).

- **Shortening the Development Cycle:**

DFMA helps designs meet manufacturability and assembly standards more quickly, reducing the need for rework or late-stage design modifications, and thereby accelerating time-to-market(Design for Manufacturing and Assembly: A comprehensive guide, no date).

- **Enabling Design-Guided Manufacturing:**

The methodology promotes tight integration between design and manufacturing. As a result, design outputs directly inform production processes, ensuring feasibility and efficiency from concept to creation(What is Design for Manufacturing: DFM Principles, Process and Techniques, no date).

- **Promoting Standardization and Modularity:**

DFMA encourages the use of standardized and reusable components, increasing consistency, reducing lead times, and improving supply chain efficiency(Design for Manufacturing: Principles and Benefits - MFG Shop, no date; Design for Manufacturing and Assembly: A comprehensive guide, no date).

- **Streamlining the Design Process:**

By shifting consideration of assembly and manufacturing constraints to the beginning of the design stage, DFMA reduces late-stage trial-and-error, enhances iteration cycles, and improves coordination across design teams(Design for Manufacturing and Assembly: A comprehensive guide, no date; 'BIM for DfMA (Design for Manufacturing and Assembly) Essential Guide', no date).

In essence, DFMA optimizes the entire product development lifecycle by embedding manufacturing and assembly considerations at the heart of the design phase—leading to better, faster, and more sustainable outcomes.

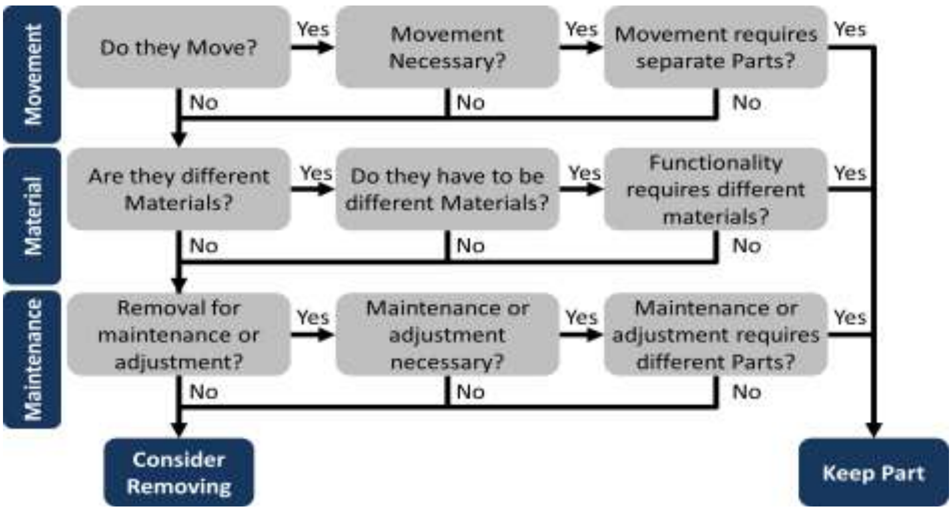

Figure 2:(DFMA Logic Tree Remove Part – AllAboutLean.com, no date)

4.2 DFMA: A Key Enabler for Construction Industrialization

With rapid shifts in the global economic and technological landscape, the construction industry is undergoing a fundamental transformation. According to (C. L. C. ; Roxas et al., 2023b), the sector faces five key challenges: the financialization of markets, aging labor forces, increasing demands for social equity, the need for structural reform, and productivity gaps. Simultaneously, it is experiencing five transformative trends: marketization, differentiation, integration, greening, and intelligence.

In response to these dynamics, construction industrialization has emerged as a critical pathway for enhancing project efficiency and sustainability. This approach emphasizes standardization, modularization, and automation, enabling higher quality outputs while addressing pressing challenges such as labor shortages, material waste, and environmental degradation.

DFMA plays a pivotal role in supporting this transformation. As an innovative design strategy, DFMA introduces manufacturing and assembly considerations early in the design phase. This proactive integration allows construction projects to realize higher efficiency, reduced timelines, lower maintenance costs, and improved environmental performance (C. L. C. ; Roxas et al., 2023b)(Gao, Low and Nair, 2018b).

