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Sustainable and Affordable Residential Construction in the U.S.: Modular Construction and Domestic Resource Strategies

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Abstract - The United States (U.S.) has a growing affordable housing crisis driven by construction costs and prolonged project duration. Traditional construction technologies are often cost-ineffective and time-consuming; modular construction (MC) can decrease construction costs, labor, material waste, and time. Challenges such as regulatory barriers, financial issues, and preconceptions about design flexibility and robustness still affect its adoption. This study will examine ways to incorporate MC into Silver Spring, Maryland, U.S. residential housing by exploring the roles of national strategies through domestic timber production, thus stabilizing cost of material and enhancing economic security while providing cost-effective, locally produced housing solutions.

Case studies, literature reviews, industry reports, and policy frameworks were reviewed to help identify the factors that either support or hinder the adoption of MC. Technological advancements, regulatory reforms, and industry collaboration are explored as ways to increase the use of MC for affordable housing, and strengthen local economies, and enhance environmental resilience. This study will investigate barriers to the adoption of MC related to policy and people's perceptions and offer practical recommendations to improve MC and help solve the housing affordability problem in Silver Spring, Maryland U.S., Providing feasible and environmentally friendly options, and enhancing time effectiveness and cost reduction in the residential housing sector.

Keywords: Modular Construction (MC); Affordable Housing; Domestic Timber Policy; Housing Cost Burden; Sustainability; Urban Development; Policy and Regulatory Barriers

1. INTRODUCTION

The U.S. is facing a persistent affordable housing crisis due to rising construction costs, lengthy construction time frames, and rapid urbanization. This has resulted in the need for affordable housing (Enwin & Ikiriko, 2023). According to Reeh (2019), in 2016, approximately 100 million individuals lived in low-density sub-urban environments surrounding significant cities in the U.S. projecting that by 2050, over 301 million suburbanites will exist due to the cost of housing in major cities. Given the current market conditions, research into new construction approaches and adopting new building techniques is required.

According to Congressional Budget Office (2025), the construction of new residential housing plays a significant role in the U.S. economy, providing housing for growth and serving as a source of economic activity, single-family housing construction worth ranges between three to four percent of gross domestic product. The residential construction sector which represents residential fixed investment maintained a 4.5% share of U.S. gross domestic profit between 1980 and 2007 with its peak at 6.3% in 2005 followed by a decline during the housing crisis. The construction sector maintained different GDP percentages between 1995 and 2015 as it reached 9.4% in 1999 and declined to 5.1% in 2010 (Associated Builders and Contractors, 2016). Traditional building methods often fail to provide cost-effective, less labour intensive and time-efficient solutions for the housing market, resulting in the need to explore innovative construction techniques (Mandala & Nayaka, 2025).

According to Mukhija (2022), lack of suitable housing for low and moderate-income in the U.S. is linked to the persistent increase in the cost of residential construction, the cost of materials, labor, and land has been increasing at an estimated rate of 7 - 8 percent yearly since the 1990s, which is not in correspondence with the rate of wage growth and consumer inflation, thereby causing a large disparity in housing affordability for average income levels.

MC is a building method where building components are prefabricated off-site and assembled on-site, these provide a promising solution to reduce construction costs and accelerate product delivery (National Association of Home Builders, 2025). MC has been successfully implemented in various project demonstrating its ability to reduce construction timeline by 35% and costs by 22% (Gómez & Sánchez, 2024). Hurx (2023) noted that until the mid-20th century, the intricate and multifaceted architectural development process intrinsically intertwined with the fabrication development process. Crafted or mass-manufactured products, whether produced on a small scale or large scale, were skillfully manufactured in a workshop or factory by skilled carpenters, proficient masons, or dedicated steelworkers. These meticulously created elements were efficiently delivered to the construction site, assembled, and constructed into the final building. However, in the 1950s, architecture development and building construction experienced a radical and transformative change as some innovative architects began to spearhead the MC revolution, which significantly altered traditional practices in the field (Wuni & Shen, 2020).

According to Jiang et al. (2019) adoption of MC in residential construction has however remained relatively limited due to concerns over financing, design limitations, and regulatory barriers. MC is majorly dependent on engineered wood and timber part which importing may pose a financial burden (Staub-French & Khanzode, 2007). Developers and construction companies most often navigate complex approval processes, transportation logistics, and market perception that modular fabricated construction lacks the durability and qualities of traditional build. Song, Li, Deng & Li (2022) noted that despite the efficiency of prefabrication in delivery time and cost-efficiency, critics it may not be efficient for quality and safety assurance because members are manufactured in a controlled factory environment and assembled on-site, issues may arise from materials or workmanship which can result in structural weakness.

Cranston (2025) suggested that adoption of MC is difficult due to restricted flexibility in design; MC components are manufactured in standardized sizes and configurations, which pose a challenge in designing to clients' specifications and tastes, which makes MC less adaptable for nontraditional layouts. Fegan (2025) argued that the cost of logistics in transporting pre-fabricated units to the site can be a significant expense, especially in dense and inaccessible locations. The factory also requires technological investment in machines and labor, which may impose an additional cost (Fegan, 2025).

Walk-Morris (2021) opined that local regulations and zoning laws may pose challenges to the adoption of MC. Most building regulations and codes are formulated for traditional construction methods, and these may require amendment (Walk-Morris, T., 2021). Adam et al. (2015) noted that time and cost are pivotal elements significantly illustrating the detrimental impacts that could negatively affect construction activities; construction industry stakeholders most often do not contemplate these time and cost-saving innovations that could significantly enhance their operations and drive better results. Given these challenges, it is exceedingly important to identify how MC can be implemented for residential applications.

This study aims to explore ways to streamline MC adoption by identifying major factors that influence it, providing actionable recommendations for overcoming existing barriers, and advancing MC as a mainstream solution for affordable housing in the US.

MC is a potential strategy to reduce the cost of construction and accelerate delivery time. It has been evident in past projects that MC has been beneficial in streamlining processes, reducing material waste, and optimizing labor output, thereby reducing overall construction costs. Despite these proven benefits, its adoption has been limited due to financial constraints, concerns about design flexibility, regulatory challenges, and market hesitance regarding durability and long-term values (Wuni & Shen., 2020).

This has resulted in the need to investigate scalable strategies for integrating MC into mainstream residential development in the U.S. This study aims to explore how MC can be integrated to improve affordability, examining barriers, policy implications, and industry innovative solutions that can enhance its adoption to advance MC as a viable and sustainable approach to affordable housing crisis in the U.S.

This study investigates strategies for integrating MC techniques into residential housing construction in the U.S. to reduce construction costs, improve project efficiency, and enhance affordability. It identifies barriers and opportunities and provides actionable recommendations for adopting MC as a solution to persistent housing costs.

The research Objectives are:

1.Examine barriers to adopting MC in the residential housing sector in Silver Spring, Maryland.

2.Analyze successful case studies of MC implementation and evaluate best practices that can be adopted.