4.3 Core DFMA Strategies in Building Industrialization

4.3.1 Design Simplification and Standardization

DFMA encourages the simplification of component designs while maintaining functional and aesthetic performance. By minimizing the number of parts and promoting the use of standard components, designers can streamline production processes, reduce material costs, and shorten construction cycles (What is Design for Manufacturing: DFM Principles, Process and Techniques, no date).

4.3.2 Provision of Design Principles

DFMA promotes the use of manufacturing-aware design principles early in the design stage. These principles support integrated design approaches that reduce component counts, simplify assembly steps, and align outputs with actual factory production capabilities (Jiao et al., 2021).

4.3.3 Multi-Scheme Analysis

A key feature of DFMA is its use of comparative analysis during the conceptual phase. By evaluating multiple design alternatives using scientific tools and metrics, designers can identify optimal solutions that balance manufacturability, assembly efficiency, and cost-effectiveness—minimizing rework and design changes later in the project lifecycle(Lu et al., 2021).

4.4 Conditions for Successful DFMA Implementation

To effectively implement DFMA, organizations must foster cross-functional collaboration among design, engineering, and manufacturing teams. This requires a robust distributed communication network, supported by technologies such as CAX (Computer-Aided technologies) and PDM (Product Data Management) systems. These tools provide the technical infrastructure needed for real-time coordination and efficient decision-making(Xie et al., 2013; Udroiu and Udroiu, 2016).

4.5 Technology Outlook and Cross-Industry Relevance

Globally, DFMA is recognized as a core enabler of concurrent engineering and is widely used in industries such as automotive, aerospace, and defense. Its benefits, reduced costs, shorter development cycles, improved product qualityare now being realized in the building sector as well (DFMA, 2023 n.d.) . The Figure 3 shows composition of DFMA visually summarizes how DFMA integrates with various stages of the building life cycle.

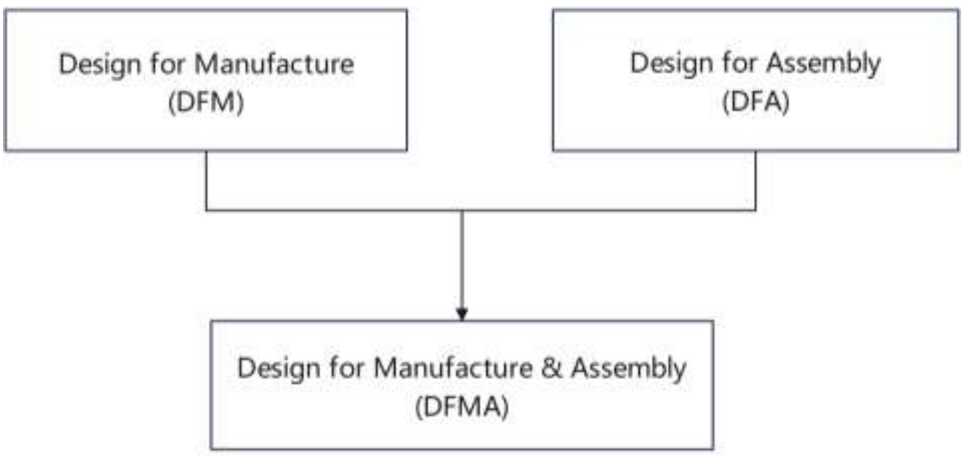

Figure 3: Composition of DFMA (Lu et al., 2021)

4.6 DFMA in the Manufacturing Stage

In the context of construction, DFMA simplifies component production by encouraging standardized, prefabricated designs. This allows components to be efficiently manufactured in controlled factory environments, reducing reliance on weather conditions and manual labor. For instance, the use of precast concrete elements has significantly improved speed, quality, and reliability in many projects.

Moreover, DFMA encourages the adoption of advanced technologies such as robotics, CNC machinery, and 3D printing enhancing manufacturing precision, enabling complex geometries, and reducing waste (DFMA, 2023 n.d.) .

4.7 DFMA in the Assembly Stage

On-site, DFMA improves construction efficiency by promoting the use of easily assembled components and reliable connection systems. These strategies help reduce labor intensity, speed up installation, and lower costs

Critically, DFMA also supports environmental sustainability. By minimizing material waste, lowering energy consumption, and enhancing resource efficiency, DFMA contributes to more sustainable construction practices (Widanage and Kim, 2024a). Figure 4, adapted from (Gupta and Kumar, 2019), illustrates the growing impact of DFMA when introduced early in the design process. It demonstrates how design adjustments made during the conceptual and early design stages incur significantly lower costs compared to changes made during or after production. This reinforces DFMA's value in reducing rework, streamlining workflows, and minimizing project risk through early-stage integration.

4.8 The specific application of DFMA :

In the context of building industrialization, DFMA is revolutionizing traditional construction practices by enhancing efficiency, improving quality, and reducing environmental impact. A prime example of its real-world application is the Forge office building project in London, United Kingdom, which demonstrates the tangible benefits of DFMA-based strategies (The Forge: The world's first P-DfMA commercial office building completes | Ideas | Bryden Wood, no date).

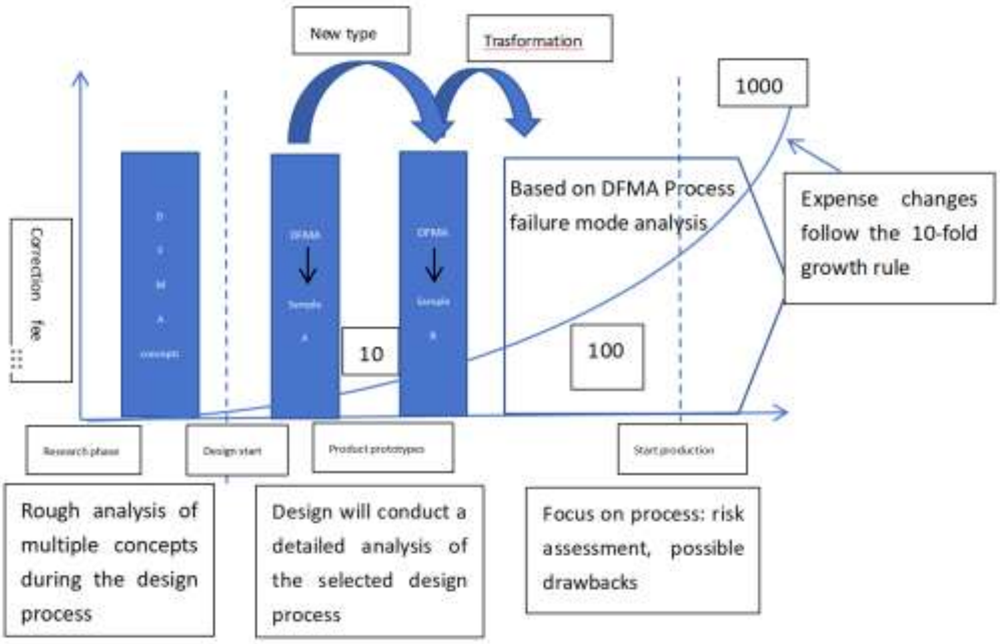

Figure 4: Growing impact of DFMA (Gupta and Kumar, 2019)

4.8.1 Case Study: The Forge Project, London

The Forge project showcases how DFMA principlessuch as design simplification, process automation, and off-site prefabricationcan significantly optimize construction workflows. These strategies enabled improved safety, reduced material costs, and accelerated construction timelines, all while maintaining high-quality standards.As illustrated in Figure 5, the Forge project adopted an approach known as Platform Design for Manufacture and Assembly (P-DFMA), developed by Bryden Wood. This approach emphasizes lean construction through early-stage collaboration and the elimination of non-value-adding activities. The results were notable:

- 30–50% reduction in on-site staff
- 25% reduction in material costs
- 13% increase in construction speed

These outcomes reflect DFMA's ability to control resource use and streamline construction logistics from the design phase onward.