3.Assess policy and local regulations affecting the adoption of MC and propose ways of reforming this policy to support its adoption.

4.Provide a model that can serve as a basis for easy adoption of MC.

This study identifies methods for improving housing construction efficiency and scalable techniques that can be adopted. However, despite MC's broad adoption in commercial projects, its use in residential construction is limited (Gibbs & Pendlebury, 2006). This study will help policymakers, urban planners, developers, and construction professionals better understand MC feasibility and economic viability for affordable housing, identify barriers, and propose strategies to overcome adoption barriers while contributing to sustainable development by integrating locally produced timber, reducing material waste, improving energy efficiency, and sustainable urban initiatives.

2. BODY OF PAPER

Traditional construction, also called stick-built construction, involves the on-site creation of building components in phases. Traditional construction is still the most common method for residential and commercial buildings today. Laborers assemble them using materials that are procured to the site. The main advantage of traditional construction is that it is easy to alter the design of the building and solve quite complex architectural designs. However, delays, labor-intensive work, and extended project duration are likely to increase the cost of the project and reduce its efficiency. MC is a new approach that has many advantages over conventional construction methods. Building modules are constructed off-site, ensuring that the construction's quality is well controlled during the production process as it is done in a controlled environment with close supervision (Jones, Smith, & Williams., 2019). The construction time is reduced since as the modules are being manufactured, the site is being prepared. MC is efficient because it minimizes waste and has little or no environmental impact due to the optimal utilization of materials. Lawson and Ogden (2020) noted that MC positively impacts cost reduction and enhances overall efficiency and environmental sustainability. MC seems to reduce project timeline by up to 50 Percent compared to traditional methods and hence a means of reducing housing shortage (Bertram et al., 2019). MC is compatible with sustainable development principles by reducing construction waste and energy consumption. Because of the controlled environment in which the construction is performed, the materials used are utilized to the maximum, and there is minimal waste. MC has been established to save costs, optimize time efficiency, improve sustainability, and ensure quality control. According to a study by Smith 2020, MC can significantly reduce up to 20% overall project costs due to economies of scale, reduced material wastage, and reduced labor costs. MC also reduced the project timeline by 30 - 50% compared to the traditional approach of construction, attributed to module production and parallel site implementation, eliminating delays like weather and all other factor. Gibb & Isack (2003).

Jaillon & Poon (2010) also revealed that MC reduced wastage in construction by up to 80%, contributing to sustainability and green building initiatives. It also ensures quality control by prefabricating modules in factory-controlled environments, where high precision and consistency contribute to better building quality and performance (Lawson et al., 2012). A study by the Modular Building Institute (MBI) of 17 PMC projects revealed that an average of 45% cut timeline and costs were 16% lower than traditional site-built methods (Modular Building Institute, 2019). The reduction in time was due to parallel site development and module fabrication, which enabled simultaneous multiple construction activities. Furthermore, cost savings were realized by utilizing economies of scale in material procurement and better labor productivity in factory settings.

A case study from Guerdon Modular Buildings, a leading modular housing manufacturer, revealed how MC is cost-predictable compared to traditional construction. They found that cost overruns were minimized because the construction work activities were conducted in a controlled environment, eliminating weather-related delays and fluctuations in the price of materials (Guerdon Modular Buildings, 2021). This study also pointed out that MC is not only cost-saving but also offers a financial guarantee, which is helpful for developers operating on a strict budget. The 62M Condominium project in Winnipeg, Canada, has shown how MC can produce innovative architectural designs without bursting the cost budget. The project used a circular modular design that lessened material waste and optimized space use (Murray, 2014). As a result of the MC method, the project was built within less than two years, which is considerably less than a similarly sized, traditionally built condominium. This shows the versatility and adaptability of modular methods. A study carried out in Seattle investigated the practicability of modular prefabrication for mid- to high-rise residential buildings (Gambatese & Rogge, 2018). The study revealed that although MC had some challenges in terms of transportation logistics and regulatory approvals, it helped lower labor costs and speed up the project duration. Developers in high-cost urban areas can use MC to address labor shortages and enhance project efficiency.

Despite the advantages MC proffers, the adoption has faced significant challenges, including economic, logistical, local regulation, and design-related factors. Gibb (2001) noted that MC requires a high capital investment for setting up a factory, machinery, and specialized equipment, which can be a significant disadvantage and discouragement for housing developers contrary to the traditional method of construction, which requires on-site labor and periodic material procurement In an area like Silver Spring MD involving dynamic real estate and generally expensive this capital investment can seem to be a barrier to adoption of modular housing firms.

Also, MC may require standard procedures, limiting the creative innovation of architecture and options to be customized according to individual preferences and tastes, making it less adaptable for some projects (Lawson et al., 2012). Traditional construction incorporates the freedom to customize structures to client preference. The lack of ability to customize poses an issue for the adoption of MC in the Silver Spring area, where home-buyers and investors explore unique architectural styles, which may be difficult to achieve with MC. Also, Zoning and building codes and regulations in Silver Spring are majorly designed for traditional construction, making it difficult for approval (Smith, 2020).

Goodier and Gibb (2007) noted that prefabricated modules can be huge and bulky, resulting in transportation and handling challenges, cost overruns, and project delays. Considering Silver Spring's dense traffic and urban congestion, road and bridge constraints in the form of load restrictions and limited open space for storing modules can pose an excellent challenge for MC regarding the risk of damage and added costs.

3. METHODOLOGY

This study adopt a qualitative research design approach using secondary data collection. A descriptive research method was used to analyze factors affecting MC, such as industry perception, regulatory constraints, and economic considerations. A systematic and comprehensive approach to reviewing household trends, government regulations, and industry reports to establish challenges to MC adoption. Data analysis were carried out using meta-analysis to review the findings from the sources and provide more detailed insight into the adoption of MC.

Previous literature on MC was reviewed by;

1. An economic research approach was used to derive information on housing affordability and median income and to explain how housing costs affect affordability for individual households.

2. Urban planning and Public Policy to understand existing zoning laws, housing regulations, and policies to understand how to navigate the adoption of MC

The meta-synthesis was used because it provides a framework for collection of barriers reported in different studies. The barriers identified were classified into major category for conceptual framework and recommendation for adoption of MC was proposed based on thee findings.

The data collection method adopted was secondary data research collection, whereby existing data, such as literature reviews, statistical databases (US census, DSS), and historical trends, are used to evaluate existing information on the adoption of MC. Data analysis were carried out using meta-analysis to review the findings from the sources and provide more detailed insight into the adoption of MC. Meta-synthesis was also adopted because it provides a framework for collection of barriers reported in different studies. The barriers identified were classified into major category for conceptual framework and recommendation for adoption of MC was proposed based on thee findings

The research identified 30 articles on issues affecting MC adoption through a period of 2010 to 2025 which emphasize the need and significance of the research area and also have a better perspective on the current research topic. The period from 2010 to 2011 (Fig 4) showed minimal research activity because only one article appeared yearly. The topic received little research attention or interest during this period. The number of published articles experienced small increases during the years 2013 and from 2019 through 2020. The field shows occasional periods of rising interest because three articles were published during these specific years. The number of articles shows a steady growth pattern from 2022 through 2024, with the most significant increase observed in 2023 and 2024 when the article count reached 5 and 7, respectively. MC has gained more research interest during this period.