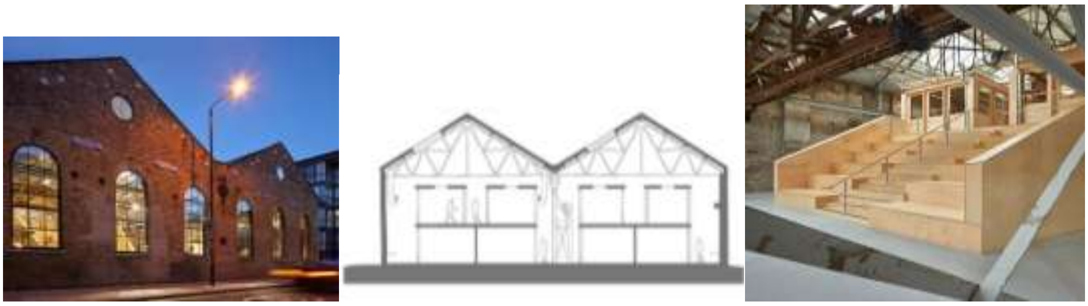

Figure 5: DFMA in Practice – The Forge Building, (The Forge: The world's first P-DfMA commercial office building completes | Ideas | Bryden Wood, no date)

4.8.2 Environmental Sustainability through DFMA

Beyond efficiency gains, DFMA plays a vital role in promoting sustainable building practices. By enabling precise prefabrication, it minimizes construction waste and optimizes resource usage. The Forge project, for example, successfully applied DFMA principles to reduce energy consumption and environmental impact while ensuring long-term building performance.

Overall, the Forge case illustrates how DFMA, when embedded into the design and construction lifecycle, can transform the delivery of large-scale projects. It highlights the method's potential to improve productivity, cost-efficiency, and environmental performancemaking it a pivotal tool for advancing industrialized construction across global markets(P-DfMA Platform Design for Manufacture and Assembly, no date).

4.9 Leveraging DFMA to Unlock Innovation Potential in the Construction Sector:

DFMA is increasingly being adopted in the construction industry to enhance productivity, reduce costs, and drive innovation. Its ability to refine manufacturing and assembly processes makes it a powerful tool for transforming traditional construction practices.

4.9.1 Cross-Industry Impact and Cost Savings

One of the most cited successes of DFMA comes from the automotive sector. For example, Ford Motor Company reportedly saved billions by applying DFMA principles to streamline the production line for the Ford Taurus (DESIGN FOR MANUFACTURE & ASSEMBLY – Kaizen Chronicles, no date)(DFMA Cuts Billions in Manufacturing Costs, no date). By reducing design complexity, minimizing material waste, and optimizing the manufacturing process, DFMA led to substantial cost reductions.

These principles have also been embraced by consulting firms such as Curry Consulting, whose DFMA-based cost-reduction services have helped clients significantly improve operational efficiency (Langston and Zhang, 2021). A key strength of DFMA is its emphasis on design stability and reliability, which in turn enhances product consistency and quality.

4.9.2 Accelerated Development and Sustainability

DFMA accelerates the product development cycle by addressing manufacturability and assembly challenges early in the design phase. This early integration helps eliminate the need for costly redesigns, leading to faster transitions from design to production.

Environmental sustainability is another area where DFMA demonstrates significant value. By reducing material consumption and waste output, DFMA supports eco-friendly construction practices. This aligns with the growing consumer demand for sustainable buildings and products (Wasim, Vaz Serra and Ngo, 2022).

4.9.3 Construction Sector Potential

Within the construction sector, DFMA holds substantial potential—especially in modular and prefabricated structures. Despite ongoing productivity issues in the industry over the past two decades, DFMA offers a pathway to improve efficiency, reduce environmental impact, and elevate project outcomes(Montazeri et al., 2024).

Emerging research focuses on DFMA's role in:

- Innovation and technological advancement
- Sustainability and environmental outcomes
- Regulatory and policy frameworks
- Collaborative methodologies
- Lifecycle applications and challenges

4.9.4 Design Process Transformation

DFMA streamlines the architectural design process by embedding manufacturing and assembly considerations from the outset. This reduces the need for late-stage design revisions and shortens development timelines. As noted in a research, modular and parametric design approaches promoted by DFMA improve flexibility, material selection, and cost analysis reshaping traditional design thinking (Razak et al., 2022b).

4.9.5 Digital Tools and Process Integration

Advanced tools such as Building Information Modelling (BIM) play a critical role in enabling DFMA. BIM ensures alignment between design, production, and construction, improving information flow across stakeholders and enhancing project accuracy and coordination(A review of the application of Design for Manufacturing and Assembly (DfMA) in the construction industry, n.d.).

Figure 6adapted from DFMA Technology for Manufacturing and Assembly and Its Application Case Analysis, highlights the contribution of DFMA to improved build quality, reduced site labor, and consistent component performance when manufactured in controlled environments.

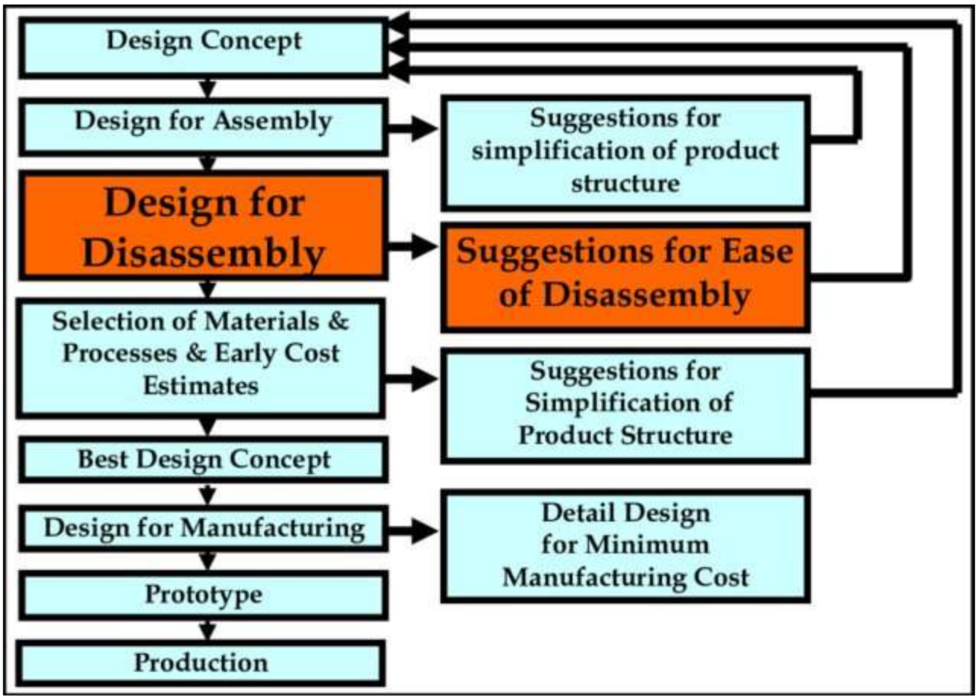

Figure 6: Process Integration Using DFMA (Motevallianet al., 2010)

4.9.6 Environmental Sustainability and Industrialization

DFMA promotes environmental sustainability by optimizing designs to reduce construction waste and energy consumption. It supports resource efficiency and helps create greener, more responsible building practices (Montazeri, Lei and Odo, 2024b).

When integrated with modular construction, BIM, and smart building technologies, DFMA fosters vertical integration across design, manufacturing, and assembly stages. This interconnected approach propels the industrialization of construction and enables scalable, sustainable project delivery(Zhang Baiyan et al., 2023).

DFMA serves as both a cost-saving tool and a driver of innovation in the construction sector. Its ability to streamline design, boost sustainability, and align with digital technologies positions it as a key enabler in the evolution of large-scale structural design and modern building industrialization.

V. Challenges and Opportunities

The application of DFMA in the industrialization of buildings presents a range of both challenges and opportunities. While these challenges can impede implementation, they also act as catalysts for technological advancement and new business models in the construction sector(Liu et al., 2023).