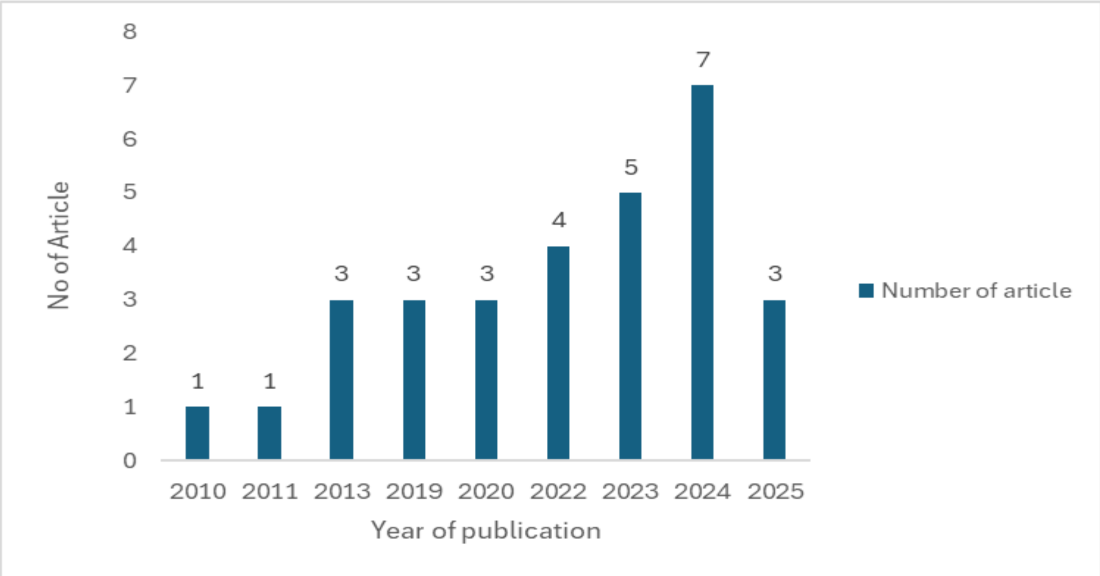

Figure 5 : Trends of article published in journal on MC

The article included in this research were published in high impact journals. Table 4.3 shows the journal distribution included in the study.

Table 4.3 : *Trends of article*

Name of Journal	**No of Article**
Alexandria engineering journal	1
Discover Applied Sciences,	1
Sustainability	3
International Journal of Construction Education and Research,	1
Journal of Construction Engineering	1
International Journal of Construction Management,	4
Journal of Engineering, Design and Technology	2
Mdpi	2
Journal of cleaner production	3
Sustainable development	1
Applied Sciences	1
Springer	2
International Journal of Civil Engineering and Construction	1
Construction management and economics	3
Int. J. Res	1
Construction Innovation	1
International Journal of Structural Engineering	1
Construction Research Review	1
International Journal of Innovative Technology and Exploring Engineering	1
Total	30

4. Result and Discussion

4.1 Housing Cost Burden

4.1.1 Gross Rent / Percentage of Household Income

Table 4.1 reveals the distribution of the percentage of household income spent on gross rent. The table shows a total of 20,683 household respondents. It can be inferred that there is a high housing cost burden with 4,250 households, which is the largest group that spent 50% or more of their income on housing, and 2,422 households spent between 40% and 49.9% on housing. The housing percentage income between 25.0% to 29.9% and 30.0% to 34.9% are approaching cost burden and may be at risk of being severely burdened due to slight income fluctuation or rent increase.

Over 6,672 households spent more than or almost 40 % of their income on housing, facing financial strain. This shows that residential housing is a concern, as many households are above the 30% affordability benchmark, reinforcing the need for affordable housing projects.

Table 4.1 : *Gross Rent as a Percentage of Household Income*

Percentage Income (%)	Estimate (nos)
Less than 10.0	288
10.0 to 14.9	2,587
15.0 to 19.9	4,160
20.0 to 24.9	1,840
25.0 to 29.9	3,525
30.0 to 34.9	1,593
35.0 to 39.9	960
40.0 to 49.9	2,422
50.0 or more	4,250
Not computed	498

Source : U.S. Census Bureau, ACS 1-Year Estimates, Table S1903 (2023). Retrieved from https://data.census.gov on April 1, 2025

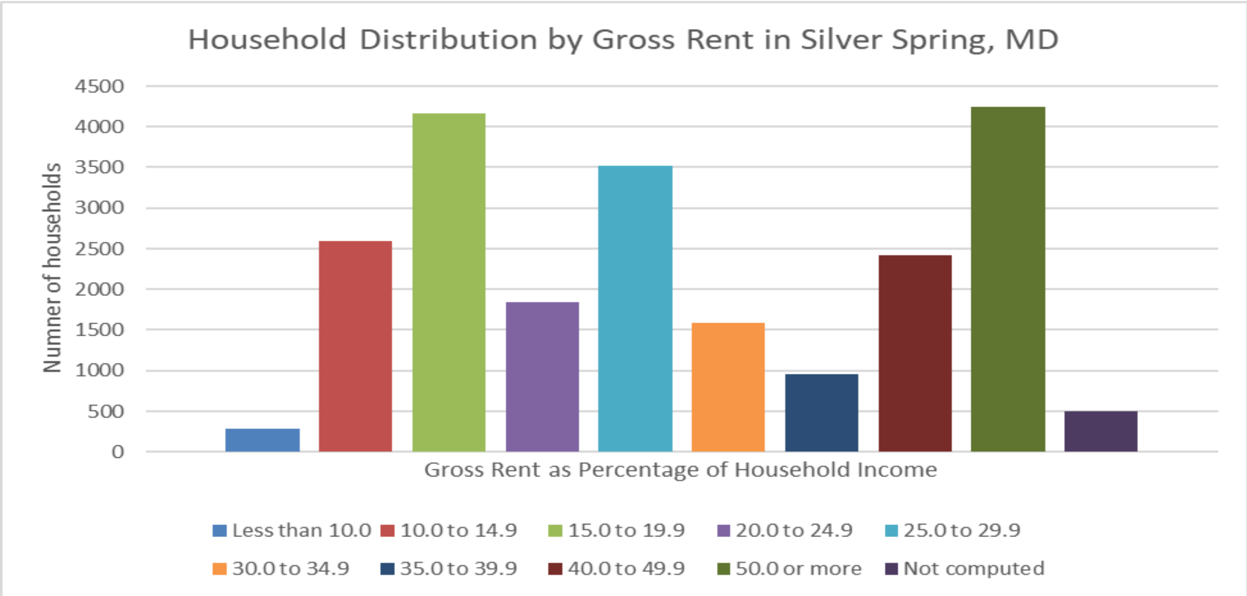

Figure 1 : Gross Rent as a Percentage of Household Income

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4.1.2 Mortgage Status and Monthly Owner Costs as a Percentage of Household Income.

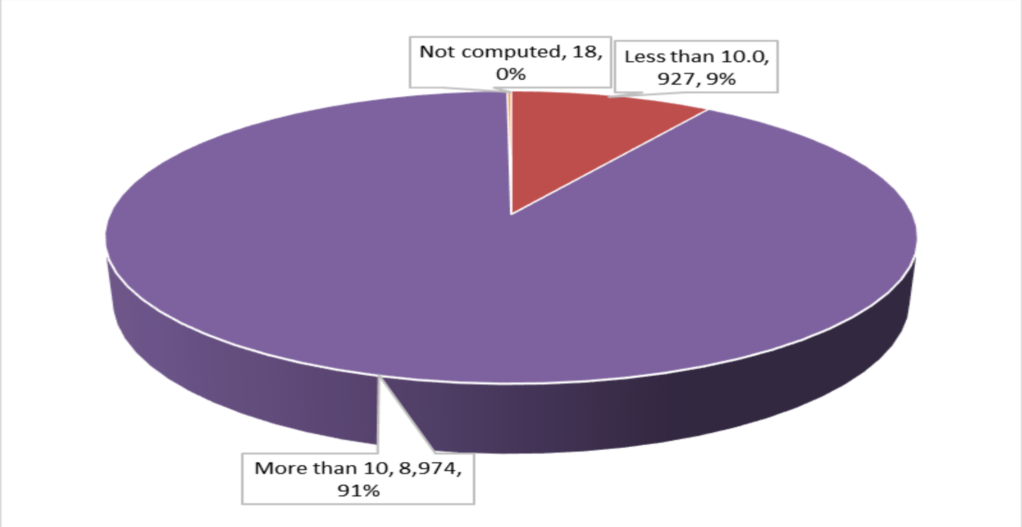

Figure 2 : Distribution of housing unit with a mortgage by Income Percentage

The pie chart above illustrates the distribution of household mortgage payments as a percentage of income. The majority of homeowners spend more than 10% of their income on mortgage payments, which reinforces that housing affordability is a concern for many homeowners.

4.2 Assessment of Housing Affordability Using HUD Metrics

According to Housing and Urban Development, the household burden threshold is categorized into two;

1. A cost burden greater than 30% indicates that households spend more than 30% of their income on Housing.
2. A cost burden greater than 50% indicates households spending more than 50% of their income on Housing.

4.2.1 Renters and Owners Housing Income Cost Burden

Table 4.2 : *Household Income as Percentage of Household Area Median Family Income (HAMFI)*

Household Income as percentage of HAMFI	**Cost Burden > 30%**	**Cost Burden > 50%**	**Total**
<= 30%	4690	3890	5300
30% to <= 50%	4120	1430	4,845
50% to <= 80%	1140	155	2,645
80% to <= 100%	1075	115	3,010
>100%	870	105	17,500
Total	12,195	5,690	33,295

Source : U.S. Department of Housing and Urban Development. (2025). Comprehensive Housing Affordability Strategy (CHAS) data. https://www.huduser.gov/portal/datasets/cp.html

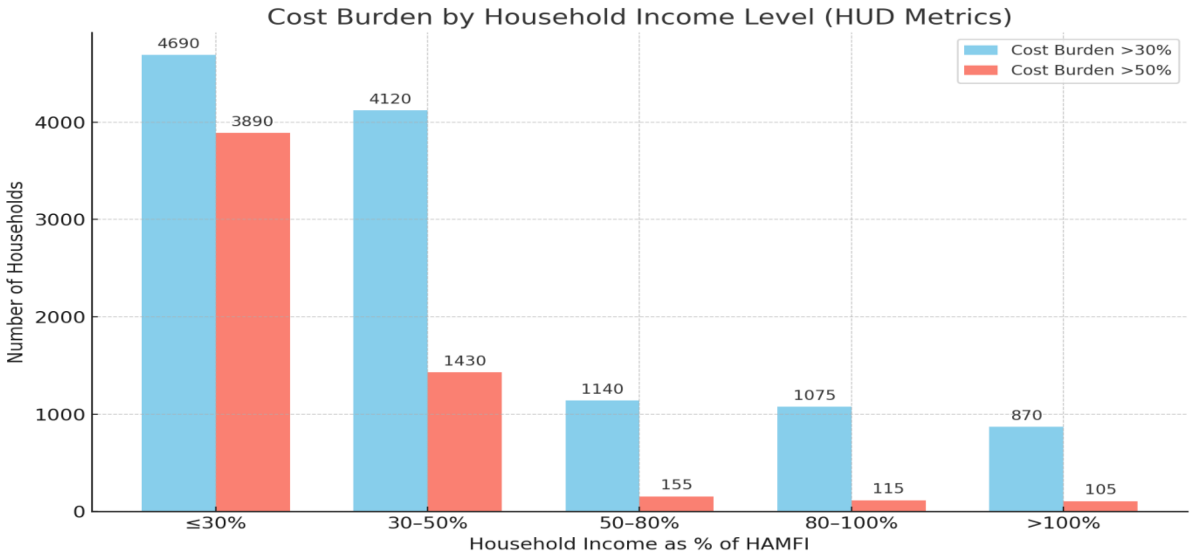

Figure 3 : Household Income as Percentage of Household Area Median Family Income (HAMFI)

The above data shows the distribution of renters' and homeowners' household levels of cost burden based on income levels. The table indicates that lower-income households of less than 30% of HAMFI bear the highest cost burden, with 4690 households spending more than 30% and 3,890 spending more than 50% of their income on housing expenses. A cost burden greater than 30% indicates that a household spends more than 30% of its income on housing. The housing cost burden makes achieving financial stability difficult, indicating a high-cost burden among low-income earners.