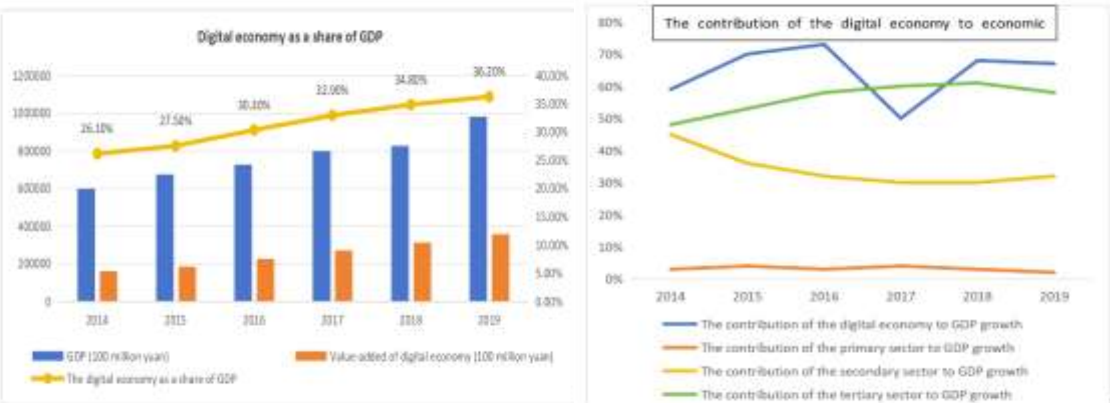

Figure 7: DFMA's Economic Impact on GDP

5.1 Technical Challenges

One of the most significant obstacles in DFMA implementation is overcoming technical barriers. These include the need for:

- Mastery of new materials and manufacturing processes
- Adoption of advanced automation and digital tools (e.g., BIM, ERP, MES)
- Upgrading of design platforms to accommodate early-stage manufacturing inputs

DFMA requires a high level of integration between design and production. This calls for system-wide collaboration across disciplines and may necessitate technical training and substantial investment in new technologies(Montazeri, Lei and Odo, 2024b) .

As shown in Figure 7, DFMA's influence on national GDP underscores the need for resolving such technical bottlenecks to realize full industrial-scale benefits.

Waste management is another area of concern. The construction industry remains one of the largest global contributors to waste. DFMA addresses this by improving design efficiency and minimizing material loss, thus lowering both environmental impact and economic costs (C. L. C. Roxas et al., 2023b) .

Furthermore, the effective application of DFMA hinges on quality control. This includes:

- Implementing advanced testing methods
- Ensuring compliance with safety protocols
- Aligning production outcomes with design standards

Finally, DFMA must consider environmental sustainability by reducing the carbon footprint of buildings, supporting green materials, and optimizing resource consumption ('"Environmental Impact and Sustainability of Industrial Buildings"', no date) .

5.2 Management Challenges

Implementing DFMA also presents organizational and managerial challenges. These include:

- Shifting from siloed departments to cross-functional collaboration
- Adapting project management models to be more iterative and flexible
- Encouraging a culture of innovation and digital readiness

To support DFMA adoption, companies may need to restructure team communication channels and leadership approaches to integrate design, production, and on-site assembly seamlessly (Montazeri et al., 2024).

5.3 Environmental and Sustainability Challenges

DFMA inherently supports sustainability but only if implemented thoughtfully. Environmental challenges include:

- Choosing eco-friendly and renewable materials
- Improving energy efficiency during production
- Reducing greenhouse gas emissions and site-level waste

DFMA-driven modular and prefabricated construction minimizes on-site waste and optimizes resource utilization. It contributes to a circular economy model by reducing energy use and ecosystem disruption(Roxas et al., 2023).

There is also growing pressure for the construction industry to adopt green finance mechanisms including incentives for carbon reduction, urban renewal, and sustainable business models. DFMA plays a crucial role in meeting these expectations through design innovation, performance modeling, and policy alignment.

5.4 Opportunities: Innovation and Market Potential

Despite the challenges, DFMA opens substantial opportunities for the construction industry. Key benefits include:

- Enhanced market competitiveness through increased productivity and cost efficiency
- Shortened construction timelines and improved delivery reliability
- Access to new markets driven by demand for energy-efficient and green buildings
- Support for compliance with future regulations on sustainability and prefabrication

DFMA offers firms a strategic advantage in an increasingly sustainability-conscious market, positioning them to lead in innovation while fulfilling both economic and environmental goals.