4.3. Linking Cost Burden to Construction Method Limitations and the Need for Innovation

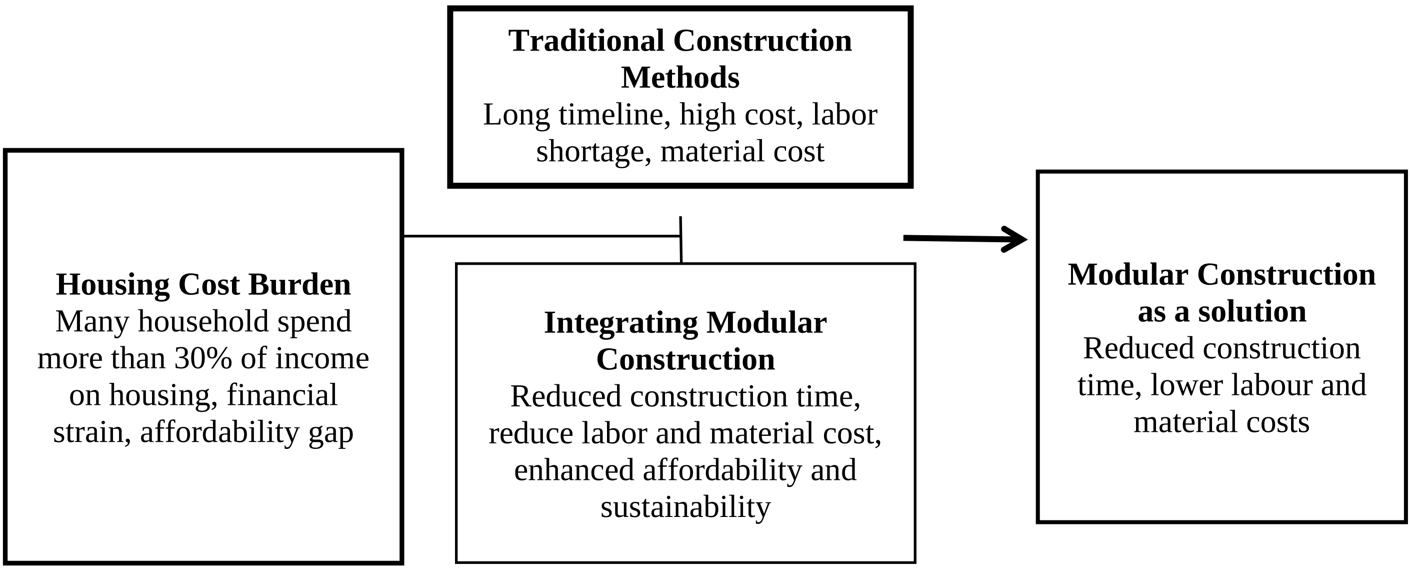

Figure 4 : Relating Housing Cost Burden with Construction Methods.

The data presented in 4.3.1 reveals the extent of the housing cost burden; a significant percentage of the sample group earns less, spending more than 30% and 50% of their income on housing expenses, which indicates the spread of financial housing constraints. This affordability gap indicates the failure of traditional construction methods to meet the demand for cost-efficient houses. Literature revealed that the traditional construction method is known for the high cost of materials, labor shortages, and delays due to complexities, which further reinforce the need for alternative solutions. MC offers compelling solutions. Case studies and literature reviews revealed its potential to reduce costs by up to 50%, reduce labor dependencies, and leverage domestically sourced timber for material cost stability.

4.4 Analysis of barriers to MC Adoption

4.4.1 Lack of awareness and Public Perception

Ribeiro, Arantes, & Cruz, (2022) noted that public perception issues and a widespread lack of awareness about the technology has affected the adoption of MC. Traditional stick-built construction methods remain the most well-known residential construction approach because people feel more at ease with this established method. The widespread knowledge of traditional construction techniques leads people to doubt alternative building approaches, including modular construction. According to Agapiou (2022), one of the significant barriers identified in the study was the perception that MC might not align with preferences, especially when compared to traditional construction methods..

People commonly mistake modular homes for tiny homes or mobile homes. However, these homes serve different purposes and lack the structural strength and design versatility of contemporary modular systems. The modular home industry provides full-scale residential solutions that match or exceed traditional construction standards in terms of quality, energy efficiency, and visual appeal (Lawson, Ogden, & Goodier, 2012). The public remains unaware of these distinctions, which leads to decreased demand and resistance toward modular construction.

The negative perception of non-standard building techniques intensifies in areas where people link new approaches to dangerous risks. Doubts about resale value act as barriers that prevent people from showing interest in modular housing. Williamson, Ganah, and John (2019) emphasize that lack of awareness suppresses innovation, investment, and collaboration in the modular sector. Developers and policymakers avoid investing in modular projects because they fear both community opposition and market unpredictability (Pan & Sidwell, 2011).

4.4.2 High Initial Factory Setup Costs

The main obstacle to MC adoption is the high initial factory setup costs which can prevent new entrants from entering the market and limit production capacity. MC's high initial capital requirements stand as a significant barrier to its broad market adoption. The construction process of MC demands significant financial investments during its initial stages to build or obtain advanced manufacturing facilities, purchase specialized equipment, and train personnel who understand modular systems. The initial costs of MC include expenses for precise engineering work, digital BIM tools, and quality-controlled fabrication spaces. The capital requirements of MC create substantial financial risks for developers and contractors who lack financial reserves or have limited credit access during uncertain market conditions. The time-based return on investment in MC makes stakeholders who focus on short-term financial gains and have limited patience for delayed returns less likely to invest. Wuni and Shen (2020) state that financial support through modular-friendly loans, public-private partnerships, and government subsidies is necessary to overcome firm hesitation that restricts MC growth in public and private sector projects. To make MC more accessible and scalable for affordable housing initiatives, it is important to address this financial hurdle through public-private partnerships,start-up grants, and government-backed financing programs.

4.4.3 Transportation Challenges in Urban Areas

The MC process differs from traditional methods because it requires transporting prefabricated modules, such as volumetric or panelized units, from manufacturing facilities to the construction site for assembly. The transition to this new approach creates multiple logistical problems that require detailed planning and precise execution. Tsz Wai et al. (2023) state that route selection, road clearance, traffic conditions, and module size constraints need a thorough evaluation to achieve safe and timely transportation. Transporting large modular units poses major logistical challenges that hinder the widespread adoption of this construction method throughout dense urban areas such as Silver Spring, Maryland. Transportation of large modular units from factory settings to building sites becomes challenging during MC because traditional construction relies on sending materials in smaller pieces for piece-by-piece assembly on-site.

The dimensions of modular units surpass standard transportation restrictions because they are considered oversized loads. Urban construction sites face constraints from limited storage and staging space because they typically have less available space than rural or suburban locations. Thus, just-in-time delivery is necessitated, which heightens traffic-related and scheduling-related risks. Project expenses rise substantially when developers need to acquire specialized transportation logistics combined with pilot cars and route planning and obtain permits. Sometimes, they need police escorts, which reduces some of the cost advantages of MC. Developers working on urban projects avoid MC because the complex transportation needs outweigh the time and cost advantages of off-site manufacturing.

4.4.4 Structural Performance of MC

According to Parisi and Donyavi (2024), the construction industry expresses skepticism about modular construction because of concerns about quality assurance, design limitations, and regulatory challenges. Modular homes have superior structural resilience as opposed to the notion that they may not be able to perform like traditionally built homes. Impresa modular (n.d) noted that modular homes have 20%-30% strength than traditional stick-built homes due to the need for transport modules. A study conducted by FEMA after Hurricane Andrew in 1992 revealed that modular homes in Dade County, Florida, withstand the storm more than traditionally built homes due to their rigid construction and material density.

4.4.5 Comparing Traditional and Modular Home Codes and Regulation.

Ali, Kineber, and Elyamany's (2025) study identifies the non-alignment between current building codes and the need for modular construction practices. Traditional building codes and regulatory frameworks were mainly developed with conventional, site-built construction in mind and, therefore, often do not consider the specific features and processes involved in modular building. Adopting MC in affordable housing faces significant barriers because building regulations remain inflexible while standardized codes are lacking. The regulatory ambiguity occurs because MC operates between manufacturing and construction domains, which does not fit within established conventional construction codes. The scalability of modular housing solutions becomes more complex because different local codes between states and municipalities create additional challenges for companies that want to operate across multiple regions. The sector faces investment and innovation challenges because of these inconsistent regulations. Khan, Amirkhani, and Martek (2024) stress that modular construction needs standardized policies, national modular construction standards, and supportive regulatory frameworks for off-site manufacturing and quick on-site assembly that maintain safety and quality standards. According to the Montgomery County Department of Permitting Services (2024), both Traditional and modular constructed homes have the same process for permits and regulations. Both construction methods require obtaining a building permit, which may include electrical, mechanical, and zoning compliance before construction. They both require the provision of Right-of-Way and Sediment Control permits before installation. Approval from agencies concerned, including but not limited to the Department of Permitting Services (DPS) and Maryland- National Capital Park and Planning Commission (MNCPPC), is necessary.

4.4.6 Housing Insurance Policy

Traditional risk models in the insurance industry rely on conventional construction approaches. The insurance industry views modular projects, combining factory fabrication and complex logistics, as higher risk, resulting in difficulty getting insurance coverage. (Jaillon & Poon, 2014). Multiple insurance policies are required for MC projects, which poses a difficulty for insurance companies. Insurance policies must protect multiple construction phases between factories and construction sites, including manufacturing, transportation, storage, and on-site assembly. Insurance products designed for conventional construction fail to address this dual nature site requirement, creating overlapping coverage, administrative challenges, and gaps in protection (Lawson et al., 2019).

The lack of sufficient data about MC claims forces insurers to practice conservative underwriting, which results in higher premiums (Modular Building Institute, n.d). The increased exposure prevents professionals from working on modular projects without suitable insurance coverage, creating additional project execution challenges (Kamar et al., 2011). Traditional financing and insurance frameworks represent a significant barrier to modular construction adoption because they do not match the modular delivery model. The modular construction process demands significant initial funding for design manufacturing and off-site fabrication before any construction work appears on-site.

The capital requirements of modular construction at the beginning of a project do not align with standard lending procedures that depend on on-site inspection and payment milestones. The funding approach appears risky to financial institutions because no physical construction assets are present on-site during the initial project phases. Insurers currently do not provide specialized policies addressing the specific risks of transporting and assembling prefabricated modules. The risks associated with transporting modules, storing them, and assembling modules on-site present challenges for which insurance coverage is not readily available. Developers need tailored insurance products that understand and provide coverage for these distinctive risk profiles because standard insurance products either increase premiums or provide insufficient protection. Azhar, Lukkad, and Ahmad (2013) demonstrate that financial and insurance system rigidity prevents modular construction from reaching its full scalability potential. The authors suggest that standardized financial instruments and insurance models should be developed to match modular workflows, and stakeholders need better awareness and trust in modular delivery systems.

4.6 Impact of Material Sourcing Policy on Housing Affordability and MC

Timber is a significant component of MC, affecting initial cost and long-term affordability, which makes modular housing affordability dependent on its pricing and affordability. The present administration aimed to increase the domestic production of timber through sustainable logging (U.S. Department of Agriculture, 2020). This initiative is projected to reduce timber supply volatility and enhance pricing stability, reducing total construction costs by 10-15% (Lawson & Ogden, 2020). The potential outcome of this initiative shows that any 10% decrease in construction costs can help reduce housing costs for low- and moderate-income households.

5. Conclusion

The analysis of Table 4.0, based on 20,683 households, reveals a critical challenge in housing affordability, with 4,250 households spending 50% or more of their income on housing expenses and a significant portion exceeding the 30% affordability threshold. These findings reveal a significant financial strain across the population and demonstrate an immediate need for more affordable residential construction solutions. According to HUD guidelines, the households that earn less than 30% of the area median family income (HAMFI) face the most significant financial strain because 4,690 households pay more than 30% of their income for housing. In comparison, 3,890 households pay more than 50% of their income for housing, which shows that these populations face a significant financial strain.

Traditional construction methods, which are characterized by high labor, material costs and long construction duration, also perpetuates the housing affordability crisis. The literature reviewed shows that MC provides significant benefits although, several factors have limited the widespread implementation of MC. High initial factory setup costs remain a significant financial hurdle, deterring new market entrants and limiting production scalability. In addition, urban transportation challenges such as oversized load restrictions, traffic congestion, and limited staging areas in dense cities such as Silver Spring, Maryland, substantially increase logistical complexity and project costs (Goodier & Gibb, 2007). However, These transportation barriers decrease some of the time and cost advantages usually associated with MC.

Contrary to the misconceptions that have been made about structural resilience, evidence shows that modular homes are more durable than traditionally built structures. A study by FEMA (1992) after Hurricane Andrew showed that modular homes were more resistant to extreme weather events because of their dense construction and rigid assembly. Furthermore, increasing domestic timber production through national policy initiatives can stabilize the material costs and reduce the overall cost of MC by 10% to 15%, which can provide further economic benefits to low and moderate-income households.

Regulatory frameworks in Montgomery County, Maryland, reinforced that the permitting and compliance procedures for modular and traditional construction are similar, which means there is no regulatory barrier to the wider adoption of MC. MC has great potential for addressing the U.S. housing affordability crisis. However, specific efforts must be made to address financial, logistical, and perceptual barriers to realize its full potential

5.1 Recommendations

Based on findings the following recommendations are proposed;

1. Public-Private Partnership (PPP) : Public-private partnerships between the government and developers provide grants, low-interest loans, and tax incentives for MC developers to help them cover their initial factory setup expenses. The Modular Housing Innovation Fund should be introduced to provide financial support through funding and loan guarantees for businesses that build modular production facilities. Developers can be encouraged by receiving funding in exchange for dedicating specific portions of their manufacturing output to affordable housing development. The combined investment between public and private entities decreases financial exposure while speeding up modular industry expansion and maintaining alignment with affordable housing targets.
2. Micro-modular designs should be encouraged for urban settings to address logistic barriers because these modules are smaller and easier to transport through congested city roads. Adopting temporary close-to-site modular fabrication hubs located in or near urban areas should be encouraged to reduce long-haul transportation. Local governments should provide flexible permitting for off-hours transportation and logistical support for modular deliveries to help reduce project costs and improve scheduling reliability for modular housing projects.
3. Government agencies, industry bodies, and developers should create public awareness campaigns on misconceptions about modular home durability using verified studies such as FEMA's Hurricane Andrew research, which proved modular homes outperform traditional structures under extreme conditions.
4. The government should establish mandatory structural certification programs for modular units that grant "Hurricane-Resilient" or "Enhanced Structural Integrity" labels following strict engineering testing procedures. The certification process should be promoted to both home-buyers and investors to increase trust in MC methods and drive broader adoption in disaster-prone areas.
5. Streamline Regulatory approvals through expedited permitting pathways and zoning reforms to accommodate high-density and flexible land use for modular developments.
6. Incorporate the use of domestic timber through tax credits and procurement mandates, enhancing sustainable logging to ensure affordability and environmental responsibility.