VI. Future Trends and Development Directions

As DFMA continues to evolve within the construction sector, future research and practice are expected to explore new frontiers in technology, industrial application, and regulatory alignment. These advancements will shape the next generation of construction innovation and sustainability. The Figure 8 shows the key field that are related to DFMA in the construction sector.

Figure 8: Key Fields Related to DFMA in Construction

6.1 Technological Innovation Trends

Technological progress will remain the primary driver of DFMA advancement. Innovations in materials, digital tools, and automation are expected to significantly enhance production efficiency and product quality. One of the most promising developments is additive manufacturing (3D printing), which has the potential to revolutionize how complex building components are designed and fabricated.

Such technologies not only reduce waste and lead time but also allow greater flexibility in form, structure, and customization positioning DFMA as a core enabler of next-generation construction solutions(Montazeri et al., 2024).

6.2 Industry Practice Trends

Industry adoption of DFMA is accelerating, particularly in regions prioritizing off-site construction, modular assemblies, and digital transformation. As more organizations experience its benefits such as shortened timelines, improved consistency, and reduced costs, DFMA is expected to become a standard practice in the design and delivery of both public and private sector projects.

Moreover, emerging construction models such as design-build-operate (DBO) and integrated project delivery (IPD) are increasingly aligning with DFMA principles to improve collaboration, minimize waste, and streamline decision-making across project life cycles(Montazeri et al., 2024).

6.3 Policy and Regulatory Support

Government policy and regulatory frameworks play a pivotal role in the broader adoption of DFMA. In many countries, authorities are introducing incentives, mandates, and green certification programs to promote industrialized, sustainable construction practices.

These policy shifts are intended to:

- Accelerate construction modernization
- Encourage adoption of low-carbon and digital construction techniques
- Align infrastructure development with sustainability goals

Supportive regulation will be essential to standardize DFMA-based methodologies and ensure that its benefits, efficiency, safety, cost savings, and environmental performance are consistently realized across projects (DFMA,2023,n.d.).

VII. Conclusion

This report has presented a critical review of the application of Design for Manufacturing and Assembly (DFMA) in the industrialization of construction and its transformative role in large-scale structural design. The findings highlight DFMA's significant contributions to improving building productivity, reducing costs, and minimizing environmental impact. By simplifying design, standardizing components, and optimizing the assembly process, DFMA enhances both construction efficiency and project outcomes.

Beyond operational benefits, DFMA also supports broader sustainability goals by reducing construction waste, lowering energy consumption, and promoting better resource utilization. Its integration contributes to improved building quality, enhanced construction safety, and accelerated project delivery making it a vital approach in modern construction practices.

Despite these advantages, the implementation of DFMA continues to face challenges. These include technical limitations, regulatory constraints, supply chain complexity, and environmental sustainability considerations. Overcoming these barriers requires coordinated efforts from industry stakeholders, policymakers, and researchers alike.

Looking ahead, several areas merit further investigation:

- Empirical research to evaluate the real-world impacts of DFMA through case studies and field trials.
- Technological innovation, particularly the integration of emerging tools like 3D printing, robotics, and automation.
- Sustainability-focused studies that explore DFMA's role in reducing carbon footprints and supporting circular construction practices.
- Policy and regulatory analysis to identify barriers and propose frameworks that support broader adoption of DFMA in the built environment.

In summary, DFMA holds tremendous potential to reshape the construction industry by fostering efficiency, sustainability, and innovation. With continued research and support, it can become a cornerstone of future-ready, high-performance building systems.

Statements and Declarations

Funding Declaration

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Ethics Declaration

Ethics declaration: not applicable.

Consent to Participate

Consent to Participate declaration: not applicable.

Consent to Publish
Consent to Publish declaration: not applicable.

Author Contributions

Zetong Yu: Conducted the literature review, compiled relevant case studies, and contributed to the initial manuscript draft and data visualization.

Amarnath Krishnamoorthy: Conceptualized the study, led the critical analysis, contributed significantly to the methodology and structure, and supervised the overall development and final revision of the manuscript. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Competing Interests
The authors declare that they have no competing interests.

Data Availability
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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