7. Insurance practices need reform to match the special risk characteristics of modular projects. The insurance industry should work with stakeholders to create unified single-policy insurance solutions that protect MC from off-site manufacturing through on-site assembly. The insurance industry should promote increased data collection from modular projects because this information enables them to understand actual risk levels better and set appropriate premiums. Professional organizations and policymakers must develop standardized MC guidelines that will decrease uncertainty and promote consistent underwriting practices. These measures will enhance MC's financial viability and market attractiveness by addressing insurance gaps and lowering perceived risks for developers contractors, and design professionals.

5.2 Proposed Model for Adoption of MC:

5.4. SAMHI – Sustainable and Affordable Modular Housing Integration

In a bid to enable easy incorporation and findings of the study and offer a framework for addressing housing affordability through MC, this research is proposing a model known as the Sustainable and Affordable Modular Housing Integration (SAMHI), presenting key insights from the literature, policy review, and analysis on affordability to a structured multi-layered approach by integrating construction technology, domestic resources, policy, and community engagement for holistically implementing MC.

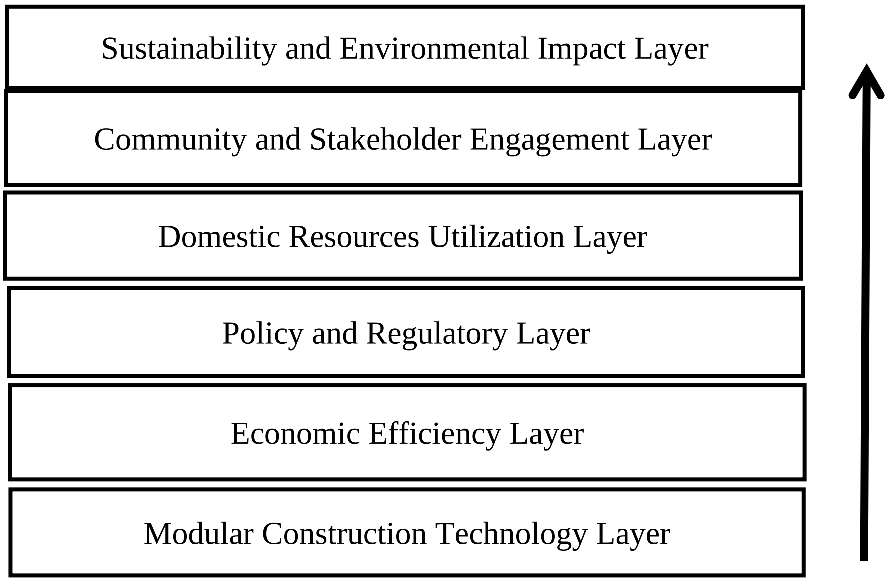

Figure 6: SAMHI – Sustainable and Affordable Modular Housing Integration

The model is characterized into six layers explained below,

1. Policy and Regulatory Layer -The first layer emphasized integrating MC into the existing regulatory framework. Modular homes in Montgomery have similar permitting and zoning policies as traditional homes, which provides a framework for scaling modular housing. State and local governments can enhance this layer by providing expedited approvals for modular projects and improving the zoning code to promote high-density innovative building layouts.

2. MC Technology Layer -This layer involves leveraging MC to reduce cost, shorten project delivery time, and enhance quality control through the use of parallel construction processes and incorporating hybrid modular systems that allow for greater flexibility.

3. Domestic Resources Utilization Layer - MC affordability and sustainability depend on the sourcing of construction materials. This model advocates for the integration of locally produced engineered timber like CLT

and SIPs. Integrating sustainable logging policy can enhance this layer by providing stable, low-cost supply chains, promoting job creation, and reducing import material dependency.

4. Economic Efficiency Layer - This layer establishes financial accessibility through cost predictability and investment incentives, providing long-term viability.

5. Community and Stakeholder Engagement Layer - This layer of the model introduces strategies to enhance public trust through informative campaigns, quality assurance, addressing misconceptions, and increasing acceptance.

6. Sustainability and Environmental Impact Layer - The final layer and outcome of the previous combined layers emphasize MC's environmental performance, economic viability, and sustainability.

Stakeholder that benefits from this model are governments, developers & builders, urban planners, policy makers, environmental advocates, residents/communities, academic researchers.

REFEERENCES

Adam, A., Josephson, P. E., & Lindahl, G. (2015). Implications of cost overruns and time delays on major public construction projects. *In Proceedings of the 19th international symposium on advancement of construction management and real estate* (pp. 747-758). Springer Berlin Heidelberg.

Agapiou, A. (2022). Barriers to offsite construction adoption: A quantitative study among housing associations in England. *Buildings*, 12(3), 283.

Ali, A. H., Kineber, A. F., Elyamany, A., Hussein Ibrahim, A., & Daoud, A. O. (2025). Exploring stationary and major modular construction challenges in developing countries: a case study of Egypt. *Journal of Engineering, Design and Technology*, 23(2), 569-598.

Associated Builders and Contractors. (2016). *The importance of construction to state economies* – 2015 GDP update. https://www.abc.org/News-Media/News-Releases/the-importance-of-construction-to-state-economies-2015-gdp-update

Azhar, S., Lukkad, M. Y., & Ahmad, I. (2013). An investigation of critical factors and constraints for selecting modular construction over conventional stick-built technique. *International Journal of Construction Education and Research*, 9(3), 203-225.

Bertram, N., Fuchs, S., Mischke, J., Palter, R., Strube, G., & Woetzel, J. (2019). Modular construction: From projects to products. *McKinsey & Company: Capital Projects & Infrastructure, 1(1), 1-34.*

Congressional Budget Office. (2025). The outlook for housing starts. Retrieved from https://www.cbo.gov/publication/60727

Cranston, M. (2025). *CBA opens up prefab mortgages in bid to fix housing crisis*. The Australian.

Enwin, A. D., & Ikiriko, T. D. (2023). Balancing urban development: Literature on the nexus between affordable housing and urban sprawl. *Int. J. Res. Rev*, 10, 560-572.

Fagan, K. (2025). T*his S.F. affordable housing project is building faster and cheaper apartments. Here's how*. San Francisco Chronicle.

Gambatese, J., & Rogge, D. (2018). *Modular prefabrication in Seattle: Opportunities and constraints*. University of Washington. https://cm.be.uw.edu/resource/modular-prefab-in-seattle/

Gibb, A. G. F. (2001). *Offsite fabrication: Prefabrication, pre-assembly, and modularization*. John Wiley & Son.

Gibb, A., & Isack, F. (2003). Re-engineering through pre-assembly: client expectations and drivers. Building research & information, 31(2), 146-160.

Gibb, A., & Pendlebury, M. (2006). Design for Modular Construction: Addressing Housing Needs. Proceedings of the Institution of Civil Engineers, 159(4), 127–135.

Gómez, M. F., & Sánchez, R. J. (2024). Impact of modular construction techniques on cost and time efficiency in large projects. *International Journal of Civil Engineering and Construction*, 3(2), 43–47.

Goodier, C., & Gibb, A. (2007). Future opportunities for offsite in the UK. *Construction management and economics*, 25(6), 585-595.

Guerdon Modular Buildings. (2021). Cost predictability and value engineering with volumetric modular construction. https://www.guerdonmodularbuildings.com/cost-predictability-and-value-engineering-with-volumetric-modular-construction/

Hurx, M. (2023). Collaboration and Competition: Master Masons and Painters in the Production of Architectural Designs in the Low Countries in the 16th Century. *Architectural Histories*, 11(1). https://doi.org/10.16995/ah.9179

Impresa Modular. (n.d.). Modular construction. Impresa Modular. Retrieved April 2, 2025, from https://impresamodular.com/modular-construction/

Jaillon, L., & Poon, C. S. (2010). Design issues of using prefabrication in Hong Kong building construction. *Construction management and economics*, 28(10), 1025-1042.

Jiang, Y., Zhao, D., Wang, D., & Xing, Y. (2019). Sustainable performance of buildings through modular prefabrication in the construction phase: A comparative study. *Sustainability*, 11(20), 5658.

Jiang, Y., Li, M., Guo, D., Wu, W., Zhong R. Y., & Huang, G. Q. (2022). Digital twin-enabled smart modular integrated construction system for on-site assembly. Computers in Industry, 136, 103594.

Jones, R., Smith, L., & Williams, P. (2019). Prefabrication and Modular Housing: The Future of Construction? *Construction Research Review*, 10(2), 30–48.

Kamar, K. A. M., Alshawi, M., & Hamid, Z. A. (2011). Barriers to industrialized building system (IBS): The case of Malaysia. *Journal of Engineering, Design, and Technology*, 9(3), 256–271.

Khan, A. A., Amirkhani, M., & Martek, I. (2024). Overcoming Barriers to Modular Construction in Affordable Housing: A Systematic Review. *Sustainability* 2024, 16, 7611. htps. doi. org/10.3390/su16177611 Academic Editor: Manuel Duarte Pinheiro Received, 18.

Lawson, R., & Ogden, R. (2020). Developments in modular construction. ICE Publishing.

Lawson, R. M., Ogden, R. G., & Goodier, C. I. (2012). Design in modular construction. CRC Press.

Mandala, R. S. K., & Nayaka, R. R. (2025). A state of art review on time, cost and sustainable benefits of modern construction techniques for affordable housing. *Construction Innovation*, 25(2), 363-380.

Modular Building Institute. (2019). Study finds modular can be faster, safer, and less costly. https://www.enr.com/articles/16684-study-finds-modular-can-be-faster-safer-and-less-costly

Modular Building Institute. (n.d.). Insurance and risk management in modular construction. https://www.modular.org/

Montgomery County Department of Permitting Services. (2025). Building permits and regulatory process for traditional and modular homes. Retrieved from https://www.montgomerycountymd.gov/dps

Mukhija, V. (2022). Remaking the American Dream: *The Informal and Formal Transformation of Single-Family Housing Cities*. MIT Press.

Murray, J. (2014). The 62M Condominium: Modular innovation in urban housing. Wikipedia. https://en.wikipedia.org/wiki/62M_Condominium

NAHB (National Association of Home Builders). (2021). Housing Affordability and Construction Costs: Trends and Challenges. NAHB Publications.

Pan, W., & Sidwell, R. (2011). Demystifying the cost barriers to offsite construction in the UK. *Construction management and economics*, 29(11), 1081-1099.

Parisi, L., & Donyavi, S. (2024). Modular momentum: assessing the efficacy of modular construction in alleviating the UK housing crisis. *Discover Applied Sciences*, 6(10), 548.

Reeh, C. (2019). Generative Suburban Frameworks: Emerging Architect-Guided Optimization Workflows Within Suburban Mass Production

Ribeiro, A. M., Arantes, A., & Cruz, C. O. (2022). Barriers to the adoption of modular construction in Portugal: An interpretive structural modeling approach. *Buildings*, 12(10), 1509.

Smith, R. E. (2020). Prefabricated and Modular Construction: Innovations in the Built Environment. Routledge.

Song, L., Li, H., Deng, Y., & Li, C. (2022). Understanding safety performance of prefabricated construction based on complex network theory. *Applied Sciences*, 12(9), 4308.

Staub-French, S., & Khanzode, A. (2007). 3D and 4D modeling for design and construction coordination: issues and lessons learned. *Journal of information technology in construction (ITcon)*, 12(26), 381-407.

Tsz Wai, C., Wai Yi, P., Ibrahim Olanrewaju, O., Abdelmageed, S., Hussein, M., Tariq, S., & Zayed, T. (2023). A critical analysis of benefits and challenges of implementing modular integrated construction. *International journal of construction management*, 23(4), 656-668.

United States Department of Agriculture. (2020). The forest products industry and its role in sustainable construction. U.S. Forest Service. https://www.fs.usda.gov/

U.S. Census Bureau, U.S. Department of Commerce. "Median Income in the Past 12 Months (in 2023 Inflation-Adjusted Dollars)." American Community Survey, ACS 1-Year Estimates Subject Tables, Table S1903, 2023, https://data.census.gov/table/ACSST1Y2023.S1903?q=Gross+Rent+as+a+Percentage+of+Household+Income&g=160XX00US2472450. Accessed on April 1, 2025.

U.S. Census Bureau, U.S. Department of Commerce. "Mortgage Status by Selected Monthly Owner Costs as a Percentage of Household Income in the Past 12 Months." American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B25091, 2023, https://data.census.gov/table/ACSDT5Y2023.B25091?q=Table+B25091:+Mortgage+Status+and+Monthly+Owner+Costs+as+a+Percentage+of+Household+Income&g=160XX00US2472450. Accessed on April 1, 2025.

U.S.Department of Housing and Urban Development. (2025). Comprehensive Housing Affordability Strategy (CHAS) data. Retrieved from https://www.huduser.gov/portal/datasets/cp.html

Walk-Morris, T. (2021). How adaptive reuse can help solve the housing crisis. American Planning Association.

Williamson, M., Ganah, A., & John, G. A. (2019). Barriers to adopting modern methods of construction in the UK. *Journal of Construction Engineering,* 2(1), 30-39.

Wuni, I. Y., & Shen, G. Q. (2020). Barriers to the adoption of modular integrated construction: Systematic review and meta-analysis, integrated conceptual framework, and strategies. *Journal of Cleaner Production*, 249, 119347.

Wuni, I. Y., & Shen, G. Q. (2022). Towards a decision support for modular integrated construction: An integrative review of the primary decision-making actors. *International Journal of Construction Management, 22(5),*